Fundamentals of SUPPLY CHAIN MANAGEMENT

SECOND EDITION

A Practitioner's Perspective

William McLaury
Eugene Spiegle

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Photo courtesy of Anthony Alvarez

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He is a member of the American Production and Inventory Control Society (APICS), the Institute for Supply Management (ISM), and the Council of Supply Chain Management Professionals (CSCMP) where he serves as the Education Chair for the NJ Roundtable. He continues to be a frequent guest speaker at numerous industry and academic events.

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Mr. Spiegle has performed consulting, conducted training and delivered workshops for organizations like AT&T, Bechtel, Black & Veatch, Boeing, Chrysler Corporation, City of Los Angeles DPW, and U. S. Corp. of Engineers, Datek Online Inc., General Motors, Hewlett Packard, MIT National Labs, Xerox Corporation and the United Nations.

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After retirement from the United Nations where he was Director of Projects, Mr. Spiegle served in various positions from President of a firm pioneering and specializing in automated systems to Vice-President of engineering of a Fortune 500 company. Gene holds degrees in psychology and engineering with an advanced degree in psychology. Mr. Spiegle has been an adjunct faculty in project management, engineering management, and communications at University of Pittsburgh and University of Alabama, The Conference Board of New York and Battelle Memorial Institute.

He is also the author and designer of *Project Management Guidelines*, a process currently utilized by many organizations to manage their projects. Gene's book *Taming a Silent Killer—Your Stress* was released in May of 2002 followed by *Project Management – The Basics for Success.*

PLAN

Chapter 1

Introduction to Supply Chain Management

CHAPTER OUTLINE

INTRODUCTION

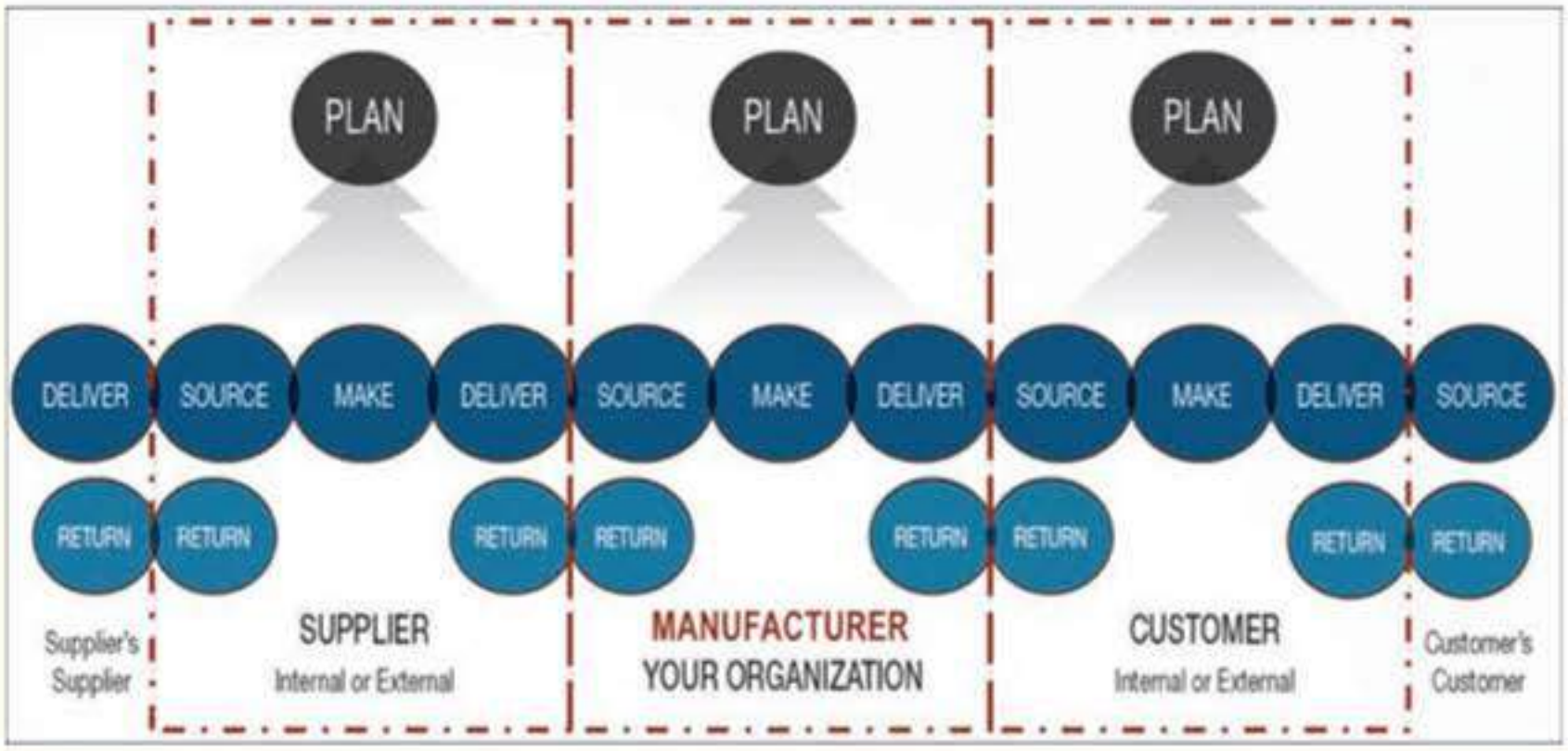
The discipline of supply chain management is dynamic and evolving. Innovation, technology, the internet, and the escalation of globalization, among other things, have contributed to the ongoing and rapid evolution of the field. In addition, pressure is being applied to supply chains by fluctuating demand, changing customer expectations, reduced product lifecycles, speed to market, and increased complexity. All of these factors intensify the need to understand and examine how we manage our supply chains. This text will explore supply chains and the fundamentals of how supply chains are managed in an effort to improve our understanding.

The American Production and Inventory Control Society (APICS), the premier professional association for supply chain and operations management, defines a **supply chain** as "the global network used to deliver products and services from raw materials to customers through an engineered flow of information, physical distribution, and cash."[1] In simpler terms, a supply chain is everything that happens to a product on the journey from "concept to consumer."

There are different ways to set up and operate a supply chain depending on the type of product or service a company provides. A company may even operate multiple supply chain setups simultaneously if the company's product portfolio is broad or complex. Regardless of the specific setup, supply chains are generally described as spanning from end to end (i.e., from your supplier's suppliers, to your suppliers on one end, through your organization's operations, and out to your customers, and to your customer's customers, on the opposite end). Most supply chains follow the basic Supply Chain Operations Research (SCOR) model shown in figure 1.1.

FIGURE 1.1

SCOR Model, Council of Supply Chain Management Professionals (CSCMP)



The model depicts the relationships and linkages between the trading partners that form a supply chain. Companies plan what they make, source the materials, make the products, and deliver them to the marketplace. Companies may also have to handle return of products back through the supply chain. Whether you are a supplier, a manufacturer, or a customer, you're likely doing each of these activities. If you are a manufacturer, as shown in the middle of figure 1.1, you have suppliers on one side that must make the products or materials that you need, and they likely have sources of raw materials to support their production. Similarly, you as the manufacturer are a supplier to your customers. You make the products that your customers want. If your customers are not the end consumers of the product, they are also suppliers to their customers who will ultimately consume the product. Suppliers and customers can be internal (i.e., part of your organization) or external to your organization, and many companies have both internal and external suppliers and customers. In addition to the functions of plan, source, make, deliver, and (potentially) return, which each of the trading partners must execute, supply chains are also typically enabled through various types of processes and technologies (e.g., systems software and hardware).

This text will use the SCOR model as an outline to describe all of the functions, processes, and activities involved in managing a supply chain. To better understand this model, following is a description and quick overview of each major function.

Plan: The first phase of the model is "Plan." Planning establishes the parameters within which the supply chain will operate. Companies need a strategy for managing all of the resources necessary to address how a product or service will be created and delivered to meet the needs of their customers. Planning includes the determination of marketing and distribution channels, promotions, quantities, timing, inventory and replenishment policies, and production policies. Part of supply chain planning is developing metrics to monitor the supply chain so that it is efficient and cost effective and also delivers high quality and value to the customers it serves.

Source: The next phase of the model is "Source." Sourcing is the process of identifying the suppliers that provide the products/materials and services needed for the supply chain to deliver the finished product(s) desired by the customer(s). This phase involves not only identifying reliable suppliers but also building a strong relationship with those suppliers. Supply chain managers must also develop pricing, shipping, delivery, and payment processes with suppliers and create metrics for monitoring and improving the performance of the buying process over time and potentially supplier performance as well.

Make: The third phase of the model is "Make." Make or manufacturing is the series of operations performed to convert materials into a finished product. This is the step where the finished product is manufactured, tested, packaged, and scheduled for delivery. Quality management is an important aspect of the manufacturing process. Aspects such as LEAN Manufacturing and Six Sigma are introduced in the "Make" process. This is the most metric-intensive portion of the supply chain, where companies are able to measure quality levels, production output, and worker productivity.

DELIVER: The fourth phase of the model is "Deliver." Also known as the logistics phase, this is the part of supply chain management that oversees the planning and execution of both the forward and reverse flow of goods and related information between various points in the supply chain to meet customer requirements. During the deliver phase, companies coordinate the receipt of orders from customers, develop a network of warehouses, pick carriers to transport products to customers, and set up an invoicing system to receive payments, among other aspects.

RETURN: The fifth phase of the model is "Return." Also known as reverse logistics, this is the part of supply chain management that deals with planning and controlling the process of moving goods specifically from the point of consumption back to the point of origin for repair, reclamation, remanufacture, recycling, or disposal. As this process quite literally goes against the normal outbound flow of products to the market, this can be a problematic part of the supply chain for many companies. Supply chain managers have to create a responsive and flexible network for receiving defective and excess products back from their customers and supporting customers who have questions and problems with delivered products. It is often an unwanted part of the supply chain and is frequently outsourced to a third party to handle for the company.

ENABLE: An additional aspect of the model is "Enable." Enabling processes facilitate a company's ability to manage the supply chain. Enabling processes include elements such as supply chain systems and network operations, systems configuration control, interfaces, gateways, database administration, electronic data interchange (EDI), telecommunications services, performance measurement, contract management, business rules, standards, and training and education, to name just a few. The processes associated with this component of the SCOR model are spread throughout every stage. In other words, we want to enable our capabilities as we plan, source, make, and deliver (and return). This is not a stage that occurs sequentially after all of the others.

WHAT IS SUPPLY CHAIN MANAGEMENT?

In order to define what supply chain management is, we should start by dispelling some common misconceptions. Supply chain management is NOT just a chain of businesses, it is NOT just a new name for purchasing or operations management, and it is NOT just a synonym for logistics. People may think of supply chain management as simply controlling the sequence of steps involved in the production of a product, that you obtain some materials and manufacture or assemble them step by step into a product that you then sell to a customer, but supply chain management is really **the coordination of a network of independent organizations** (i.e., trading partners) **involved in creating a desired product or service, where the partners function together as one seamless organization**. APICS defines supply chain management as "the design, planning, execution, control, and monitoring of supply chain activities, with the objective of creating net value, building a competitive

infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally."[1] Supply chain management is not just the production of products; it's about how people, process, technology, equipment, infrastructure, money, and information all integrate efficiently and effectively to facilitate the flow of products and services from the raw material stage to finished product manufacturing, out into wholesale and distribution channels, and ultimately to retailers and consumers, to the benefit of everyone in the supply chain.

The principle mission of supply chain management is to ensure that demand is met. Supply chain management delivers value by managing the processes of all of those otherwise independent trading partners so that they collaborate with one another in an efficient, effective, and cost-conscious way. The goals are to improve customer service while simultaneously reducing both inventory investment and operating expenses. By reaching these goals, companies will make significant progress toward achieving world-class supply chain management. In line with these goals, the two main reasons that firms implement supply chain management are to achieve cost savings and to better coordinate their resources.

Because these individual goals can be diametrically opposed to one another, they can be very hard to achieve. Companies that want to improve their customer service have a tendency to do it by increasing their inventory in an effort to always have enough product available to supply any potential demand and to offset any deficiencies in their ability to maintain a continuity of supply. This may be the easiest and fastest way to improve customer service in terms of availability; however, increasing inventory in turn increases operating expenses and ties up capital that could otherwise be used for activities such as research and development, marketing and sales, new product launches, salary increases, shareholder dividends, and more. We will detail more on the trade-offs between customer service, inventory investment, and operating expenses throughout this text.

SUPPLY CHAIN MANAGEMENT VERSUS LOGISTICS

There are those who confuse supply chain management with logistics. The concept of **logistics** refers to "the art and science of obtaining, producing, and distributing material and product in the proper place and in proper quantities."[1] On the surface this sounds very similar to supply chain management. Whereas supply chain management refers to a network of independent companies that work together and coordinate their actions to deliver a product(s) or service(s) to market for the benefit of all companies in the supply chain, **logistics is more inwardly focused on your own organization's operations,** encompassing activities specific to inventory management, warehousing (i.e., material handling and storage), distribution (i.e., order fulfillment, pick, pack and ship), and transportation (i.e., the movement of inventories into and out of an organization). These internal processes are often aligned functionally but operated independently, creating inefficiencies due to a lack of coor-

dination. **This lack of cohesion is where supply chain management goes beyond logistics by recognizing the need for integration of these functions and by promoting collaboration between internal and external members of a supply chain**. Supply chain management extends beyond the four walls of your organization and incorporates your supply chain partners on both the supplier side and the customer side, bringing them into a collaborative process with you to the **benefit of all participants in the supply chain**. Supply chain management incorporates all of those traditional logistics activities as well as aspects of activities such as forecasting and demand management, procurement, supplier relationship management, planning and scheduling, new product development, finance, and customer relationship management—all of which will be covered in this text.

YOUR ROLE IN A SUPPLY CHAIN

Any organization that offers a product or a service has a supply chain. Supply chains can be **very simple** or **very complex**. At first glance, the supply chain for bottled water looks very simple, but it is more complex than you may think. There are suppliers of the bottles, caps, labels, corrugated boxes, clear shrink wrapping, energy/utilities, maintenance supplies, office supplies, warehousing, distribution, transportation services, insurance, etc., and of course, a source of supply for the water itself. However, this supply chain is certainly not as complex as the supply chains for producing automobiles or airplanes which may involve hundreds if not thousands of suppliers and trading partners.

Both **large** and **small organizations** have supply chains, from major corporations that can have multiple supply chains for their products located all over the world, down to even the small mom-and-pop operation on the local corner, which also has a supply chain for whatever products or services that they are providing. **Public** or **private organizations** whether they are **for-profit** or **nonprofit** all have supply chains. Organizations such as Johnson & Johnson, Walmart, and General Motors are publicly traded major for-profit corporations with extensive and complex supply chain operations. Nonprofit organizations such as American Red Cross, Doctors without Borders, and Habitat for Humanity also have supply chains for the products and services that each provides. You don't need to be a large company or have significant revenue to realize the need to manage your supply chain. All businesses need resources, materials, and services, whether they are large or small, public or private, for-profit or nonprofit. They all have a supply chain.

You are part of multiple supply chains whether you are aware of it or not. You are on the supply side if you work for a company that provides a product or a service. You are most certainly on the demand side of many supply chains as a consumer of products and services. We all consume food, use fuel and utilities, and take advantage of numerous services such as banking, insurance, hotels, dry cleaning, and car repair. On the demand side, companies make and ship products to customers, either directly or through intermediaries, based on customer demand. Customer demand may be in

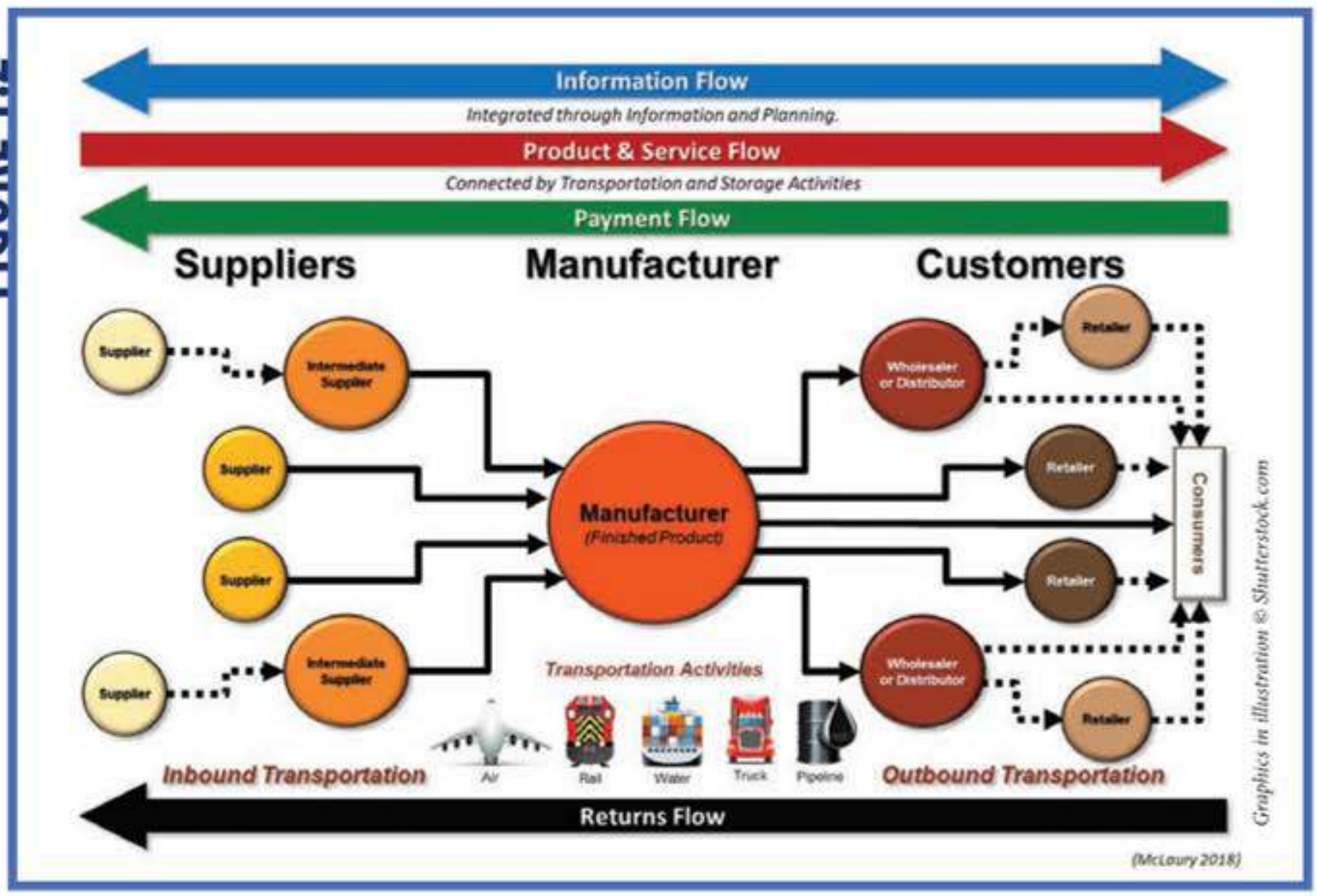
the form of actual orders, or part of a forecast model based on knowledge of what consumers want. Companies use forecast information to develop plans to produce the products and services they determine their customers want, so almost everyone is part of multiple supply chains.

