2022

2022 LEARNING SYSTEM
VERSION 5.0

MODULE 2

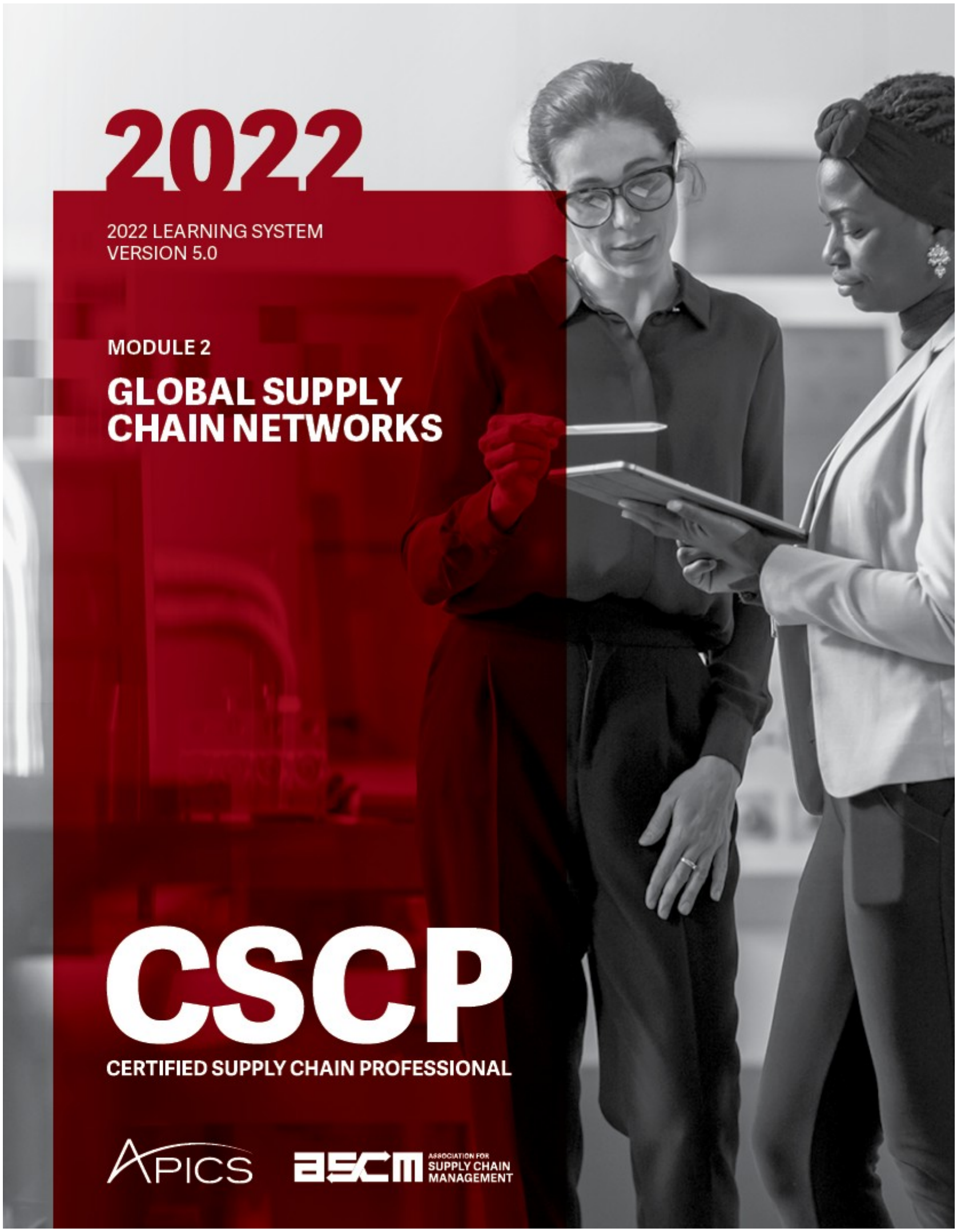
GLOBAL SUPPLY CHAIN NETWORKS

CSCP

CERTIFIED SUPPLY CHAIN PROFESSIONAL

APICS

ASCM ASSOCIATION FOR SUPPLY CHAIN MANAGEMENT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APICS Certified Supply Chain Professional (CSCP) Learning System

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Module 2: Global Supply Chain Networks

This module starts with a discussion of supply chain design. This involves determining how to align the supply chain with organizational strategy and related business requirements, IT strategy, and cyber security requirements. Part of this process is deciding on whether the supply chain should focus on being efficient versus responsive. The focus on IT is needed these days to ensure that the supply chain enables end-to-end connectivity and visibility.