SUPPLY CHAIN FLOW

To fully understand your supply chain, you need to understand the flow. It may help to see what your supply chain looks like, which means that you may need to actually draw it, at least at a macroscopic level. To facilitate this task, it may help to ask and answer the following questions: Who are my suppliers? Where do they get their materials? Who is manufacturing the product or service that I'm selling? How is it being distributed? Who are my customers and where are they? Do I sell direct to consumers or to wholesalers or distributors? How are the products actually transported: by truck, by ocean, by rail, etc.?

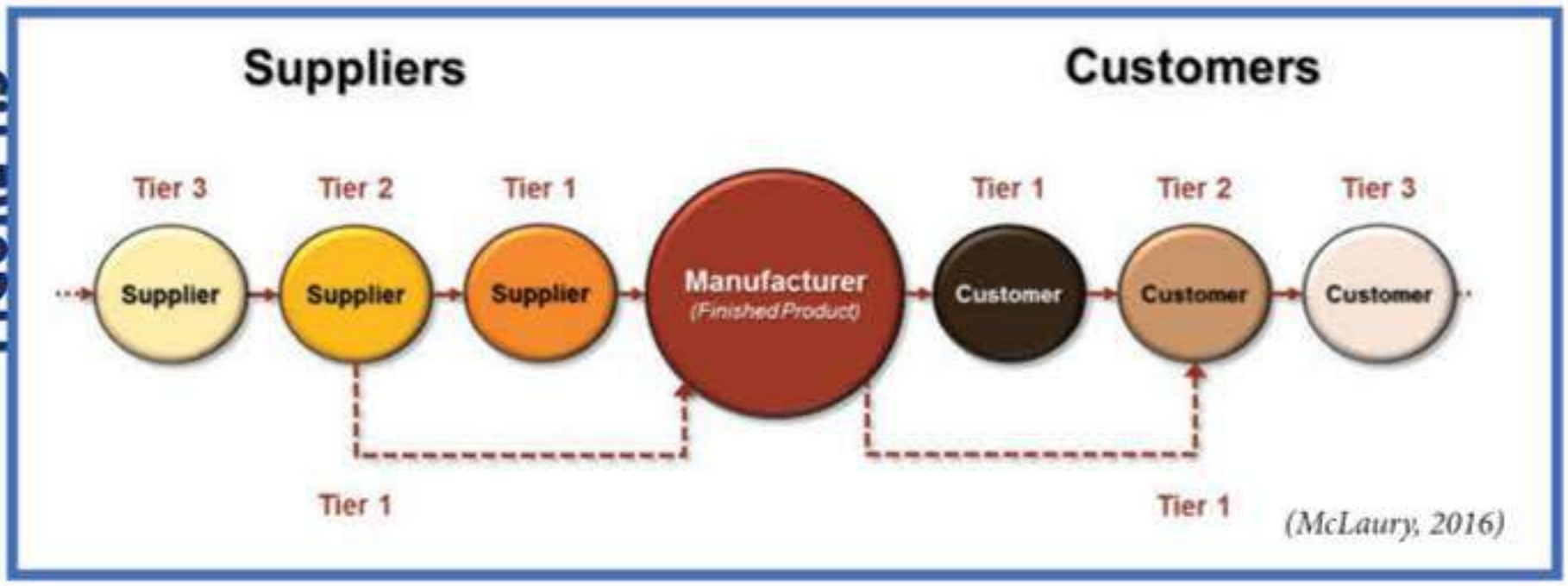
Figure 1.2 is a generic supply chain showing the linear flow of supply from left to right as indicated by the **Product & Service Flow** arrow.

FIGURE 1.2



For illustrative purposes, let's assume we are the manufacturer in the middle of the diagram producing a finished product. Beginning on the left side, we see **links** or **nodes** (the circles) for our suppliers and intermediate suppliers, who are providers of materials and services that we as the manufacturer will need in order to produce the product(s) that our customers want. Some suppliers provide products or services to us indirectly through intermediate suppliers while other suppliers provide products or services to us directly. Referring to figure 1.3, any company that delivers to us directly is a Tier 1 supplier. A supplier that supplies products we need to our Tier 1 supplier is our Tier 2 supplier. The tiers continue to grow as we move through more and more entities (Tier 3, Tier 4, etc.). In other words, Tier 1 is our direct supplier, and Tier 2, Tier 3, and so forth, are our indirect suppliers. It is also possible for a supplier to occupy multiple tiers. We might buy a component from one supplier directly but another product from that same supplier through an intermediate supplier. In this case, this supplier is a Tier 1 supplier for the first component and Tier 2 supplier for the second component. Just as our suppliers occupy different tiers, our customers occupy different tiers as well. To the right of the manufacturer are the customers, including wholesalers and distributors, retailers, and consumers. Wholesalers, distributors, and retailers are generally intermediaries in the supply chain who facilitate the transfer of products from manufacturers to the consumer (i.e., the entity who is actually going to use the finished product). Anyone we ship directly to is our Tier 1 customer. As manufacturers we might provide our products to wholesalers and/or distributors, retailers, or consumers. Our Tier 2 customers are any customers who receive our product(s) or service(s) through a Tier 1 customer. Customers can occupy multiple tiers simultaneously just as suppliers can.

FIGURE 1.3



The arrows connecting each of the links or nodes in the supply chain indicate **transportation** activities, both inbound to the manufacturer and outbound from the manufacturer. Transportation modes can vary widely and include rail, water, truck, air, and pipeline. Using more than one mode of transportation to make a single shipment is referred to as intermodal. Transportation will be explored in more detail in Chapter 9.

To facilitate the physical flow of products and materials along the supply chain, information such as forecasts, orders, confirmations, and invoices must flow in both directions as shown by the dou-

ble-sided **Information Flow** arrow at the top of figure 1.2. Information is vital for planning all of the activities in the supply chain, and for allocating and managing all of the resources necessary to execute the plan once developed.

The **Payment Flow** arrow indicates the flow of funds or money paid to members in the supply chain for product and services rendered.

While products generally flow from left to right, there may be the need for some reverse logistics (i.e., right to left flow) to accommodate returns, recycling, rejected products, and so forth, as depicted by the **Returns Flow** arrow. Companies need to invest in managing both their outbound flow of products to the marketplace and their reverse flow, handling customer issues and problems that might occur in the field with the products that have already been sold and distributed.

The following are examples of supply chains from various industries.

Example #1: Fresh Produce

The example depicted in figure 1.4 is for fresh produce such as strawberries or peaches, which may come from South America to the United States. From the orchards in South America, the produce

FIGURE 1.4

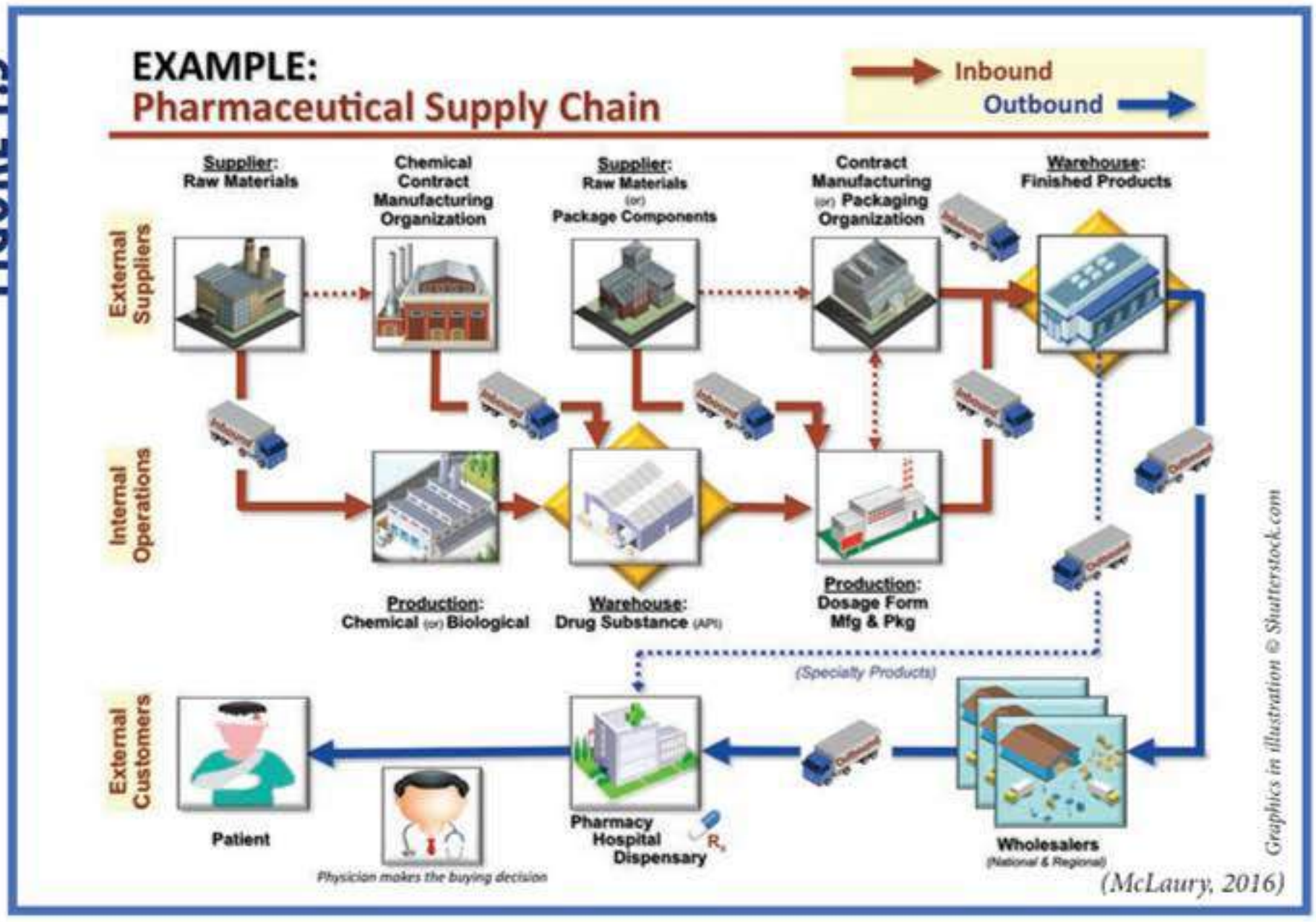
is picked and then moved to a pack-house. In the pack-house, the produce is inspected for quality and then packed for shipment. To preserve freshness and shelf life, most produce is cold stored (i.e., refrigerated). An extra inspection may be needed before transportation to make sure the quality has been maintained through the picking and packing process. The produce is then loaded onto a truck and transported to the port for export to the United States. At the port, the produce is transferred from the truck into a refrigerated container and then the container is loaded onto a cargo ship that travels from South America to the United States. When the ship arrives in the United States, the produce goes through an import process and inspection. It is then discharged or offloaded from the cargo ship into the port. There is another inspection to make sure the produce is still good. The produce will likely then go back into cold storage temporarily until the produce is actually released by U.S. Customs and Border Protection and any other government agencies involved in the import process, such as the U.S. Agricultural Department. Once released, the produce is removed from the port and transported to the distribution center where it is likely put back into cold storage. Before the produce is shipped out from the distribution center to the retail outlet (e.g., supermarket), there is yet another inspection to make sure the produce is still good. Finally, the produce is shipped out to a supermarket where we as consumers are able to select and buy the produce off the shelf. Each one of these separate activities may be performed by a different legal entity. In this simple example of supplying produce from South America to U.S. consumers, there are numerous steps and multiple parties involved in delivering the product from one stage to the next throughout the entire supply chain.

Example #2: Pharmaceuticals

Another example comes from the pharmaceutical industry. This particular example is laid out in three swim lanes or groupings: external suppliers, internal operations of the pharmaceutical company, and external customers.

Starting from the top left of figure 1.5, to produce a pharmaceutical product, the first step is to make the active pharmaceutical ingredient (API)—that is, the actual molecule of the drug itself. You must complete this step before you can incorporate the drug into a dosage form (tablet, capsule, injectable, inhaler, etc.). The creation of the API is a chemical or biological production step. In a large pharmaceutical company, this step will likely be done internally. In a smaller pharmaceutical company the formulation may be provided to a third-party contractor to produce the API. Some pharmaceutical companies may use both internal and external manufacturing. To make the API, raw material suppliers ship the necessary starting materials in to either the internal chemical/biological production operation or to an external contract chemical/biological manufacturing organization. In the pharmaceutical industry, APIs are generally produced in a large campaign/production run (e.g., maybe a years' worth of inventory at a time), as the synthesis for producing a drug product may involve many steps and take months to complete. Once the API is produced, it is likely transported to a warehouse and held in inventory.

FIGURE 1.5



The API will then be used in the manufacture of different dosage forms—not only tablets, capsules, inhalers, injectables, and the like, but also different strengths/concentrations (100 milligram, 50 milligram, 25 milligram, etc.) for each dosage form type. From the drug substance/API warehouse, the API is transported to either an internal pharmaceutical dosage form production site, an external contract manufacturing organization, or a combination of both, where the API will be converted into a finished dosage form.

To produce the finished dosage form, in addition to the API, you may also need raw materials such as starch, lactose, and other excipients from external suppliers to bind with the API to make a tablet. Other external suppliers may provide materials to package the product such as capsule shells, bottles and caps, blister foils and plastics, an inhaler device, an injectable syringe, labeling, corrugated boxes, or pallets. All of these materials are provided by external suppliers to the internal or external manufacturing and packaging operations.

Once the packaged finished product is completed, it will be shipped to an internal or external finished product warehouse for storage until it is ordered by a customer.

When customers place orders, the finished product will be picked/selected from the warehouse and packed for shipment to the customers by an external freight carrier (e.g., motor carrier/truck). Almost all pharmaceutical product in the United States is sold through wholesalers. Wholesalers buy the product from the manufacturer and sell it to pharmaceutical dispensing outlets such as pharmacies, hospitals, mail-order outlets, and institutions.

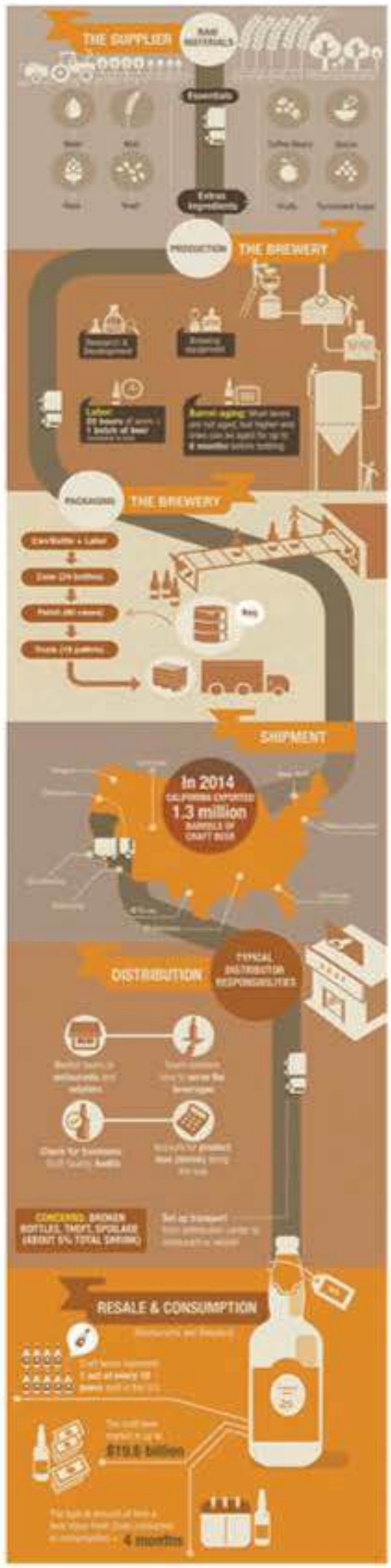
The dispensing outlets order the product from the wholesaler who then ship the product out to the dispensing outlets where consumers/patients like you and I go to get our prescriptions filled. Dispensing outlets like pharmacies hold a very small amount of inventory due to cost, space, and shelf life issues; therefore, they need frequent replenishments (e.g., daily) from wholesalers to avoid running out of stock/inventory.

An interesting aspect of the pharmaceutical industry is that the customer (i.e., the patient) is not actually making the buying decision and also may not be directly paying for the product. Consumers/patients are not deciding which prescription pharmaceutical to buy. Their physician actually makes the buying decision by determining which product the patient needs for his or her particular health situation and providing the patient with a prescription accordingly. Physician prescribing preferences have a huge impact on demand for these pharmaceutical products. Additionally, the payment for the product may come from an insurance company that also influences demand for pharmaceutical products by deciding which products they will and will not cover/reimburse.

Example: Craft Beer Industry

The craft beer supply chain requires suppliers and asset management, beer production, inventory control, transportation, and distribution. Craft breweries must also carefully balance their supply and demand to maximize their annual profit and lower their costs while keeping their doors open and their customers happy. Figure 1.6 provides a look at the supply chain in the craft beer industry from the acquisition of grains to the pouring of growlers.

FIGURE 1.6



SUPPLY CHAIN MANAGEMENT IN THE SERVICE INDUSTRY

Up to this point we have been mainly discussing supply chains that produce a physical product, but supply chains exist in the service industry as well. Service firms offer intangible products, meaning products that cannot be physically touched. What customers are actually paying for in the service industry is the labor and the intellectual property of the service provider. While the service itself is not tangible, it likely involves use of or work on a tangible item. For example, we do not pay a dry cleaner for a shirt; instead, we provide our own shirt and pay the dry cleaner for the service of cleaning the shirt. Service products include such things as insurance, healthcare, entertainment, finance/banking, training/education, transportation, warehousing, and business consulting, to name a few.

Because the nature of service products is so significantly different from physical products, the supply chain models for service products operate differently from those of physical products. Service products cannot generally be produced in advance or inventoried, and frequently the customer of a service provides the tangible item that will receive the service (e.g., a car for automotive repair, hair for a haircut, carpets for cleaning). Customers play a vital and more involved role in the delivery aspect of the service supply chain than they do in the supply chain for a physical/tangible product. Customers supply clothes to the dry cleaner to be cleaned, their refrigerator to the appliance repair shop to be serviced, and themselves to the healthcare provider to receive checkups and treatment. These types of services are said to provide *state utility*, meaning that the service is performed on something that is owned by the customer. In this context, without the customer also being a supplier in the service supply chain, the service could not be delivered. **Consequently, in the service supply chain, it is much more about managing the relationships between the trading partners than it is about managing the chain of supply**.

Some services require tangible items but do not provide state utility because the customer does not provide the item. Customers do not provide their own hotel room, for example. It is important to note, however, that a customer does not pay a hotel for the room; instead, a customer pays the hotel for use of the room. Similarly, we do not pay a rental car company for the car; rather, we pay the company for use of the car. In these cases, the service is predicated on the existence of a facilitating good. Facilitating goods, contrary to the services themselves, can be made and inventoried ahead of time. Some facilitating goods are far less obvious than the preceding examples. A glass is a facilitating good for a glass of ice tea in a restaurant. Customers do not pay for the glass; instead, customers are paying for the tea that is simply served in the glass. **Facilitating goods** will be discussed in more detail in Chapter 12.

ORIGINS AND EVOLUTION OF SUPPLY CHAIN MANAGEMENT

1950s and 1960s: The basic concept of supply chain management goes back to the 1950s. In these early years, the discipline was limited to **materials management** and **logistics**. In the 1950s and 1960s, the entire focus was on how to produce as much product as possible at the lowest possible cost. Policies and practices were established to maintain large material inventories to keep production running. Manufacturers were internally focused: They looked primarily at maximizing their own internal operations, asking and answering one question: How can we be the most efficient with our resources? External collaboration and partnerships were virtually nonexistent. The focus of materials management and logistics was on the material flow cycle: purchasing the necessary materials, managing the work-in-process, storage/warehousing, shipping/transportation, and the downstream distribution of the finished product to customers. Advantages brought forward through this period included higher output and more productivity, reduced cycle times, and lower work-in-process inventories. The drawbacks included high investment in facilities and infrastructure, the overall cycle time was limited by the slowest operation, and a breakdown of one machine could stop an entire production line.

1960s and 1970s: Computer technology was introduced in the 1960s and 1970s, and concepts such as material requirements planning (MRP) and manufacturing resource planning (MRP II) were developed and propagated throughout industry along with related software applications. The managing of the supply chain was still internally focused but evolving to a higher level of sophistication. MRP was introduced as a fundamental method of determining what materials were needed and when they were needed to support the production plan and to coordinate inventory management. MRP II was developed to improve internal communication and operations. Manufacturers extended their processes to include their own finance, marketing, sales, research and development, etc. functions to bring all their expertise into the process. As an example, manufacturers began using the expertise from internal marketing and sales functions to improve their forecasts since these were the individuals who were interacting with the customers directly. They would have the best information about how much and when the customer would buy. They would also have known what competitors were doing.

1980s, 1990s, and 2000s: In the early 1980s, the term *supply chain management* was coined by Dr. Wolfgang Partsch and his team at Booz, Allen & Hamilton, and the concept began to come into its own. Instead of focusing only internally, companies started to look beyond their four walls and incorporate their supply chain partners into their planning activities. Global competition was intensifying throughout the 1980s to 2000s, and this intense global competition led U.S. manufacturers to adopt new practices such as just in time (JIT) management, total quality management (TQM), and business process reengineering (BPR) to remain competitive.

> **Just in time management** is a philosophy of manufacturing based on the planned elimination of all waste and continuous productivity improvement.[1]

TOTAL QUALITY MANAGEMENT is a management approach to long-term success through customer satisfaction based on the participation of all members of an organization in improving processes, goods, services, and the culture in which they work.[1] Everyone in the organization has to take ownership for quality.

BUSINESS PROCESS REENGINEERING is a procedure that involves the fundamental rethinking and radical redesign of business processes to achieve dramatic organizational improvements in such critical measures of performance as cost, quality, service, and speed.[1]

THE FUTURE OF SUPPLY CHAIN MANAGEMENT

The old supply chain paradigm involved companies that were seeking to integrate vertically. They subscribed to the idea of doing as much for themselves as possible in an effort to maintain ultimate control. If they were in control of all aspects of the supply chain, they did not have to rely on anyone else who could possibly let them down. A company gained synergy as a vertically integrated firm encompassing the ownership and coordination of several supply chain activities. In addition to manufacturing the product, they performed their own warehousing, distribution, transportation, etc. These organizations focused on the short term and on their own company's performance.

In the new supply chain paradigm, a company in a supply chain focuses activities in its area of specialization and enters into voluntary, trust-based relationships with suppliers and customers. Companies actively and increasingly look at outsourcing their non-core competencies to external partners based on a two-part question: What is it that I do well, and what is it that an external trading partner can do better than I can? By transferring responsibility for non-core competencies to trusted trading partners who have those functions or activities as their core competencies, businesses can accomplish two things. First, they can focus on what they do well and use their resources more efficiently. As a result, companies may need fewer resources or can focus more of their resources on doing what they do well: their core competencies. Second, companies can develop these partnerships and use their partners' expertise potentially to improve their own product. Their partners may be able to deliver innovation through their expertise/core competencies for an advantage that would not otherwise be available to the original company. This can be done on either end of the supply chain, with suppliers and with customers. **Focusing on core competencies, outsourcing those things are not core competencies, using the expertise of trading partners, and strengthening those relationships are the key components of a successful supply chain.** All participants in the supply chain benefit from individual focus on core competencies.

Establishing supplier and customer partnerships is not without risk. A chain is only as strong as its weakest link. You will want to perform a **risk assessment** and potentially take some **risk mitigation**

steps. Many companies will qualify backup sources of supply for critical materials and services and/or carry some select additional inventory for critical materials as a measure of risk protection.

Companies are focusing on **sustainability** at the behest of customers from every market. Issues of sustainability will only increase in importance in the future. Bottled water makes use of plastic bottles and caps. What happens to that plastic after the product is consumed? Will it end up in a landfill and degrade over many years? Will it end up floating around in the ocean? Is there a program to collect those plastic bottles and caps and recycle them, reuse them, or convert them into some other product? Companies are looking at the sustainability of their supply chain, making a commitment to environmental responsibility. How can we be more efficient, and less wasteful with our supply chain resources? We ask such questions as: Can we use less materials? Can we use materials with less environmental impact? Can we use less energy, burn less fossil fuel? There are potential cost savings, the benefit to the environment, and public goodwill for companies that can establish and achieve sustainability goals.

Companies are also focusing on **corporate social responsibility:** a commitment by a company's management not only to behave ethically but also to contribute to community development (e.g., establishing a policy of not buying from suppliers in countries where they have unfair labor practices or use child labor or establishing a program to provide training, education, and job opportunities to underprivileged populations).

FOUNDATION OF SUPPLY CHAIN MANAGEMENT

The underlying foundation of supply chain management consists of four functional, elemental areas: operations management, supply management, logistics management, and integration.

Operations Management

The operations management area involves managing internal resources: How am I determining my demand? How am I planning my supply? How am I running my operations? What equipment and people do I have? What is the level of quality I am producing? The major elements of operations management include forecasting and demand planning, planning systems, inventory management, and process management. In the SCOR model, the entire area of Make, where materials are converted into finished product, is part of the operations management area. Processes such MRP, MRP II, LEAN manufacturing, and Six Sigma are integral to managing operations efficiently and effectively. LEAN is an operating philosophy that focuses on eliminating wastes and improving efficiency. Six Sigma is an operating philosophy that focuses on reducing both defects and process variations. These are processes that complement one another. LEAN and Six Sigma will be discussed in Chapter 8.

Supply Management

The supply management area involves all of the supplies and suppliers that you need to run your business. What materials do you need? How much of those materials do you need at a given time period in your operation? Who are your suppliers? What capabilities do they have? How well are they performing? The major elements of supply management include purchasing management, strategic sourcing, and supplier relationship management. You need to have great suppliers who can meet your requirements not only today, but also as your company grows and evolves in the future. What priority is your company in their business? How important are you as a customer to them? You must evaluate your suppliers, their capabilities, reputation, quality, pricing, and current customers. You may want to create a strategic partnership with them and qualify them as a certified supplier to your organization. Managing your suppliers is not only managing the physical supply but the entire supplier relationship, too.

Logistics Management

The logistics management area involves all of the movement and storage of products and materials within the supply chain, whether the flow is forward or reverse. It is the planning and coordination of the physical movement aspects of a firm's operations such that a flow of raw materials, parts, and finished goods is achieved in a manner that minimizes total costs for the levels of service desired. The major elements of logistics management include warehousing, distribution, transportation, international trade management, and customer relationship management.

Integration

The integration area involves all of the enabling systems, software packages, processes, policies, procedures, performance standards and measures, information, and risk management necessary to facilitate the complete integration of the operations, supply, and logistics functions outlined above. Integration also involves collaborating with your trading partners to maximize total supply chain profits. Companies must integrate internally as well as externally to create a more efficient and cost-effective supply chain. Performance measurement is a critical element to determine if the supply chain is achieving its goals and delivering desired benefits. Performance measurement can also be used to identify areas for improvement and further integration.

SUPPLY CHAIN CAPABILITIES MODELS

Efficient versus Responsive Model

There are two different supply chain capability models. In order to determine which model is best suited for your organization, you first need to understand what type of product(s) you are producing: functional or innovative. You also need to understand your customers' requirements and expectations as well as the competitive market. What do your customers want? Do they want the product immediately? Do they want product they can customize? Is comparable product to yours readily available from multiple sources? What are your core capabilities? What do you do well and how can you use what you do well to satisfy your customer? What supply chain capabilities do you need to develop to be able to meet your customers' expectations if you don't possess them already? Once all those questions are answered, you can determine whether you need to establish an efficient supply chain model or a responsive supply chain model.

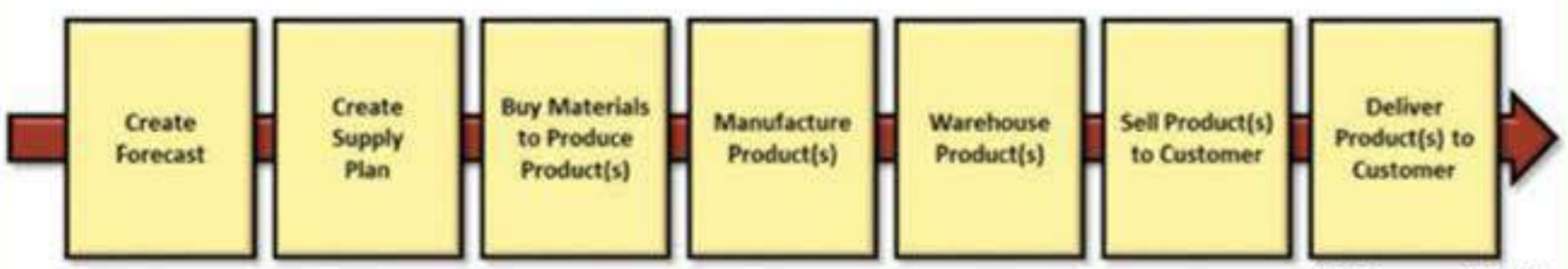
An **efficient** supply chain model is designed to minimize cost and to maximize capacity utilization. It is generally the appropriate strategy for functional products. **Functional products** are low margin and have stable demand, high inventory turnover, high volume, and are readily available from multiple sources (e.g., home, school, and office supplies). Consumers have many choices. Manufacturers producing these types of products want to produce and distribute mass quantities as efficiently and effectively, and as cost conscientiously, as they can in order to be competitive.

A **responsive** supply chain model is designed to respond quickly to market demand with minimal stockouts. Flexibility in capacity is necessary to meet fluctuating demand so there is normally an inventory of parts and materials readily available and production lead times are minimized. The responsive supply chain model is generally the appropriate strategy for innovative products. **Innovative products** are newly developed products with high margins, volatile demand, short product lifecycles, and relatively less competition than functional products. Computers and smartphones are examples of innovative products. Unlike the efficient model, the responsive model is designed for customization where customers want some flexibility. A good example is a laptop computer. Computer companies such as Dell have a base model for which they offer all kinds of different features customers can specify. Customers can choose different amounts of RAM and hard drive capacity, different graphics models and interfaces, different size screens, and so forth. Companies such as Dell provide responsiveness/flexibility by buying and holding quantities of the various component parts and not holding large inventories of finished laptops in stock. When a consumer places an order, Dell will assemble exactly what the consumer wants and deliver it very quickly (this is known as an assemble-to-order manufacturing strategy). This approach is wholly dedicated to being responsive to customer demand. It's allowing some customization, some flexibility, but still trying to get the product to the customer when and where he or she wants it. These types of innovative products have a short lifecycle as there is always a new innovation coming out.

Push Model versus Pull Model

The vast majority of businesses today follow the **push** business model (figure 1.7).

FIGURE 1.7



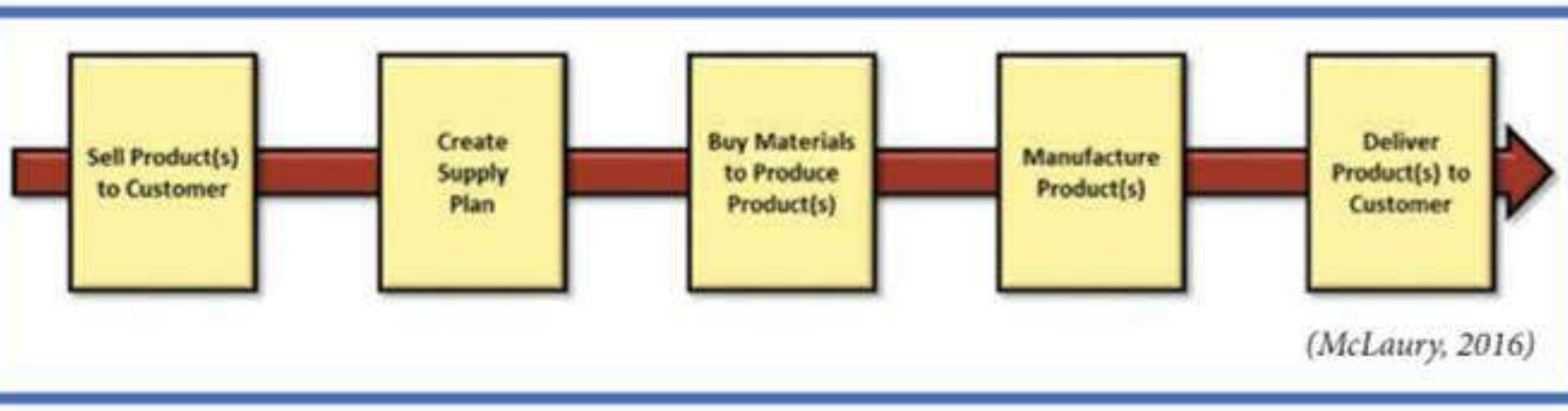
(McLaury, 2016)

In this model, manufacturers create a sales forecast, create a supply plan based on that forecast, buy the materials necessary to satisfy the supply plan, manufacture the product(s) accordingly, and then store the product(s) in a warehouse until they receive a customer order for the product(s). This production strategy is known as plan-to-stock or make-to-stock, where products are finished before receipt of a customer order, and then these orders are typically filled from the existing stock. New production orders are used to replenish the depleted warehouse stocks. The product is pushed through the supply chain toward the customer based on anticipated need.

- The major advantages of this model are that if the manufacturer creates a good forecast and supply plan, the product is immediately available to ship to the customer on demand from the existing finished product inventory in the warehouse. Manufacturers also have the opportunity to plan resources better or with more flexibility, and can maximize the utilization of resources at the lowest cost.

- The major disadvantages are high inventories (and capital tied up in inventory), long lead times, dependency on forecasting, and forecasting errors that create nonvalue by adding time, inefficiencies, obsolescence, shortages, and additional cost.

FIGURE 1.8



(McLaury, 2016)

Only a small percentage of businesses today follow the **pull** business model (figure 1.8).

In this model, manufacturers sell the product(s) first, then they create the supply plan, buy the materials, manufacture the product(s), and deliver the finished product. This production strategy is known as make-to-order, where the manufacturer is actually waiting for the customer to pull production of the product through operations, triggered by the customer order.

- The major advantages are high levels of customer service through responsiveness and flexibility to meet uncertain customer demand. Pull models have short lead times, reduce dependency on forecasting, use short and flexible production runs, store very low inventories, reduce waste, provide opportunities for customization, and improve cash flow.

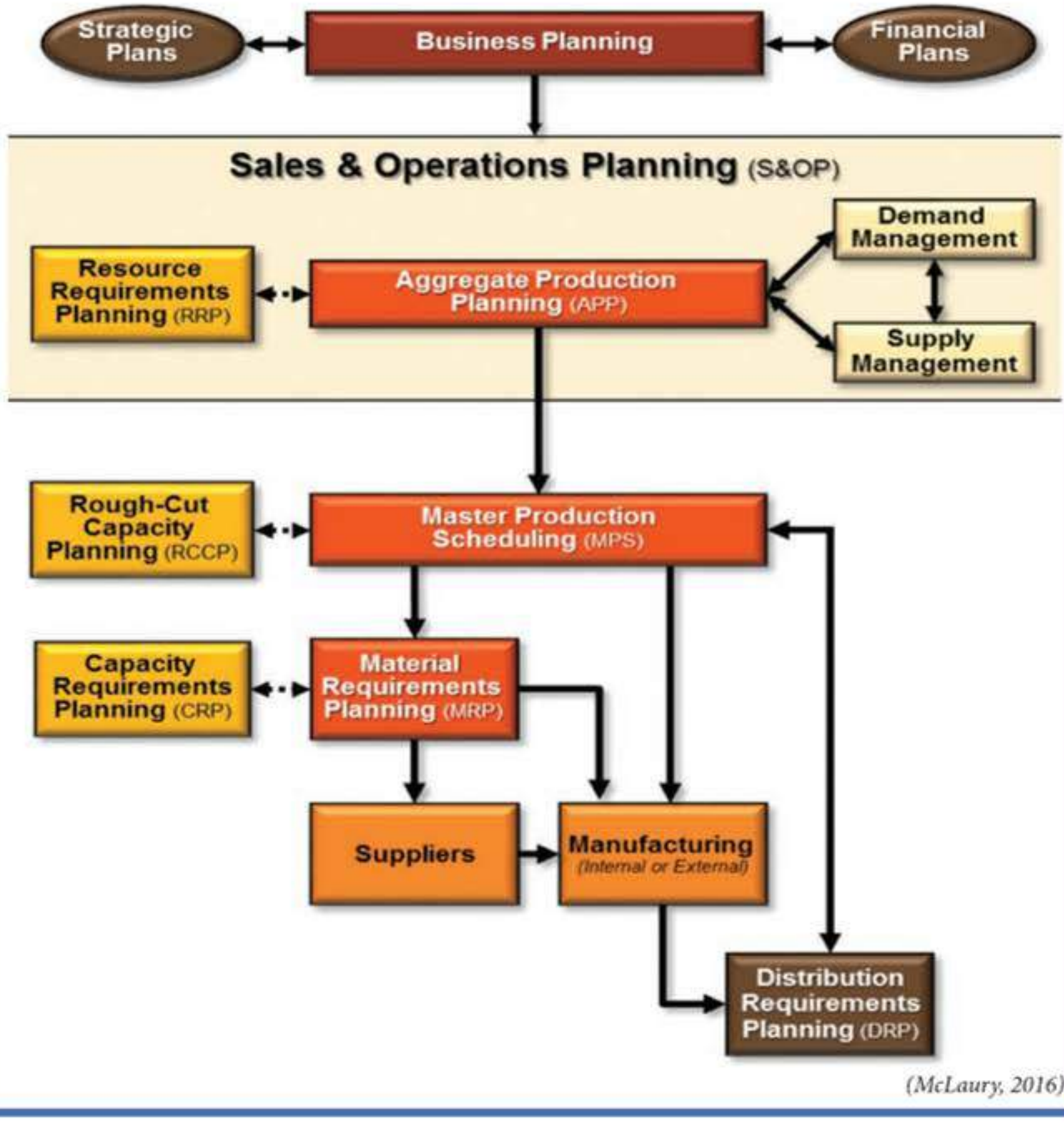
- The major disadvantages are that every order is a rush order, and any problems will lead to customer dissatisfaction. Pull models are highly dependent on customer relationships. This model inherently has a reduced ability to take advantage of economies of scale. Fast, responsive, flexible, robust, and integrated systems and processes are a must for this model to work. Resource issues will have a significant and immediate impact on throughput and customer satisfaction.

MANAGING THE SUPPLY CHAIN THROUGH DEFINED TASKS

In order to manage all these activities efficiently and effectively, you will need to have a formal, stepwise, and robust process in place so that you are able to consistently deliver your products when and where your customers want them.

Figure 1.9 shows the major processes that companies must plan and execute on a regular schedule/cycle to manage their supply chain. We will introduce each of these processes in more detail later in the text: however, it is important to note that to be efficient and effective, all of these activities should be fully integrated and as seamless as possible, not only in your internal operation, but also with your suppliers and your customers. In order to be successful, companies must **bring key suppliers and key customers into their processes** and work with them to identify what primary processes they have and who their suppliers and customers are. Companies must determine how they can work with their suppliers and customers to make the collective operations more efficient. Companies must establish a collaborative relationship with their key supply chain partners and share critical supply planning information such as forecasts, production plans, and inventory levels with them. If they can look beyond the four walls of their company and include trading partners on either end of the supply chain in planning activities, these companies will be collectively much more efficient as a supply chain.

FIGURE 1.9



(McLaury, 2016)

THE CHALLENGE OF SUPPLY CHAIN MANAGEMENT

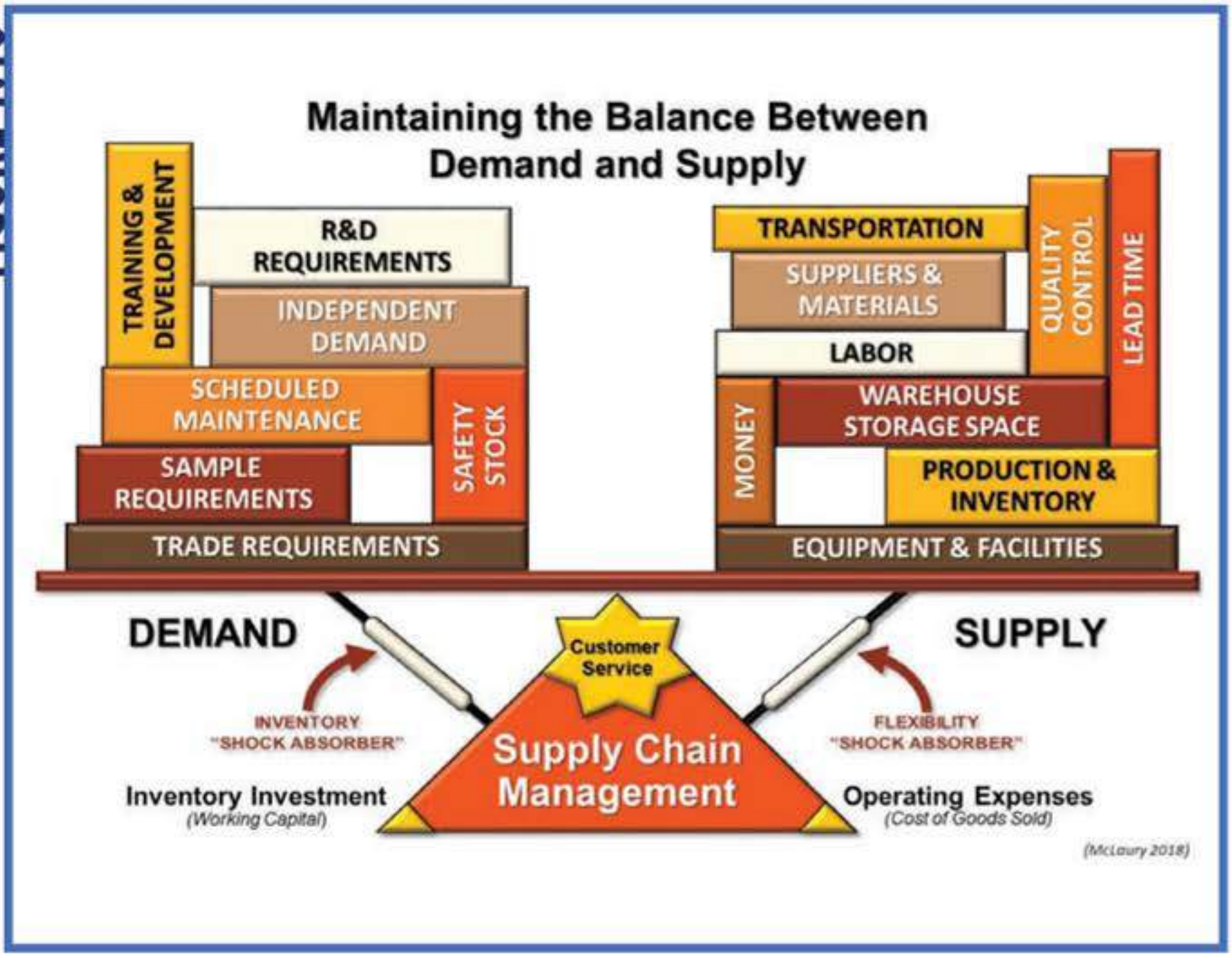
One of the key challenges in supply chain management is managing or balancing demand versus supply. There are potentially many different demands that place a burden on a company's resources. There are also potentially many different resources that companies use to create supply capabilities. The aim of supply chain management is to balance all of the demands against all available supplies on a continuous basis.

Demand (as shown in figure 1.10) includes trade requirements. This is the demand that most people think of: the finished product(s) that companies sell. However, there are other types of demand that impact a company's resources and supply as well. The need to do maintenance on equipment and facilities, the need to do training and development of personnel, and the need to do research and development work on new products are all examples of activities that demand time from these various supply resources, which takes away from the time available to produce product. Even the decision to maintain safety stock as a buffer against unexpected demand is a demand in and of itself as the safety stock has to be produced.

Supply (as shown in figure 1.10) includes equipment and facilities, labor, suppliers and materials, lead time, warehousing and transportation, and even money/capital—all of the resources that a company amasses to be able to support its anticipated demand.

The ideal situation would be for demand and supply to be in balance (i.e., just the right amount of supply to support demand, not more and not less). The function of supply chain management is to

FIGURE 1.10



maintain this ideal balance in an effort to deliver exceptional customer service (the fulcrum in figure 1.10), with the minimal amount of inventory investment and the lowest possible operating costs.

In order to assist in balancing demand and supply and to deliver against these customer service goals, a robust supply chain management process has some built-in *shock absorbers* that allow an organization to withstand some variability in demand and in supply.

Inventory acts as a shock absorber for both demand and supply variability. For example, we don't always know exactly what our demands will be and we may actually sell more than we projected. Having additional inventory may help to meet this unanticipated demand and maintain customer service. If our planned supply is not available as expected due to late deliveries, product rejections, and so forth, having additional inventory may also help to meet demand in the face of this potential supply shortage.

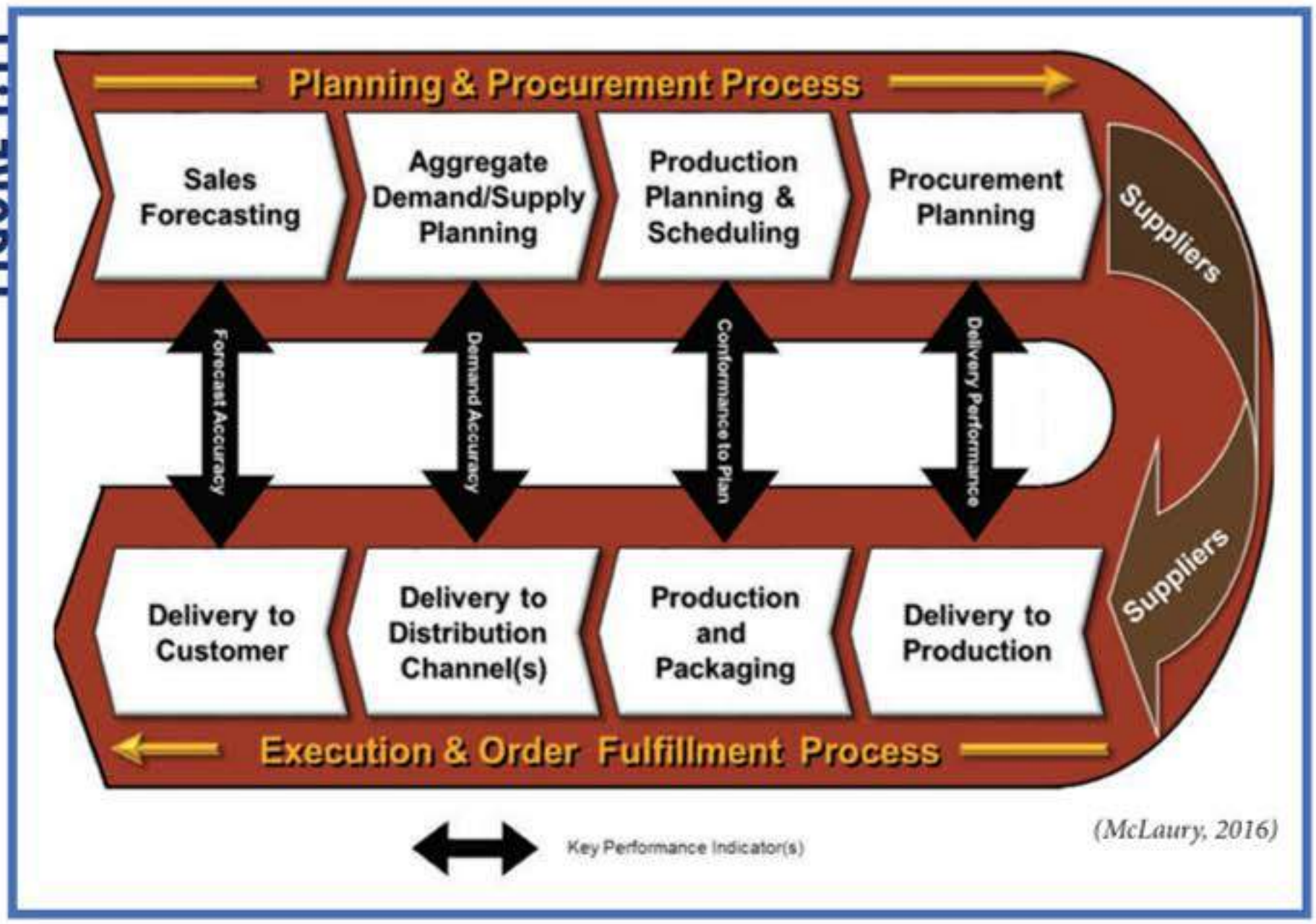
Flexibility acts as another shock absorber for both demand and supply variability. Flexibility might mean having extra capacity (i.e., capacity beyond what was projected and needed). If a company does sell more than was projected, having the flexibility to produce more may allow us to meet this unanticipated demand. On the supply side, if a supplier delivers late or there is a quality issue, a company can use this same flexibility to buffer for that variability by ramping up production. This is one way that supply chain management tries to manage and balance supply and demand. Establishing and maintaining these shock absorbers costs money. Obviously, less variability in the system is better, as companies will need to utilize shock absorbers less frequently and the supply chain will be more efficient.

SUPPLY CHAIN PLANNING AND EXECUTION

Supply chain planning and execution can be viewed as two mirror image processes complementing one another. Figure 1.11 shows both the Planning and Procurement Process (top) and the Execution and Order Fulfillment Process (bottom). Companies make a plan and then execute against that plan.

Planning and Procurement Process: The starting point on the top left side of figure 1.11 is the sales forecast (i.e., the volume of finished product[s] a company expects to sell to its customers). From here the company determines its aggregated demand and supply plans, determining what it actually needs to produce to support the sales forecast, taking into consideration what inventories it already has. The next step is the production planning and scheduling of the product(s) through internal or external production operations or both, as needed to support demand. This involves establishing the specific quantities of product and the specific time frame and necessary resources for production. The company then uses the planning and scheduling information to establish a

FIGURE 1.11



purchasing (procurement) plan to buy all of the required materials and services to support production. The purchase plan is then negotiated with the company's suppliers and confirmed through the issuance of purchase orders.

Execution and Order Fulfillment Process: The execution and order fulfillment process proceeds in reverse of the planning and procurement process. It starts with the suppliers delivering the materials and services which were ordered, to the company's internal or external production operations, or both. Production and packaging activities can then be executed according to the plan. These activities are followed by delivering the finished product(s), including any necessary additional quantities from inventory, out into the various distribution channels and ultimately to the end customer.

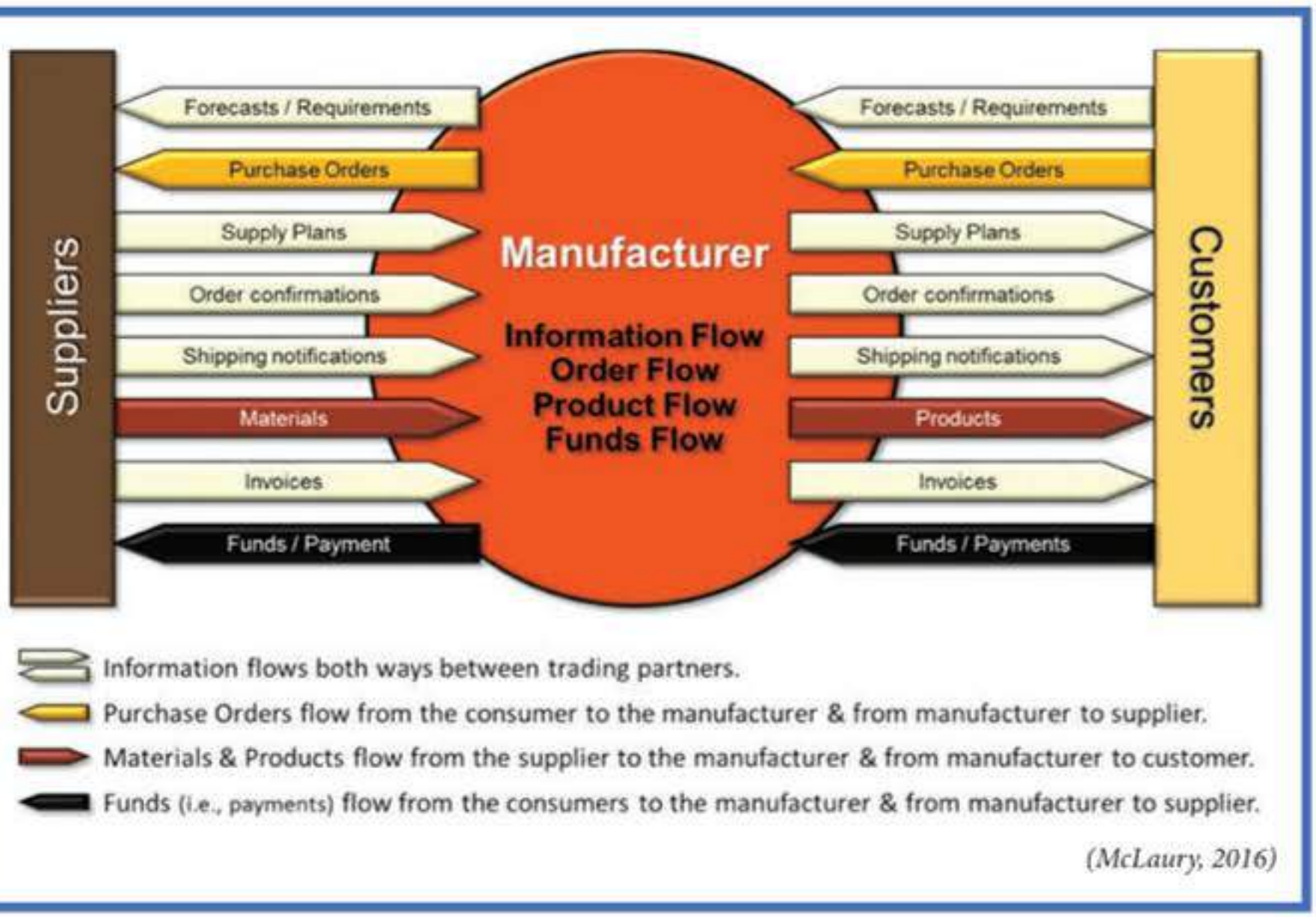
Key Performance Indicators: At each major point along the continuum, a measurement can be established and checked to determine if what was planned was executed as planned. Delivery Performance: What did the company plan to buy versus what was actually delivered? Conformance to Plan: What did the company plan to produce versus what was actually produced? Forecast Accuracy: What did the company forecast in terms of product sales versus what was actually ordered by

the customer? The company can measure each major process, identify variances, determine the root cause of the variance, and develop and implement an improvement plan. If a company can do this as part of the regular planning cycle, it can identify whether its performance is getting better, worse, or staying the same. It can identify focus areas and continuously improve its supply chain performance.

Flow of Information, Orders, Products, and Funds along the Supply Chain

Figure 1.12 depicts the flow of all the various types of information and materials along the supply chain in both directions. Information moves between trading partners in both directions—from customers to manufactures to suppliers and from suppliers to manufacturers to customers. This information includes forecast requirements, supply plans, order confirmation, shipping notifications, and invoices. Purchase orders flow from the customers to the manufacturers and from the manufacturers to the suppliers. The physical material flows in the opposite direction of the purchase order flow, going from the suppliers to the manufacturers who convert it into finished products and then deliver the products to the customer. Last there is a funds flow. Based on the invoices, the customers pay the manufacturers for the products, and manufacturers pay the suppliers for the materials.

FIGURE 1.12



(McLaury, 2016)

BENEFITS OF SUPPLY CHAIN MANAGEMENT

Supply chain management provides value for both internal and external customers. Some of the major benefits are improving customer service, increasing revenues, lowering costs, providing a better utilization of assets, reducing uncertainty, and the elimination of rush activities. The better companies plan, the less they will have to react to the unexpected. Companies will be able to minimize delays, establish shorter lead times, and have lower inventory levels throughout the extended supply chain both for the company and their supply chain partners. An improvement in customer service can enhance customer value, and retain more customers, particularly when competitors don't manage their supply chain as well. Supply chain management can be a competitive advantage by creating the ability to respond to disruptions and conflicts effectively. Companies with well-run supply chain processes might be positioned better to satisfy their own customers during a crisis and also potentially gain customers from their competitors.

Who benefits the most from implementing supply chain management processes? Obviously, companies that have a large and or complex supply chain benefit the most. They have large inventories, large numbers of suppliers, and large purchasing budgets. They have the most to lose, but they also have the most to gain. The obvious benefit to large companies doesn't mean that a small company can't also benefit. Small companies may actually be in a more precarious situation. A supply chain issue could be enterprise threatening for a smaller company, causing them to go out of business, so implementing supply chain management can be just as important for smaller companies as it is for larger companies.

CURRENT TRENDS IN SUPPLY CHAIN MANAGEMENT

Globalization: One of the trends in supply chain management is globalization. Companies are doing business in an ever-expanding marketplace and technological advancements are making the world smaller. Even the small mom-and-pop operation on the corner can now source materials and sell products internationally through the internet. Many companies large and small are now competing in a global marketplace whether they are ready for it or not. Companies can expect the complexity of their supply chains to grow significantly in the coming years in terms of new customers, locations, markets, products and variants, and demand volatility.

There are two aspects of globalization: breadth and depth. Breadth involves companies having foreign suppliers and foreign customers. Global business often requires some foreign manufacturing and foreign offices taking orders, providing customer service, and distributing products. Depth

involves companies having not only foreign first-tier suppliers and customers but second- and third-tier suppliers and customers in foreign markets as well.

Globalization is a major driving force for acquiring supply chain talent. Companies of all sizes in all industries all over the world need professionals with significant supply chain training and education to run their operations in a global environment. This demand is a significant contributor to the current supply chain talent shortage.

Demand Volatility and Forecast Inaccuracy are creating major challenges to supply chain management. Globalization, technology, and other factors have provided customers with increased competitive choices that allow them to make more and easier decisions to switch between alternatives. The lack of flexibility in a company's supply chain to manage these demand changes has become an increasing problem which could be further magnified by the **bullwhip effect**, which will be discussed in more detail in Chapter 2.

The best approach to deal with this trend is to develop more flexible capacity throughout the supply chain in order to be more responsible to forecast inaccuracy. Best performing companies tend to improve supply chain responsiveness through improving visibility across all supply chain partners. Companies can also focus more effort on collaboration with key customers to reduce or eliminate unanticipated changes.

Supply Chain Cost Optimization is essential for continued economic growth for companies. Improvements in gross margins over the next couple of years will not likely come from price increases; rather, gross margin improvements will come from reductions in supply chain costs. The recent trend of outsourcing non-core competencies and specific functions is critical for controlling supply chain costs. Many companies are taking advantage of lower costs in emerging markets and increasing the flexibility of their own supply chain operations. However, process and management costs could be on the rise as supply chains become more global. Companies are embracing the concept of managing total supply chain cost across all supply chain functions and interfaces. Rigorous cost optimization across the end-to-end supply chain is a critical success factor in an increasingly competitive and global marketplace.

Risk Management has become an increasingly critical challenge across the entire global supply chain. Dealing with cost pressures, many companies have started shifting supply chain risks (i.e., holding inventory) upstream to their suppliers. Companies are also shipping finished products to customers immediately after production. However, these approaches only shift risk from one part of the supply chain to another and do not reduce risk for the overall end-to-end supply chain. Supply chain risks can only be effectively mitigated by taking the approach of managing risk at each node of the supply chain. To keep the supply chain as lean as possible, companies are taking a more active role in demand planning, ensuring they order only the amount of material needed to fill firm orders.

Sustainability and Greening the Supply Chain is an increasingly prominent trend, with companies actively trying to be more socially and environmentally responsible. They are paying attention to their carbon footprint. They want to have less of an impact on the environment. If a company can be more efficient with its production, it will potentially also have a lower negative impact on the environment, using fewer utilities and resources. If companies are able to manage their supply chain better, they can actually reduce their carbon footprint. For example, if a company ships products in full truckload quantities, the products not only cost less per unit to ship but the company can ship the same total volume of product on fewer trucks than if they are partially empty, less-than-truckload shipments. Less fossil fuel is consumed, simultaneously lessening transportation's impact on the environment and reducing costs.

Poland Spring bottled water provides a great example of greening the supply chain. The company reduced the amount of plastic in its bottle and cap by approximately 25%. This percentage doesn't seem like a whole lot when considering an individual bottle, but given the number of bottles of water the company sells, that change will result in a significant cost savings for the company and also in tons of plastic that do not end up in a landfill or as litter somewhere else. A redesigned product like the newer Poland Spring bottle and cap is also lighter, so they add less weight in transportation, potentially burning less fuel to transport.

Surveys have shown that most consumers, given a choice between two different supply chains, will pick a product that is more socially responsible, more sustainable, and greener. They will pick companies that have recycling programs and have a positive attitude toward the environment over companies and supply chains that do not, so there is a competitive advantage in sustainability and greening the supply chain.

SUMMARY

- A supply chain is the global network used to deliver products and services from raw materials to customers through an engineered flow of information, physical products, and cash. There are different ways to set up and operate a supply chain depending on the type of product or service a company provides. Most supply chains follow the basic Supply Chain Operations Research (SCOR) model: Plan, Source, Make, Deliver, Return, and Enable.

- Supply chain management is the coordination of a network of independent organizations all involved in creating a desired product or service so that they function like one seamless organization. It is about the production of products and services and also how people, process, technology, equipment, infrastructure, money, and information all integrate efficiently and effectively to facilitate the flow of products and services from the raw material stage to finished

products desired by consumers, to the benefit of everyone in the supply chain. The goals are to improve customer service while simultaneously reducing both inventory investment and operating expenses.

- Any organization that offers a product or a service has a supply chain: large or small, public or private, for-profit or nonprofit. We are all part of multiple supply chains as either suppliers, customers, or both.

- To understand a supply chain fully means to understand the flow of products and service, information, payments, and returns from end to end: Which entities form the links or nodes in the supply chain? Who are the suppliers, the manufacturers, the customers? How are the products being distributed?

- Supply chains exist in the service industry as well. Service firms offer intangible products, so customers are actually paying for the labor and intellectual property of the service provider. Supply chain models for service products operate differently from that of physical products as service products cannot be produced in advance or inventoried, and frequently the customer of a service product provides the tangible item that will receive the service.

- The basic concept of supply chain management goes back to the 1950s and has evolved significantly over time from initially being almost exclusively internally focused to now embracing collaboration and strategic partnerships with external trading partners. In the modern supply chain, companies focus on activities in their core competencies and enter into voluntary, trust-based relationships with trading partners for activities outside their core competencies.

- The underlying foundation of supply chain management consists of four functional areas: operations management, supply management, logistics management, and integration.

- There are two different strategic supply chain capability models: efficient and responsive. The type of product(s) a company is producing, functional or innovative, is one of the major considerations for determining which model is best suited for that supply chain.

- A push model is defined as a business response in anticipation of customer demand. The product is pushed through the supply chain toward the customer based on anticipated need. A pull model is defined as a response resulting from customer demand. The manufacturer waits for the customer to pull production of the product through operations with an order.

- A formal, stepwise, and robust process of defined tasks must be in place for the supply chain to be managed efficiently and effectively in order to deliver products when and where the customers wants them consistently.

- One of the key challenges in supply chain management is the need to manage or balance demand versus supply. There are many components or elements of demand and supply to consider. Safety stock inventory and supply flexibility can be employed as shock absorbers to help maintain the balance when unexpected occurrences alter the operations plan.

- Supply chain planning and execution can be viewed as two mirror image processes complementing one another: planning and procurement followed by execution and order fulfillment. Companies make a plan and then execute against that plan on a cyclical, ongoing basis. The process facilitates the flow of information, orders, products, and funds along the supply chain.

- Supply chain management provides value for both internal and external customers. Some of the major benefits are improving customer service, increasing revenues, lowering costs, providing a better utilization of assets, reducing uncertainty, and eliminating rush activities.

- Current trends in supply chain management include:

  - The impact of continued globalization on the complexity and competitiveness of the supply chain
  - Improving visibility and collaboration to combat increasing demand volatility and forecast inaccuracy
  - A focus on risk assessment and risk management
  - A focus on sustainability and greening the supply chain

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Chapter 2

Forecasting and Demand Planning

CHAPTER OUTLINE

INTRODUCTION

Forecasting and demand planning are the key building blocks from which all downstream supply chain planning activities are derived.

The first step is forecasting, where the forecast is developed through data analysis and judgment. Organizations must have a formal forecasting process to develop an agreed upon set of numbers that becomes a driver for demand planning and its requisite components: financial planning, sales planning, marketing and promotional planning, production planning, procurement and inventory planning, logistics planning, and distribution planning.

The second step is demand planning, where management and other experts within the company review the forecast to ensure alignment with strategic requirements, business policy, and business knowledge, and make adjustments if necessary.

Forecasting and demand planning are crucial components of customer satisfaction.

KEY TERMS

DEMAND is "the need for a particular product or component. The demand could come from any number of sources (e.g., a customer order or forecast, an interplant requirement, a branch warehouse request for a service part, the manufacturing of another product, etc.). At the finished goods level, demand data are usually different from sales data because demand does not necessarily result in sales (i.e., if there is no stock, there will be no sale). There are generally up to four components of demand: cyclical component, random component, seasonal component, and trend component."[1]

DEMAND PLANNING is "the process of combining statistical forecasting techniques and judgment to construct demand estimates for products or services across the supply chain from suppliers' raw materials to the individual consumer's needs. Items can be aggregated by product family, geographical location, product life cycle, etc. to determine an estimate of consumer demand for finished products and services. Numerous forecasting models are tested and combined with judgment from marketing, sales, distributors, warehousing, service parts, and other functions. Actual sales are compared with forecasts provided by various models and judgments to determine the best integration of techniques and judgment to minimize forecast error."[1]

DEPENDENT DEMAND is demand for an item that is directly related to other items or finished products (i.e., a component part or material used in making a finished product). Dependent demands are calculated and should not be forecasted. For example, the seat on a standard bicycle

is a dependent demand item. If a company forecasts that it's going to sell 100 standard bicycles next month and creates a production plan to manufacture 100 standard bicycles, then the company knows that it will need 100 seats, because there is one seat on each standard bicycle. The company does not need to, and should not, forecast the demand for bicycle seats because the demand is directly related to the number of standard bicycles that it's going to manufacture. The number of seats is calculated based on the number of bicycles the company will manufacture rather than forecasted independently.

Independent Demand is demand for an item that is unrelated to the demand for other items (i.e., a finished product or spare/service parts). The demand for finished products generally comes from the external customer and is independent from other items and may therefore need to be forecasted. Forecasting should be done for the independent demand items only. Dependent demand items can then be calculated from the forecast for the independent demand item using the bill-of-materials and material requirements planning, which will be detailed in Chapter 3. In other words, once the *independent* demand for the number of bicycles is forecasted, the *dependent* demand for seats, tires, handlebars, and so forth can be determined. It is important to note that an accessory for the bicycle would require a forecast because it is not inherently part of the production plan. In other words, a bike lock that is not packaged with the bike has its own independent demand because its demand is not necessarily related to the bike itself.

Forecast is "an estimate of future demand. A forecast can be constructed using quantitative methods, qualitative methods, or a combination of methods, and it can be based on extrinsic (external) or intrinsic (internal) factors. Various forecasting techniques attempt to predict one or more of the four components of demand: cyclical, random, seasonal, and trend."[1]

Forecasting is "the business function that attempts to estimate future demand for products so that they can be purchased or manufactured in appropriate quantities in advance."[1]

FORECASTING

If managing the supply chain were a linear process, then the process would begin with the development of a forecast. Companies need to know what demand is or will be in order to begin to plan the use of their supply chain resources and execute against that plan effectively. Managing demand requires timely and accurate forecasts. The timelier the forecast, the more accurate the forecast is likely to be.

- **Short-term** forecasts cover a period up to six months and are generally reviewed on a weekly basis

- **MEDIUM-TERM** forecasts cover a period from six months to two years and are generally reviewed on a monthly basis

- **LONG-TERM** forecasts cover a period of two years or more and are generally reviewed on an annual or quarterly basis.


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Forecasting is necessary, because it takes time to convert raw materials to a finished product delivered to the customer. Most customers do not want to wait for the time necessary to produce a product from start to finish. Most companies, therefore, cannot wait for demand to develop and then react to it. Companies must anticipate and plan for future demand so that they can react immediately to customer orders as they occur, which is why most manufacturers use a "make-to-stock" rather than "make-to-order" strategy. "Make-to-stock" manufacturers plan ahead and then deploy inventories of finished goods into distribution channels in anticipation of demand (i.e., use the push model).

There are two important considerations about a forecast that must be stated:

- The first is that statistically speaking, the forecast will be inaccurate. Although it may be inaccurate, it is still useful. Forecasting is an imprecise science at best, but in the absence of any better information, the forecast is not something that companies can operate without. Because a forecast is an estimate of future demand, which may be inaccurate, the goal of the forecasting and demand planning process is to minimize forecast error in order to be as close to accurate as possible.

- The second important consideration is that the forecast is the basis for most "downstream" supply chain planning decisions. Good forecasting can benefit a company by facilitating more effective planning, which can lead to reduced inventories, reduced costs, reduced stockouts, and improved customer service. Bad forecasting can be the root cause for creating just the opposite. There is a familiar adage that applies to forecasting: "garbage in = garbage out." If a forecast is bad, everything else (i.e., the supply plan) based on that forecast will also be bad. As a result, some companies spend a lot of time and effort trying to figure out how they can best forecast because that will make everything else downstream flow more smoothly.

Companies must consider all factors that influence demand when forecasting, not only statistical data and information, but also knowledge about the marketplace, trends, marketing and sales efforts, competitor activity, and the like. Some considerations follow:

- Is the product seasonal?
- Is there a price increase coming?
- Is a new competitor entering the marketplace?
- Is the company's new product going to cannibalize one or more of its other products already on the market?

FUNDAMENTALS OF FORECASTING

There are some fundamental truths about forecasting in business about which supply chain managers should all be aware. These fundamentals can easily be forgotten at times, to the detriment of the quality and accuracy of forecasts. Supply chain managers should consider the following fundamentals when forecasting for their company:

Adapted from Jeff Robson, 8 Fundamentals of Forecasting in Business, Business Strategy Blog, June 26, 2012.

1. Your forecast is most likely inaccurate.

- The question you should be asking is "How inaccurate is the forecast?"
- Forecasts should include an estimate of error.
- Forecasting is difficult mainly because people know it is likely to be inaccurate and nobody likes to be publicly and visibly inaccurate.
- Nevertheless, a good forecast is essential in positioning the resources necessary to satisfy customer demands.
- Forecasts require regular review as circumstances can change. You must be open to the first signs of change and be prepared to react quickly and decisively.
- You must be willing to recognize and adapt to changing conditions. Don't fall in love with your forecast and ignore evidence that it may be inaccurate. Pride of authorship in this case can be deadly to the business.

2. **Simple forecast methodologies are better than complex methodologies.**

    - Simple forecast methods are easy to understand, analyze, and adjust as necessary.
    - Complicated forecast methods often hide key assumptions built into the model.
    - When key assumptions are obscured it can be hard to trace failures.

3. **A correct forecast does not prove that the forecast method is correct.**

    - Accurate forecasts could have been chance.
    - If you only question your methods when there is a large variance in the data, you'll miss all those times your forecast was just lucky – potentially hiding a multitude of sins.

4. **If you don't use the data regularly, trust it less when forecasting.**

    - The quality of your data is proportional to how often you use it.
    - When information is not regularly used, errors often remain undetected. Regular use of data helps identify mistakes and smooth out inconsistencies over time.

5. **All trends will eventually end.**

    - Many factors will affect the pattern you are trying to forecast.
    - It doesn't matter how accurately you predict the trend, in the future the variables will change and the forecast will be inaccurate.
    - Short-term forecasts are more accurate than long-term forecasts. The further out into the future you forecast, the more likely that changes over time will undermine your estimates.

6. **Most forecasts are biased, and it is hard to eliminate bias.**

    - When you have to make assumptions (i.e., which factors to include, how strongly to weight them, etc.), it is likely that you will be introducing some bias into the forecast.
    - A forecast process with bias will eventually get off track unless steps are taken to correct the course periodically. The best course of action is to measure for bias and then correct the bias routinely.

7. **Large numbers are easier to forecast than small numbers.**

   - Forecasts are more accurate for groups than for single items. Assuming that forecasts for each item in the group are as likely to be too high as too low, the low forecasts tend to balance out the high forecasts.

   - It's usually better to forecast the bigger number and work back the calculation to determine the associated numbers than to forecast the small, related products and then add them up to determine the bigger number.

8. **Technology is not the solution to better forecasting.**

   - Technology is not the answer; it is a tool to facilitate the process.

   - Robust forecasting comes from sound logic and methodology.

   - Create an appropriate strategy and then use technology to make it more successful.

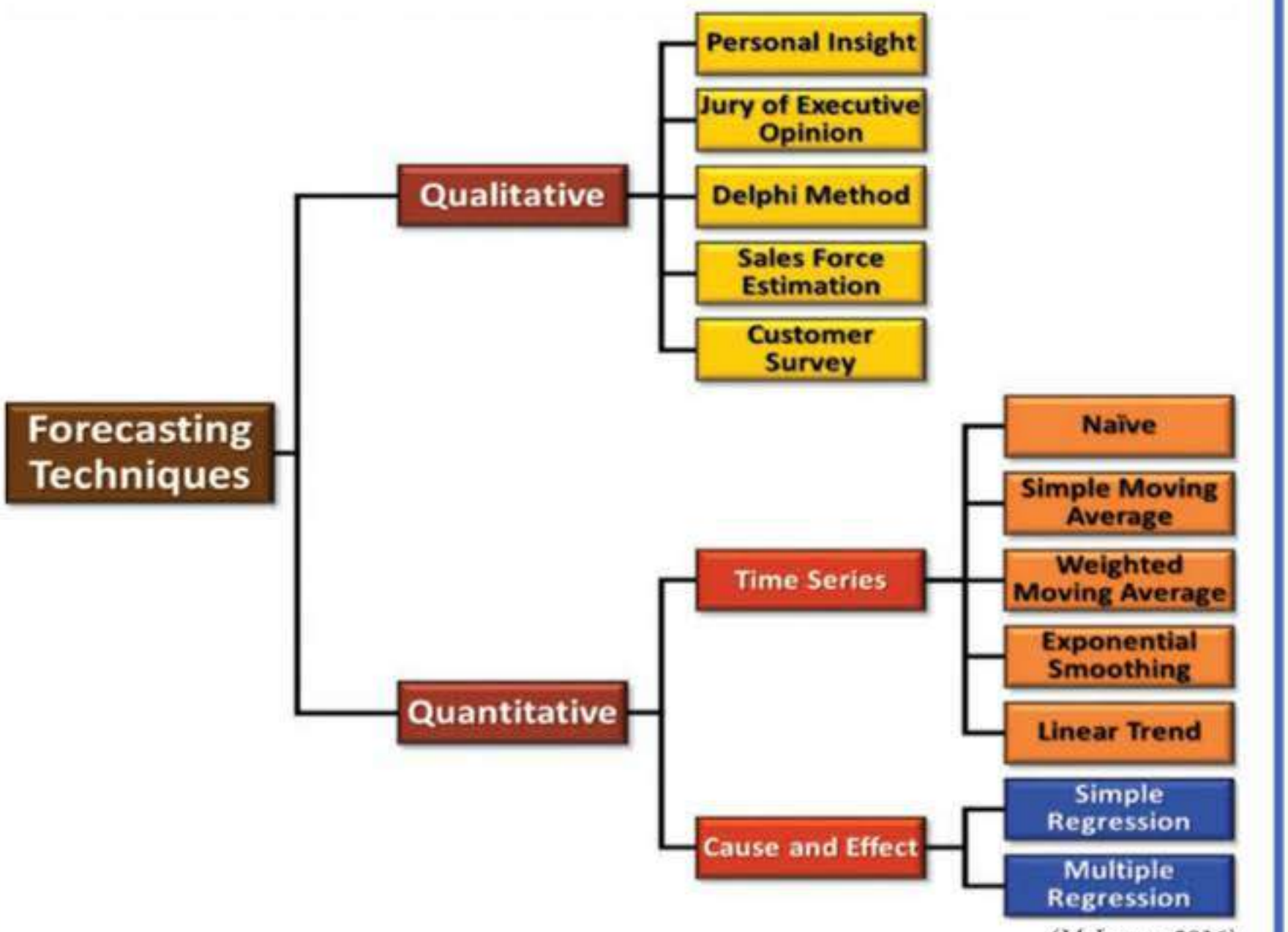
FORECASTING TECHNIQUES

There are two main categories of forecasting techniques: **qualitative** and **quantitative** (figure 2.1). A forecast can be developed by using qualitative methods, quantitative methods, or a combination of methods, and it can be based on intrinsic (internal) or extrinsic (external) factors. Companies that forecast well generally use a combination of quantitative and qualitative techniques.

QUALITATIVE FORECASTING

Qualitative Forecasting Techniques are based on opinion, intuition, and judgment. This technique is generally used when data are not available, limited, or irrelevant for some reason. For example, when companies launch new products into the marketplace, they don't have any direct statistical or historical data they can rely on to create a forecast. Although they might be able to use a similar product launched in the past by themselves or even a competitor as a model, they don't actually have hard data on which to base the forecast, so they will need to incorporate some judgments or opinions. This is qualitative forecasting, and its success depends significantly on the skill and experience of the forecasters and what information is available to them. The more experiences that can be brought into the process, the better this type of forecast will be.

FIGURE 2.1



(McLaury, 2016)

Five major types of qualitative forecasting are outlined here: Personal Insight, Jury of Executive Opinion (or Management Estimate), Delphi Method, Sales Force Estimates, and Customer Survey.

(McLaury, 2016)

1. **Personal Insight:** The forecast may be based on the insight of the most experienced, most knowledgeable, or most senior person available. Sometimes, this approach is the only option, but methods that include more people are generally more reliable.

2. **Jury of Executive Opinion or Management Estimate:** In an organization, those people who know the most about the marketplace and the product would likely form the jury or management panel determining the forecast. The

forecast relies upon a consensus of panel members. Generally, the panel conducts a series of forecasting meetings to discuss the forecast until the panel reaches a consensus.

Advantages:

- Decisions are enriched by the experience of competent experts.
- Companies don't have to spend time and resources collecting data by survey.
- It is very useful for new products.

Disadvantages:

- Experts may introduce some bias.
- Experts may become biased by other colleagues or a strongly opinionated leader.

3. **Delphi Method:** This method is basically the same as the Jury of Executive Opinion except that the insights, opinions, and judgments of each of the participants is collected separately so that people are not influenced by one another. In the Delphi method, questionnaires are submitted to individual experts for their anonymous responses. Instead of meeting face-to-face, the experts submit their responses to a panel director. A summary of all the responses is given to the individual experts requesting that they modify their original response if they think it is necessary. This is done in several rounds until a consensus forecast is achieved. The use of summaries reduces the defensiveness group members experience when challenged in person. It also reduces the potential for "groupthink." The Delphi method can be time-consuming and is therefore best for long-term forecasts.

Advantages:

- Decisions are enriched by the experience of competent experts.
- Decisions are not likely a product of groupthink.
- It is very useful for new products.

Disadvantages:

- Experts may introduce some bias.
- If external experts are used there is a risk of loss of confidential information.
- Companies must spend time and resources collecting data by survey.

4. **Sales Force Estimates:** This method is also basically the same as the Jury of Executive Opinion except that it is performed specifically with a group of salespeople. Individuals working in the sales function bring special expertise to forecasting because they maintain the closest contact with customers. The resulting forecast is a blend of the informed opinions of the group. This method can be improved by providing salespeople with incentives for accurate forecasts and by training the salespeople to interpret their interactions with customers better.

Advantages:

- No additional cost to collect data because internal salespeople are used.
- The forecast is more reliable because it is based on the opinions of salespeople in direct contact with customers.

Disadvantages:

- Salespeople may introduce some bias.
- Salespeople may not be aware of the economic environment.
- It is not ideal for long-term forecasting.

5. **Customer Survey:** This method is generally used for short-term forecasting where an organization conducts surveys with customers to determine the demand for their products and services and to anticipate future demand accordingly. Customers are directly approached and asked to give their opinions about the particular product. A customer questionnaire may be prepared for such times. Questionnaires should be simple and interesting so as to induce customers' responses. Customer surveys can be done in person (e.g., one-on-one, focus group), over the phone, by mail, email, or online.

   When collecting information with questionnaires or surveys, the number of responses compared to the number of nonresponses or incomplete answers should be tracked to determine if the data are statistically valid. Response rates for some types of survey methods may be as low as 10%.

   Rather than distribute a digital or tangible survey, some forecasters prefer a focus group, which is a small group of customers who are interviewed together to collect their input. An interviewer creates an environment that encourages different points of view without pressuring participants to vote or reach consensus. The company conducts several focus group sessions with different participants to identify trends and patterns. Careful analysis of the discussions provide clues and insights as to how a product or service is perceived by the group.

Advantages:

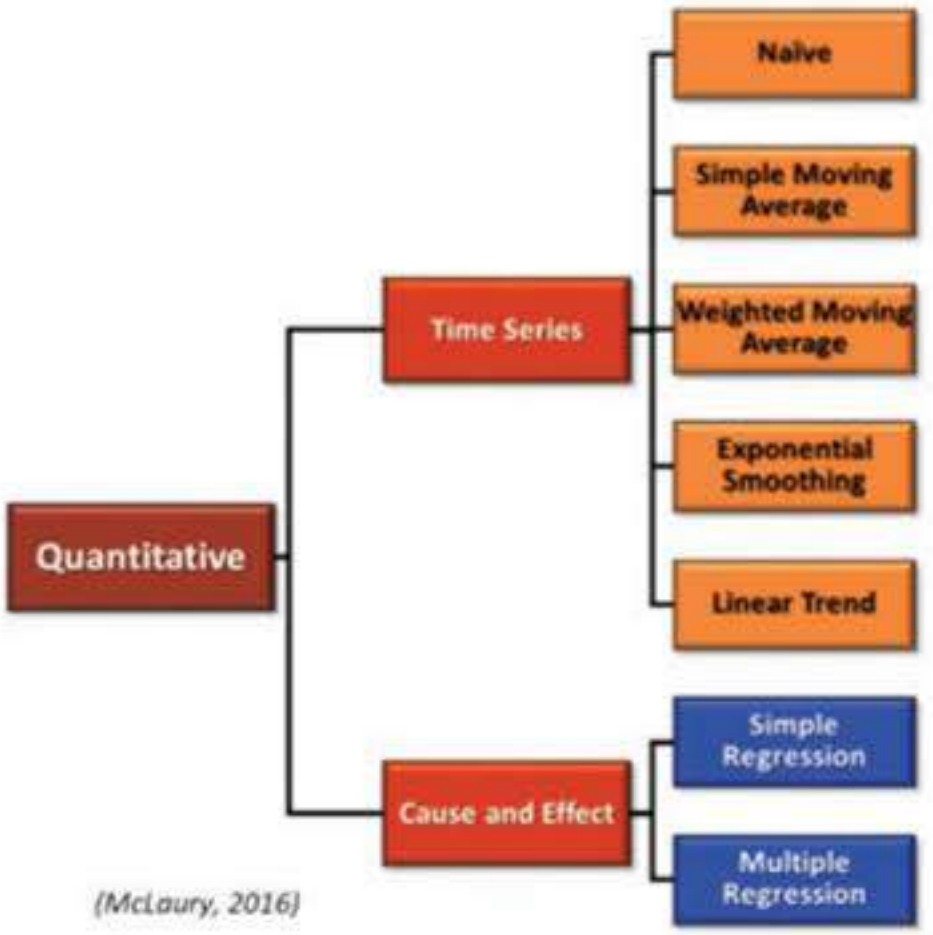
- It is a direct method of assessing information from the primary sources.
- It is simple to administer and comprehend.
- Consumer intercepts are usually held to gain a fast and quick overview.
- It does not introduce any bias or value judgment particularly in the census method if the questions are constructed carefully.

Disadvantages:

- Customers do not always answer the questionnaire.
- Poorly formed questions may lead to unreliable information.
- It is time-consuming and costly to survey a large population.

QUANTITATIVE FORECASTING

Quantitative Forecasting Techniques use historical demand data to project future demand. Whereas qualitative techniques are more of an art form, quantitative techniques are more of a science. In quantitative forecasting, historical demand data are used in conjunction with statistical models to create the forecast. Ideally, the historical data used should be actual demand data if available, rather than actual sales history. Actual sales history may reflect what the customer was forced to accept at the time due to limitations in available supply rather than what the actual customer demand was at the time.



(McLaury, 2016)

The two main quantitative techniques are **time series models** and **cause-and-effect models**.

Time Series Models are the most frequently used of any method and follow the premise that the future is an extension of the past. They

are intrinsic forecasting techniques that incorporate data collected during specific time intervals such as days, weeks, and months.

For example, if a company's actual demand was 1,000 units per month for the last 24 months, a very basic time series model would project that the company is probably going to experience demand of 1,000 units per month going forward, all other things being equal. This simplistic example demonstrates the use of historical demand data to predict future demand.

Time series models tend to be best for short-term forecasting and should also include an estimate of the degree of potential error.

Cause-and-Effect Models basically use the same historical demand data as time series models but make some assumptions and incorporate some independent variables in the effort to predict future demand more accurately. There is a "cause" (independent variable) and an "effect" (dependent variable). Cause-and-effect models are used where sufficient historical data are available, and the correlation between the dependent variable to be forecasted and the related independent variable(s) is well known.

Cause-and-effect forecasting models are extrinsic forecasting techniques because they evaluate the data based on some circumstance or event that will likely have an impact on the demand for a product or item. These approaches try to find a correlation, or a cause-and-effect relationship, between the indicator and overall market demand. Cause-and-effect models are more advantageous if they are based on recent independent variables (i.e., recent events). The more distant the event, the less useful it will be in achieving an accurate forecast. The key challenge is to choose an independent variable that has true correlation with the demand being forecasted.

The best practice for a company is to do some combination of intrinsic and extrinsic forecasting. Using internal information is powerful by itself, but external information can lend an additional layer of reliability by connecting external events to internal processes.

VARIATION IN QUANTITATIVE FORECASTING

Quantitative forecasting seeks to connect historical demand data with future demand probability. These predictions are seldom simple and must allow for variation in the demand. Variation can be problematic for forecast models if the nature of the variation is not understood, but understanding fluctuations in demand allows for a more complete forecast model.

Trend Variation: Trend variation is movement of a variable over time. Quantitative forecasts measure the rise or fall of demand for a product. Is the actual demand for an item increasing or decreasing over time; and is that pattern projected to continue into the future, and for how long?

A trend might be more easily observed by plotting actual demand on a graph over time to see whether there is an increase or decrease. Trends particularly occur at the beginning or the end of a product's lifecycle. When an item is new, the demand might be steadily increasing (trending up); when the product is mature, the demand might be steadily declining (trending down). The trend variation should be taken into consideration when creating a forecast for an item.

Random Variation: Random variation is an instability in the data caused by random occurrences. These random changes are generally very short term, and can be caused by unexpected or unpredictable events such as weather emergencies, natural disasters, and the like. A sudden demand for wood may occur, for example, after a hurricane because many homes are damaged. As these variations are unexpected and unpredictable, they are normally excluded from the forecast data as abnormal demand. Manufacturers may provide a contingency for these potential variations through a mitigation strategy such as maintaining some additional stock (i.e., safety stock).

Seasonal Variation: Seasonal variation is a repeating pattern of demand from year to year, or over some other time interval, with some periods of considerably higher demand than others. Demand may fluctuate depending on time of the year (e.g., seasonal weather, holidays). Seasonality is based on history repeating itself, and therefore can be predicted. Some industries and products have definitive seasons (e.g., snow shovels, swimsuits, Halloween candy, Christmas wrapping paper). These products predictably have large demand at certain times of the year and low demand the rest of the time. If seasonal variation is observed in the historical demand data, it is almost always built into the forecast unless there is some other overriding information to the contrary.

Cyclical Variation: Cyclical variation is a demand pattern that repeats like a seasonal variation but follows a wavelike pattern that can extend over multiple years and, therefore, cannot be easily predicted. These long-term cycles typically correlate with the general business or economic cycle. The stock market is an example of a cyclical variation. A "bull market" or a "bear market" can last for a long time, potentially even multiple years. Another example of a cyclical variation is a product going through its lifecycle, starting with a launch and rapid growth when it is new, leveling off when it reaches maturity, and then trailing off when it is in the decline stage.

TIME SERIES MODELS

The main purpose of a time series model is to collect and study the past data of a given time series in order to generate probable future values for the series. In other words, forecasts for future demand rely on understanding past demand. Accordingly, time series forecasting can be characterized as the act of predicting the future by understanding the past.

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The following are a few basic forecasting techniques using time series data.

NAÏVE: Naïve forecasting sets the demand for the next time period to be exactly the same as the demand in the last (or current) time period. For example, if a company had an actual demand for 100 bicycles in June, using the naïve forecasting method for July, the forecast would be set at 100 bicycles and so on for subsequent months. This forecasting technique does not factor in any variations (i.e., trend, random, seasonal, or cyclical). It is most useful for products or items that have a very stable/flat trend such as mature products, or for use in comparison to other, more sophisticated forecasting techniques.

Advantages: This technique works for mature products and is very easy to determine.

Disadvantages: This technique works for mature products only. Any variations in demand will create inventory issues.

SIMPLE MOVING AVERAGE: Instead of using the most recent time period demand data to forecast demand for the next time period like naïve forecasting, a moving average uses a calculated average of demand during a specified number of the most recent time periods. A simple moving average is where all the data points are assigned equal weights.

For example, a four-month simple moving average takes the average monthly demand for the preceding four months to create the forecast for the next month.

Formula: (M1 + M2 + M3 + M4) / 4

Compute the simple moving average forecast for **July** using the following data:

		Units	
	Month	**Actual**	**Forecasted**
M6	January	90,000	
M5	February	110,000	
M4	March	80,000	
M3	April	90,000	
M2	May	100,000	
M1	June	120,000	
M	July		?

(120,000 + 100,000 + 90,000 + 80,000) / 4
= 390,000 / 4
= 97,500 units for the July forecast

As the actual demand data for each new time period are added, the oldest one is dropped and the average is recalculated (i.e., a "moving" average).

Advantages: This forecasting technique provides a very consistent demand over long periods of time and smooths out random variations. Including more time periods will smooth the amount of variation in the model.

Disadvantages: This forecasting technique generally fails to identify trends or seasonal effects. It will also create shortages when demand is increasing, because it lags behind actual demand. Adding more periods to the average actually increases the amount the forecast lags behind actual demand.

Weighted Moving Average: A weighted moving average is very similar to a simple moving average except that not all historical time periods are valued equally. In the previous example, all of the time periods were weighted equally, totaled up, and then divided by the number of periods to get the simple moving average. With a weighted moving average, different weight is applied to each time period according to its importance. The weight given to each time period is flexible so long as the weight for each time period is a positive number and all of the weights total 100%.

Formula: (W1 x M1) + (W2 x M2) + (W3 x M3) + (W4 x M4)

Perhaps the company feels that the most recent month or few months are more representative or relevant to the product's demand today than the demand data from the more distant past. In this case, the most recent past time period(s) would be given a greater percentage of the total weight and the more distant past time periods would be given a lesser percentage.

Compute the weighted moving average forecast for July using the following data:

		Units		
	Month	**Actual**	**Forecasted**	**Weight**
M6	January	90,000		N/A
M5	February	110,000		N/A
M4	March	80,000		10%
M3	April	90,000		20%
M2	May	100,000		30%
M1	June	120,000		40%
M	July		?	
				100% TOTAL

(40% x 120,000) + (30% x 100,000) + (20% x 90,000) + (10% x 80,000)
= 48,000 + 30,000 + 18,000 + 8,000
= 104,000 units for the July forecast

As the actual demand data for each new time period are added, the oldest one is dropped, the weighted percentages are reapplied, and the average is recalculated (i.e., a "moving" average).

Advantages: This forecasting technique is more accurate than a simple moving average if actual demand is increasing or decreasing—that is, if there is any trend variation. Properly weighted time periods provide accurate information for forecasts.

Disadvantages: Though better than a simple moving average, this technique will still lag behind actual demand to some degree. The challenging part of using a weighted moving average is deciding on the weight for each time period. There is no guideline to help decide which weights to use. Appropriate weighting relies on experience and knowledge about the product and the market.

Exponential Smoothing: Exponential smoothing is a more sophisticated version of the weighted moving average. The equation requires three basic elements: last period's forecast, last

period's actual demand, and a smoothing factor, which is a number greater than 0 and less than 1 (used as a weighting percentage).

The formula for calculating the forecast using exponential smoothing is the most recent period's demand multiplied by the smoothing factor, PLUS the most recent period's forecast multiplied by (one minus the smoothing factor).

Forecast = (D x S) + (F x (1 − S))
Where:
D = last period's actual demand
S = the smoothing factor represented in decimal form
F = last period's forecast

Compute the exponential smoothing method forecast for July using the following data:

		Units		Smoothing
	Month	**Actual**	**Forecasted**	**Factor**
M6	January	90,000	90,000	0.5
M5	February	110,000	92,500	0.5
M4	March	80,000	97,500	0.5
M3	April	90,000	90,000	0.5
M2	May	100,000	92,500	0.5
M1	June	120,000	95,000	0.5
M	July		?	

(120,000 x 0.5) + (95,000 x (1 − 0.5))
= 60,000 + (95,000 x 0.5)
= 60,000 + 47,500
= **107,500 units for the July forecast**

The smoothing constant is not a given. It has to be determined based on the best judgment of a company's experts. The smoothing constant can be selected by experimenting with various constants in the historical data to see which one works best. Using the best possible smoothing constant is crucial to the accuracy of the forecast. In general, companies use a smoothing constant between 0.05 and 0.5. The higher the constant, the more weight that is given to the actual demand data from the preceding period. A constant of 0 would give no weight (0%) to the last period's demand, whereas

a constant of 1.0 would give all of the weight (100%) to the last period's demand, which would then produce the same result as a naïve forecast.

Advantages: Exponential smoothing will create a forecast more responsive to trends than previous methods.

Disadvantages: Exponential smoothing will still lag behind trends, especially upward trends, because the smoothing factor would need to be greater than 1.0 to approach an accurate forecast. Picking an appropriate smoothing factor is essential for this method to work, but selection of a smoothing factor requires much experience and experimentation in order to arrive at a reliable value for the smoothing factor.

Linear Trend: Linear trend forecasting is used to impose a line best fit across the demand data of an entire time series.[2] A linear pattern is a steady increase or decrease in numbers over time. In other words, linear regression will always create a straight line that can be defined by a simple formula. There are no bends (i.e., variations) in a best fit line. If a best fit line is found, it can be used as the basis for forecasting future values by extending the line past the existing data and out into the future while maintaining the slope of the line.

Advantages: When a best fit line is available, this method can provide an accurate forecast several time periods into the future. The use of linear regression allows these models to remain useful even amid random variation.

Disadvantages: While the overall trend is identified with linear regression, seasonal and cyclical variations are softened as the historical data becomes more expansive, making forecasts more useful for annual forecasts than monthly forecasts. In other words, linear regression will show the overall growth from year 1 to year 9 and be able to project year 12. It will not, however, generally show that demand increases in the summer and decreases in the winter (or some other variation), because the simple line is creating an average of sorts.

CAUSE-AND-EFFECT MODELS

There are two basic cause-and-effect models described here: simple linear regression and multiple linear regression. Regression uses the historical relationship between an independent and a dependent variable to predict the future values of the dependent variable (i.e., demand).

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Simple Linear Regression attempts to model the relationship between a single independent variable and a dependent variable (the demand) by fitting a linear equation to the observed data. The equation describes the relationship between the independent variable and dependent variable as a straight line. For example, the demand might be dependent on how much money is spent on advertising and promotion: the more money spent, the higher the demand. The line that represents this relationship can be used to forecast demand with consideration of future values of the independent variable. In other words, if a company plans on investing more in advertising, it might be necessary to increase the forecast, or vice versa.

Multiple Linear Regression attempts to model the relationship between two or more independent variables and a dependent variable (i.e., demand) by fitting a linear equation to observed data. For example, the forecasted demand might be dependent on how much money is spent on advertising and promotion **and** on the selling price charged for the product. As with the previous

example, forecasts can be adjusted with knowledge of the independent variables. If advertising is increased, and the price is lowered, it is likely appropriate to increase forecast demand.

Depending on the data and the number of independent variables, the mathematics involved can be complex. For example, if advertising is increased and the price is also increased, the impact on demand is not as obvious. The mathematics of multiple regression can help predict the impact on demand. Forecasting and statistical software packages can be useful to facilitate the computations required for this type of forecasting technique.

OTHER FORECASTING METHODS

There are numerous other forecasting models available and in use beyond what is covered in this text. The following are a few that may be worth further research.

- Drift Method
- Holt's Linear Trend Method
- Holt-Winters Seasonal Method
- Autoregressive Integrated Moving Average (ARIMA)
- Box-Jenkins
- X-11
- Econometric Model
- Input-Output Model

FORECAST ERROR

Because forecasts are almost always inaccurate, companies need to track the forecast against actual demand and measure the size and type of the forecast error. The size of the forecast error can be measured in units or percentages. In addition, calculating a value for the error may be useful to help justify the time and resources necessary to improve the forecasting process.

Forecast Error is the difference between the actual demand and the forecast demand. The error can be quantified as a unit value or as a percentage.

Forecast error value = A – F
Forecast error percentage = ((A – F) / A) x 100
Where:
A = actual demand
F = forecast demand

Error measurement plays a critical role in tracking forecast accuracy, monitoring for exceptions, and benchmarking the forecasting process. Interpretation of these statistics can be tricky, particularly when working with low-volume data or when trying to assess accuracy across multiple items.

MEAN ABSOLUTE DEVIATION

Mean Absolute Deviation (MAD) measures the size of the forecast error in units. It is calculated as the average of the unsigned (i.e., absolute) errors over a specified period of time. Absolute errors for a series of time periods are added and then divided by the number of time periods. The resulting value is the MAD measure of forecast inaccuracy. Whether the forecast is over or under the actual demand is irrelevant; only the magnitude of the deviation matters in the MAD calculation.

MAD = $\Sigma(|A - F|) / n$
Where:
A = actual demand
F = forecast demand
n = number of time periods

MEAN ABSOLUTE PERCENT ERROR

Mean Absolute Percent Error (MAPE) measures the size of the error in percentage terms. It is calculated as the average of the unsigned percentage error. Many companies use the MAPE as it is easier for most people to understand forecast error and forecast accuracy in percentage terms rather than in actual units. MAPE is a useful variant of the MAD calculation, because it shows the ratio, or percentage, of the absolute errors to the actual demand for a given number of periods.

$$MAPE = \Sigma ((|A - F|) / A) / n \text{ (expressed as a percentage)}$$

Where:

A = actual demand

F = forecast demand

n = number of time periods

MAPE allows the magnitude of the forecast error to be clearly understood without needing detailed knowledge of the product.

MEAN SQUARED ERROR

MEAN SQUARED ERROR (MSE) magnifies the errors by squaring each one before adding them, and then dividing by the number of forecast periods. Squaring errors effectively makes them absolute, because multiplying two negative numbers results in a positive number.

$$MSE = \Sigma (A - F)^2 / n$$

Where:

A = actual demand

F = forecast demand

n = number of time periods

FORECAST BIAS

Forecast error can be the result of bias, which is a consistent deviation from the mean in one direction, either high or low. In other words, bias exists when the demand is consistently over- or under-forecast. A good forecast is not biased.

$$\Sigma \text{ Forecast error} = \Sigma \text{ Actual demand} - \Sigma \text{ Forecast demand}$$

In this formula, if the sum of the forecast error is not zero, there is bias in the forecast. The size of the number reflects the relative amount of bias that is present. A negative result shows that actual demand was consistently less than the forecast, whereas a positive result shows that actual demand was greater than forecast demand.

Once bias has been identified, correcting the forecast error can be realized by adjusting the forecast by the appropriate amount in the appropriate direction (i.e., increase the forecast in the case of under-forecast [positive bias], and decrease it in the case of over-forecast [negative bias]).

A forecast process with bias will eventually create significant problems in the supply chain if left unchecked. Good supply chain planners are aware of these biases. A best practice is to measure for forecast bias routinely and then make corrections accordingly.

RUNNING SUM OF FORECAST ERRORS

Running Sum of Forecast Errors (RSFE) provides a measure of forecast bias. RSFE indicates the tendency of a forecast to be consistently higher or lower than actual demand. A positive RSFE indicates that the forecasts were generally too low, underestimating the demand. In this situation, stockouts are likely to occur as companies are unable to meet customers' actual demand. A negative RSFE indicates that the forecasts were generally too high, overestimating demand. In this situation, excess inventory and higher carrying costs are likely to occur.

$$RSFE = \Sigma e_t$$

Where:

e_t = forecast error for period t

TRACKING SIGNAL

The tracking signal is a simple indicator that forecast bias is present in the forecast model. It determines if the forecast is within acceptable control limits and provides a warning when there are significant unexpected departures from the forecast. If the tracking signal falls outside the preset control limits, there is a bias problem with the forecasting method; and an evaluation of the way the forecast is generated is warranted. Tracking signals are most often used when the validity of the forecasting model is in doubt.

A smoke detector is a good analogy for a tracking signal. It is preset to allow for a certain range of smoke, but beyond that range the alarm (tracking signal) goes off and warns individuals that circumstances are outside the safe control limits. Individuals can then take action to correct the problem (or contact those individuals who can take the appropriate action).

The tracking signal is the ratio of the running sum of forecast errors to mean absolute deviation.

$$\text{Tracking signal} = RSFE / MAD$$

The RSFE is a cumulative sum that does not use absolute value for the errors. Therefore, the tracking signal could be either positive or negative to show the direction of the bias. Companies use a track-

ing signal by setting a target value for each period. If the tracking signal exceeds this target value, it would trigger a forecast review. It is important to remember that forecasts are seldom perfect, and any error in the forecast shows a bias. Tracking signals allow a system to acknowledge that the forecast will not be perfect but should be reasonably close.

BULLWHIP EFFECT

The bullwhip effect refers to the phenomenon that even minimal variability in customer demand can be distorted and amplified with increasing volatility upstream in the supply chain. That is, variability in customer demand is magnified as the supply chain participants become more remote from the end customer. This results in large variations on orders being placed upstream and inefficiencies all throughout the supply chain as suppliers react to their customers who are reacting to their customers. The reason for the effect can be attributed to individual supply chain participants second-guessing what is happening with ordering patterns in the absence of any other information or visibility. The serial nature of communicating orders up the chain with the inherent transportation delays of moving product down the chain induces more and more overcorrection with each successive link in the supply chain.

The bullwhip effect results from a host of issues:

- Customer demand is rarely perfectly stable, and businesses must forecast demand to position inventory and other resources properly. Forecasts, however, are based on statistics, and statistics are rarely 100% accurate.

- Companies often carry an inventory buffer called safety stock due to the knowledge that forecast errors are a given. Moving back across the supply chain from the end consumer(s) to raw material supplier(s), each supply chain participant has a greater observed variation in demand and thus greater need for safety stock.

- In periods of rising demand, downstream participants increase orders. In periods of falling demand, orders decrease or stop, and inventory accumulates. Variations are amplified as one moves upstream in the supply chain (i.e., further back from the end customer/consumer).

When the retailer feels a small demand ripple in the marketplace at the end of the supply chain, the retailer will then start adjusting its orders to the wholesalers, and the wholesaler in turn will adjust its orders to the distributor, the distributor to the factory, and so on back up the supply chain. When the new demand reaches the material or components supplier at the other end of the supply chain, the magnitude of fluctuation becomes unrecognizable. An overreaction due to uncertainty occurs throughout the entire supply chain.

How can the bullwhip effect be alleviated? There is no single remedy that will completely mitigate the bullwhip effect, but there are some actions that supply chain participants can take collectively:

- Collaboration: The sharing of information through the use of electronic data interchange (EDI), point of sale (POS) data, and web-based information systems can facilitate needed collaboration.
- Synchronizing the supply chain: Supply chain participants can coordinate production planning and inventory management to minimize the need for reactionary corrections.
- Reducing inventory: Reducing overall supply chain inventory levels through the use of just in time (JIT), vendor managed inventory (VMI), and quick response (QR), all of which will be discussed later in this text, reduces overreactions to stockouts and decreases the chances of overages.

If the various participants work together to get closer to customers through collaborative planning, forecasting, and replenishment (CPFR), then the bullwhip effect can be greatly reduced and the accumulation of inventory and the inefficient use of resources throughout the supply chain can be minimized.

COLLABORATIVE PLANNING, FORECASTING, AND REPLENISHMENT

Collaborative planning, forecasting, and replenishment (CPFR) is "a process philosophy for facilitating collaborative communications"[1] whereby supply chain trading partners can jointly plan key supply chain activities from production and delivery of raw materials to production and delivery of final products to end customers. Collaboration encompasses business planning, sales forecasting, and all operations required to replenish raw materials and finished goods.

CPFR combines the intelligence of multiple trading partners who share their plans, forecasts, and delivery schedules with one another in an effort to ensure a smooth flow of goods and services across a supply chain. CPFR can significantly reduce the bullwhip effect and provide a plethora of benefits:

- Better customer service
- Lower inventory costs
- Improved quality

- Reduced cycle time
- Better production methods

CPFR requires a fundamental change in the way that buyers and sellers work together. The real value of CPFR comes from the sharing of forecasts among firms rather than firms relying on sophisticated algorithms and forecasting models to estimate demand.

Companies could forecast what they think their customers plan to buy from them, or customers could share their purchase plans with companies, so both sides could benefit.

SUMMARY

- Forecasting and demand planning are the key building blocks from which all downstream supply chain planning activities are derived.
- Demand is the need for a particular product or component. Demand planning is the process of combining statistical forecasting techniques and judgment to construct demand estimates for products or services across the supply chain from the suppliers' raw materials to the consumers' needs.
- A forecast is an estimate of future demand. Forecasting is the business function that attempts to estimate future demand for products so that they can be purchased or manufactured in appropriate quantities in advance. Forecasts, by their nature, are likely to be inaccurate but can still be useful. Forecasting is necessary, because it takes time to convert raw materials to a finished product that will be delivered to the customer.
- Dependent demand is demand directly related to other items or finished products (i.e., a component part or material used in making a finished product). Independent demand is demand for an item that is unrelated to the demand for other items (i.e., a finished product or spare/service parts).
- There are two main categories of forecasting techniques: qualitative and quantitative. Qualitative forecasting techniques are based on opinion, intuition, and judgment. These techniques are used when there is no/little historical data for the product. Quantitative forecasting techniques use historical demand data to project future demand. Quantitative forecasting is the more common method and involves two main qualitative techniques: time series models and cause-and-effect models.

- Time series models predict the future by understanding the past. Cause-and-effect models use the historical relationship between an independent and a dependent variable to predict the future values of the dependent variable (demand).

- Because forecasts are almost always inaccurate, companies need to track the forecast against actual demand and measure the size and type of the forecast error. Error measurement plays a critical role in tracking forecast accuracy.

- Mean absolute deviation (MAD), mean absolute percent error (MAPE), and mean squared error (MSE) are methods used to measure the size of the error.

- Running sum of forecast errors (RSFE) and tracking signals provide a measure and a warning of forecast bias.

- The bullwhip effect refers to the phenomenon that even minimal variability in customer demand can be distorted and amplified with increasing volatility as the participants become more remote from the end customer.

- Collaborative planning, forecasting, and replenishment (CPFR) is a collaboration process whereby supply chain trading partners can jointly plan key supply chain activities: from production and delivery of raw materials to production and delivery of final products to end customers. CPFR can significantly reduce the bullwhip effect.

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Chapter 3

Supply Chain Planning

CHAPTER OUTLINE

Introduction
Supply Chain Planning
Planning Goals and Objectives
Planning Responsibilities and Tasks
Supply Chain Planning Diagram
Business Planning
Sales and Operations Planning
Production Planning (Aggregate Production Planning)
Master Production Scheduling
Time Fencing
Basic Production Strategies
Bill of Materials
Material Requirements Planning
Capacity Planning
Distribution Requirements Planning
Enterprise Resource Planning Systems

INTRODUCTION

Supply chain planning is the element of supply chain management responsible for determining how best to satisfy the requirements created by the demand plan. Its objective is to balance supply and demand in a way that realizes the financial and service objectives of the company. It is a combination of all the planning processes across the supply chain, including aggregate production planning, master production scheduling, materials requirement planning, and distribution requirements planning. (Refer to Figure 3.2 later in the chapter.)

SUPPLY CHAIN PLANNING

Supply chain planning is hierarchical and can be divided into three broad categories:

- **Long Range** (typically 1–3 years; can be as long as 10 years)
  Involves planning for major actions such as capital expenditures including the construction of facilities and major equipment purchase, and new product introduction plans (sales and operations planning and/or aggregate production planning). Example: Fictional Motor Company needs to increase manufacturing capacity to respond to an annual 5% increase in the demand for XL-150 pickup trucks over the next one to three years.

- **Intermediate Range** (typically 3–18 months)
  Involves planning the quantity and timing of end items—that is, specific make and model (master production scheduling). Includes sales planning; production planning; setting major resource levels such as manpower, inventory, contracting; and analyzing operating plans. Example: Fictional Motor Company plans to make 1,000 XL-150 pickup trucks per month for the next 3 to 18 months.

- **Short Range**
  Involves the detailed planning process for components and parts to support the master production schedule. Includes ordering and scheduling activities using information from the bill-of-materials, inventory system, purchasing system, and so forth (materials requirement planning). Example: Plan and order the components and materials needed for production of the XL-150 pickup trucks for delivery each week over the next 24 weeks (250 engines, 250 transmissions, seats, windows, etc.).

PLANNING GOALS AND OBJECTIVES

The first step in supply chain planning is for the top management at the company to establish the desired high-level planning goals and objectives. **Example:** Meet demand within the limits of the available resources at the lowest overall cost, or obtain the resources necessary to meet demand at the lowest overall cost.

The next step is to determine what is necessary to achieve these goals and objectives. Identify the specific action steps. **Examples:** Build or acquire a new facility, hire more workers, buy more equipment.

This is followed by setting start and completion dates for each action item identified. **Example:** Begin hiring more workers in February and finish hiring by April.

Responsibility for each action item should be formally assigned to the appropriate individual or department within the company to execute. **Example:** The action item of hiring more workers would be assigned to the human resource manager or department within the company.

PLANNING RESPONSIBILITIES AND TASKS

FIGURE 3.1

(McLaury, 2016)

Responsibility for the various levels of supply chain planning is generally held by different groups within a company. Figure 3.1 shows which group(s) are typically responsible for short-, intermediate-, and long-range planning.

As long-range planning encompasses making strategic decisions and controlling the level of major resources, it is usually the responsibility of top management in an organization. This level of planning sets the direction the company will follow into the future

Intermediate-range planning translates the long-range plan into an executable plan and schedule in the near time frame. It details the specific products to be produced against a specific time schedule, and allocates the resources needed to achieve the long-range plan. This level of planning is best managed by midlevel operations management people who have the knowledge and information about the operations necessary to develop the plan.

Short-range planning encompasses converting the intermediate level plan into a detailed sequence of steps and actions necessary to execute the plan in the immediate time frame. This is the planning level where the plan becomes a reality, materials are obtained, products are produced, and orders are filled. This level of planning is best managed by the individuals within an organization who are the most directly involved with these activities—the managers, supervisors, supply chain planners, and foreperson of the manufacturing operations.

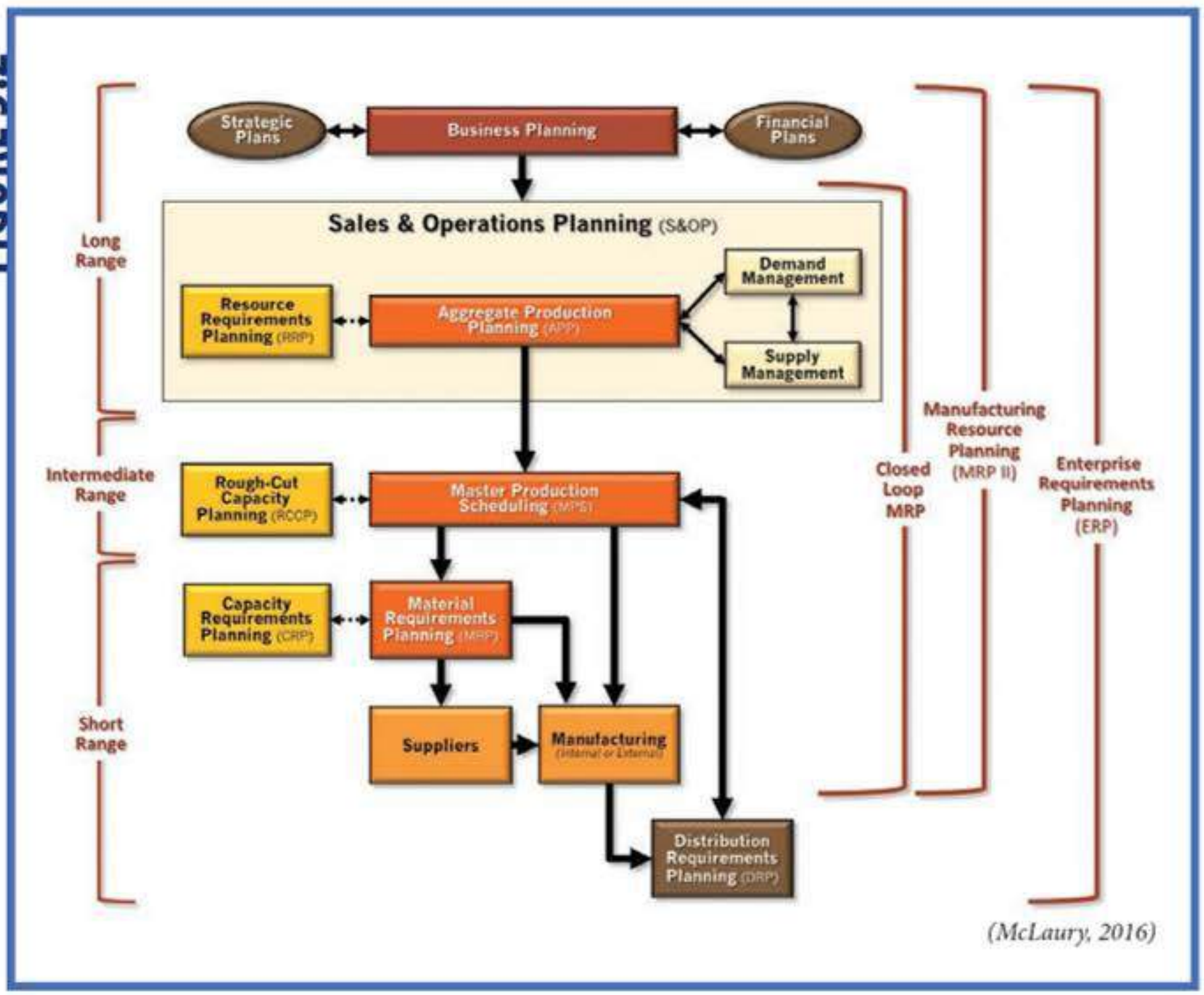
SUPPLY CHAIN PLANNING DIAGRAM

Figure 3.2 shows the sequence of supply chain planning processes, from top to bottom, and their relationship to each other. The hierarchy of processes in the figure goes from the long-range aggregated Business Planning and Sales and Operations Planning (S&OP) processes down through the intermediate range Master Production Scheduling (MPS) process to the detailed short-range Material Requirements Planning (MRP) process. Supply chain planning also includes Distribution Requirements Planning (DRP), which allocates the available and planned finished product inventory out to the various warehouses serving the distribution channels in the network.

Figure 3.2 also shows which planning steps are associated with each of the supply chain management concepts that have evolved from the 1960s to the present; Closed Loop MRP, Manufacturing Resource Planning (MRP II), Enterprise Requirements Planning, and Distribution Requirements Planning (DRP). These are computer-based "push" resource systems.

- **Closed Loop MRP:** Developed in the 1960s, closed loop MRP is "a system used for production planning and inventory control, with an information feedback feature that enables plans

FIGURE 3.2



to be checked and adjusted. Closed Loop MRP synchronizes the purchasing or materials procurement plans with the master production schedule. The system feeds back information about completed manufacture and materials on hand into the MRP system, so that these plans can be adjusted according to capacity and other requirements. The system is called a closed loop MRP because of its feedback feature."[2] It incorporates the aggregate production plan, the master production schedule, the material requirements plan, and the associated capacity planning tools needed to check the feasibility of the plan.

- **Manufacturing Resource Planning (MRP II):** Evolving in the 1980s, manufacturing resource planning (MRP II) is "an integrated information system used by businesses. Manufacturing Resource Planning (MRP II) evolved from early Materials Requirement Planning (MRP) systems by including the integration of additional data, such as employee and financial needs. The system is designed to centralize, integrate and process information for effective de-

cision making in scheduling, design engineering, inventory management and cost control in manufacturing. MRP II is a computer-based system that can create detail production schedules using realtime data to coordinate the arrival of component materials with machine and labor availability. MRP II is used widely by itself, but also as a module of more extensive enterprise resource planning (ERP) systems."[2] It incorporates the closed loop MRP system and adds the strategic, business, and financial plans.

- **Enterprise Requirements Planning (ERP):** Evolving in the 1990's, Enterprise Requirements Planning (ERP) is a process that interfaces with manufacturing to act as an extension of manufacturing resource planning (MRPII). ERP functionality includes all aspects of production planning and scheduling, material planning and inventory control, purchasing, manufacturing, capacity planning, distribution and logistics, as well as planning for the finance and human resource activities of the supply chain. ERP is typically implemented through a software platform of integrated functional modules providing computerized management of all aspects of the enterprise's supply chain. The ERP software application facilitates the sharing of information and the real-time communication and collaboration across multiple business functions necessary for the supply chain to operate efficiently and effectively.

- **Distribution Requirements Planning (DRP):** The DRP is "1) the function of determining the need to replenish inventory at branch warehouses. A time-phased order point approach is used where the planned orders at the branch warehouse level are 'exploded' via MRP logic to become gross requirements on the supplying source. In the case of multilevel distribution networks, this explosion process can continue down through the various levels of regional warehouses (master warehouse, factory warehouse, etc.) and become input to the master production schedule. Demand on the supplying sources is recognized as dependent, and standard MRP logic applies. 2) More generally, replenishment inventory calculations, which may be based on other planning approaches such as period order quantities or 'replace exactly what was used,' rather than being limited to the time-phased order point approach."[1]

BUSINESS PLANNING

The business plan, with its long-term focus, provides the company's direction and objectives for the next 2 to 10 years. Management gathers input from the various organizational functions such as finance, marketing, operations, and engineering, to develop the business plan. The plan states the company's objectives for profitability, growth rate, and return on investment. It is then typically updated and reevaluated annually. It is also typically used as the starting point for developing the organization's production plan or aggregate production plan.

SALES AND OPERATIONS PLANNING

Sales and operations planning (S&OP) is an iterative business management process that determines the optimum level of manufacturing output.

S&OP is a process that brings all the demand and supply plans for the business (sales, marketing, development, production, sourcing, and finance) together to provide management with the ability to strategically direct the business to achieve a competitive advantage.

- "It is the definitive statement of the company's plans for the intermediate to long term, covering a horizon sufficient to plan for resources, and to support the annual business planning process."[1]

- It links the strategic plans for the business with its execution, and provides a way for management to determine resource needs and to keep a handle on the business without having to review the plans at the detailed level.

- It is performed at least once a month and is reviewed by management at an aggregate (product family) level.

- Generally, issues are "bubbled-up" to senior management on an exception basis. Middle management and operational management are expected to try to resolve issues first whenever possible.

Monthly S&OP meetings are essential to decision making. Senior management meets to discuss the various trade-offs between customer service, inventory investments, production capabilities, supply availability, and distribution concerns. The process strives to determine how to best apply the company's resources to strike an optimum balance between maximizing profit and satisfying the company's most important operational goals.

The S&OP process follows some standard steps:

- Review the current plan.
- Review current demand and forecasts for changes and trends.
- Identify capacity and material/product shortages and propose solutions.
- Evaluate product portfolio changes for adding new products and phasing out older products.
- Ensure that the plan meets financial targets.

- Hold a formal S&OP meeting, typically monthly, to review the plan, major changes, and proposed scenarios, to determine and decide on the resource adjustments necessary to meet the company's objectives.

PRODUCTION PLANNING (Aggregate Production Planning)

Production planning, or aggregate production planning (APP), is an integral part of the business planning process. It is "a process to develop tactical plans based on setting the overall level of manufacturing output (production plan) and other activities to best satisfy the current planned levels of sales (sales plan or forecasts), while meeting general business objectives of profitability, productivity, competitive customer lead times, and so on, as expressed in the overall business plan. The sales and production capabilities are compared, and a business strategy that includes a sales plan, a production plan, budgets, pro forma financial statements, and supporting plans for materials and workforce requirements, and so on, is developed. One of its primary purposes is to establish production rates that will achieve management's objective of satisfying customer demand by maintaining, raising, or lowering inventories or backlogs, while usually attempting to keep the workforce relatively stable. Because this plan affects many company functions, it is normally prepared with information from marketing and coordinated with the functions of manufacturing, sales, engineering, finance, materials, and so on."[1]

Aggregate production planning is the hierarchical planning process that translates annual business and marketing plans, and demand forecasts, into a production plan for a product family (products that share similar characteristics) in a plant or facility. The aggregate plan identifies the resources needed by operations management to support the business plan over the next 6 to 18 months. It details the aggregate production rate and size of the workforce, which enables planners to determine the amount of inventory to be held; the amount of overtime authorized; any subcontracting, hiring, or firing of employees; and backordering of customer orders.[2]

Developing the aggregate production plan includes:

1. Determining the demand for each period covered by the aggregate planning horizon
2. Determining the available capacity for each period covered by the aggregate planning horizon
3. Identifying any constraints which may influence the plan
4. Determining the direct labor and material costs and the indirect manufacturing costs for each product or product family covered by the aggregate production plan

5. Identifying or developing strategies and contingency plans to manage the potential upside or downside in the market

6. Agreeing on a plan that best meets the planning goals and objectives

It is also advisable to test or challenge the plan, if possible, to determine how robust the plan is, and whether or not additional strategies or contingency plans need to be developed.

Individual products are not represented in the plan as it would be cumbersome to include every product, so a company typically develops the APP by major product family.

Example: A cosmetic company may produce many different products, such as mascara or lipstick, and each with different colors, different styles, and package sizes. Including all of these in a plan would be cumbersome. The aggregate plan considers a product grouping such as "tubes of lipstick" or "bottles of mascara" as a product measure for aggregate planning purposes.

The aim is to develop the aggregate production plan to cover all of the operations resources (machines, labor, and inventory), to produce the amount of product needed over a certain period of time. The aggregate plan will then specify, for a particular period, how many units of product are produced, how much labor is needed, and how much inventory is on hand. Using product families reduces the level of detail but still provides the information needed for decision making. Some common terms of output used in the aggregate plans are *units, gallons, pounds, standard hours,* and *dollars.*

Aggregate production planning is an iterative and ongoing process. The plan should be updated once every three months, rolling the plan out three more months into the future each time, or whenever there is a major change—whichever comes first. The APP is an intermediate plan and does not need to be updated continuously. Updating the APP too frequently will add instability to the company's operations.

Aggregate Production Planning Goals

For the aggregate production planning process to be value added, it must strive to achieve some high-level goals, including:

- Meeting demand
- Using capacity efficiently
- Achieving the inventory targets
- Minimizing costs:

- Labor
- Inventory
- Plant and equipment
- Subcontract

Available capacity versus demand:

- If capacity and demand are **nearly equal** emphasis should be placed on meeting demand as efficiently as possible.

- If capacity is **greater than demand** the firm might choose promotion and advertising in order to increase demand.

- If capacity is **less than demand** the firm might consider subcontracting a portion of the workload to an outside third party.

Aggregate Production Planning Strategies

In order for the APP to achieve the desired goals, demand and supply must be kept in balance. If the APP projects a potential imbalance in demand and supply, there are some strategies typically employed by companies to remedy the projected imbalance before it actually occurs. The following are some strategic actions companies can take on both the demand and supply sides of the plan to avoid the imbalance.

Demand Strategies:

- Influencing demand: Companies can try to influence projected demand so that it aligns better to available production capacity (e.g., airlines and hotels offering weekend discounts, telecommunication companies offering weekend rates, off-season purchase discounts, early bird specials, happy hour). These can be facilitated through advertising, promotional plans, and price discount strategies.

- Backordering: Accept that demand will be greater than supply capabilities during high demand periods and allow some demand to go unfulfilled. However, this action

may create a negative customer experience and impact the company in both the short and long term.

- Counter-seasonal product mix: Develop a product mix with opposing trends (e.g., opposite seasons) that level the cumulative required production capacity (e.g., manufacture lawn mowers for the summer and snow blowers for the winter).

Supply Strategies:

- Change inventory levels:
  - Increase inventories: Build stock in advance of demand in order to use available capacity.
  - Decrease inventories: Temporarily reduce inventory below normal safety stock levels during peak demand periods to meet customer requirements.
- Change capacity:
  - Vary production output through overtime or idle time.
  - Vary workforce size by hiring or layoff.
  - Use part-time workers.
  - Subcontract the work.

The output of the aggregate planning process is the aggregate production plan, which guides development of the master production schedule (refer to figure 3.2).

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MASTER PRODUCTION SCHEDULING

"The Master Production Schedule (MPS) represents what the company plans to produce expressed in specific configurations, quantities, and dates. It becomes a set of planning numbers that drives material requirements planning. The master production schedule must take into account the forecast, the production plan, and other important considerations such as backlog, availability of material, availability of capacity, and management policies and goals."[1]

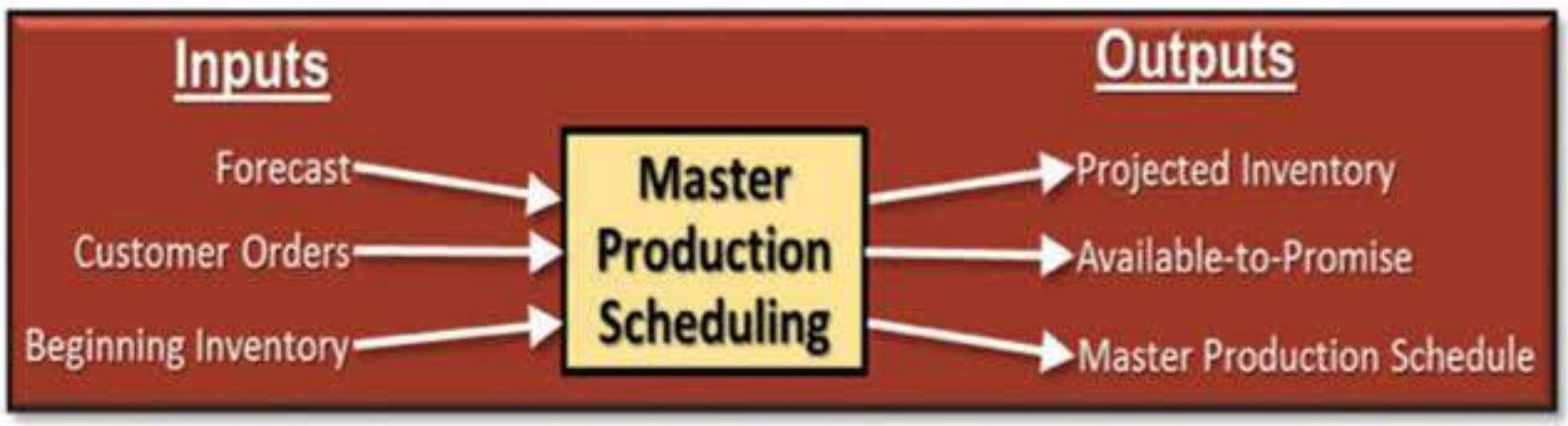
NOTE: For the service industry, the master production schedule may be the **appointment log or book**, where capacity (e.g., skilled labor or professional service) is balanced with demand.

Unlike the APP, which is expressed as product families, the MPS is expressed as specific finished goods. It is a detailed disaggregation of the aggregate production plan, listing the exact end items to be produced by a specific period, and includes how operations will use available resources. This allows the company to make informed commitments to customers.

"MPS is the plan that drives the business and commits resources and materials (costs) to meet the plan. The plan is what the business can achieve not necessarily what the customer wants."[4] The MPS is a statement of production, not a statement of demand. As such, individual products can be finished ahead of time (i.e., before they are required to meet demand) and held in inventory rather than finished as needed. The master production scheduler is the person responsible for balancing customer service and capacity usage (see figure 3.3).

- The MPS is reviewed and updated as necessary—weekly or even daily.
- The planning horizon is shorter than APP, but longer than the lead time to produce the item. Example: If the lead time to produce an item is 2 months, then the planning horizon of MPS must be more than 2 months but generally not as far out into the future as the 18 months covered by the APP. Typically the planning horizon of MPS is 3 to 12 months.

FIGURE 3.3



(McLaury, 2016)

Example: Aggregate Production Plan ➔ Master Production Schedule

FIGURE 3.4

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aggregate Production Plan												
Cars	2,000	3,000	4,000	3,000	3,000	2,000	2,000	3,000	3,000	3,000	3,000	2,000
Master Schedule	Firmed Time Period				Planned Time Period							
2-Door Cars	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
4-Door Cars	750	1,500	2,000	1,250	1,000	750	750	1,000	1,250	1,500	1,500	750
Convertibles	250	500	1,000	750	1,000	250	250	1,000	750	500	500	250
Master Production Schedule (MPS)	Firmed Time Period				Planned Time Period							
Forecast (4-Door Cars)	750	1,500	2,000	1,250	1,000	750	750	1,000	1,250	1,500	1,500	750
Customer Orders (4-Door Cars)	750	1,000	1,750	1,000								
Master Production Schedule (MPS)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Projected Available Balance 1,500	1,750	1,750	1,000	1,000	1,000	1,250	1,500	1,500	1,250	750	250	500

Projected Available Balance *(from the previous period)* – **Customer Orders** or **Forecast** *(for the current period)* + **MPS** = **Projected Available Balance** *(for the current period)*

(McLaury 2018)

Planning Formula

Beginning Inventory (projected available balance from the end of the previous period), plus production (i.e., the MPS) quantity for the current period, minus the demand (i.e., customer orders or forecast) for the current period, equals the projected ending inventory (i.e., projected available balance) for the current period (see figure 3.4).

Available-to-promise (ATP) is a business function that provides a response to customer order enquiries, based on resource availability. It generates available quantities of the requested product, and delivery due dates.

It represents "the uncommitted portion of a company's inventory and planned production maintained in the master schedule to support customer order promising."[1] In simple terms, it is a calculation to determine how much inventory the company will have at the end of each period that has not already been promised/planned/allocated to future customer orders. This information will help the company respond to new customer orders or inquiries, determining whether the company will have enough available inventory to deliver against these new customer orders or not.