Also addressed are various supply chain management technology applications, from enterprise resources planning (ERP) systems to warehouse management systems and more. Front end, middle end, and back end systems are discussed. The middle end enables integration and connectivity. Maintaining accurate and up-to-date supply chain master data is also covered, because timely and reliable data are vital for supply chain efficiency and effectiveness.

The last major subject for this module is reports, analytics, and metrics. Measurement is key to proper management. SCOR® metrics, financial metrics, and operational metrics are covered, plus reporting tools such as dashboards and balanced scorecards.

Section A: Supply Chain Design and Optimization

This section is designed to

- Explain how business strategy is translated into supply chain network design
- Explain how strategic decisions are made concerning customers and markets, technology, key processes, and sourcing
- Show how supply chain network optimization depends on a company's stage of supply chain development and has implications for the types of technology a company can use
- Show how information technology can reduce friction in the supply chain by enabling new strategies and operational methods
- Show how the return on investment for an IT initiative is computed
- Explore how a nucleus firm can take the lead and help orchestrate the supply chain or bring it to a higher level of supply chain maturity.

Supply chains need to translate organizational and supply chain strategies into reality. This is done using supply chain design and supply chain network configuration. A supply chain strategy can focus on efficiency or responsiveness, but the tradeoffs involved prevent these from being equal priorities. Supply chains also need to be resilient. Requirements for IT need to be considered up front as a supply chain is being designed. Technologies need to be assessed for their costs and benefits and should provide a net value. A supply chain's overall maturity is partly dependent on technology choices; the technology can enable or hinder a given supply chain strategy.

Topic 1: Supply Chain Design and Management

When it comes to designing a supply chain, factors to consider include translating organizational strategy into supply chain design and configuring the network in terms of the location and size of facilities and transportation design. Collectively, the decisions made regarding each of these factors should always support the organizational strategy and the supply chain strategy.

Translating Strategy into Design

An organization sets a strategy based on its capabilities and its assessment of how it will compete in its environment. Supply chain managers then determine a complementary supply chain strategy (as do other functional areas) that will support and enable that organizational strategy. For example, if the organizational strategy is to compete on low cost for commodity items, the supply chain strategy will need to be designed to be as low cost and automated as possible rather than attempting to be the fastest or most responsive. Since strategies are by definition high-level, long-term plans, the next step

for supply chain managers is to translate the supply chain strategy into a more tactical, granular level of planning: supply chain design and configuration.

The *APICS Dictionary,* 16th edition, defines **supply chain design** as

> the determination of how to structure a supply chain. Design decisions include the selection of partners, the location and capacity of warehouse and production facilities, the products, the modes of transportation, and supporting information systems.

After developing business, organizational, and supply chain strategies, the organization—or the trading partners collectively—need to support the broad strategies by defining measurable objectives for each manager along the supply chain. To borrow from the SCOR® model, the process is still in the plan phase, when objectives are defined. This phase sets the direction for all the other processes—source, make, deliver, return, and enable. Strategy and objectives are developed first at top management levels and filter down through the levels of management on each trading partner's organizational chart.

It's tempting to say that all decisions affecting the supply chain should be based on organizational and supply chain strategies. But it's more realistic to say that the decisions and the strategy should be aligned, because this is analogous to the "which came first—the chicken or the egg" puzzle. Whichever way you look at the matter, however, priorities must be set strategically. We'll look at the way strategic decisions are made in regard to customers and markets, technology, key processes and flows, and sourcing.

Customer and Market Decisions

Supply chains should be configured to reflect customers' needs as well as trading partners' capacities. There is no universally appropriate supply chain strategy. One example of this variability is Inditex, which holds several fashion brands including Pull & Bear, Massimo Dutti, Stradivarius, Oysho, and notably the Spanish clothing brand Zara, with its two distinct supply chains: one for its more functional products and the other for its fashion products. A company with multiple product lines needs to conduct a careful market assessment and match multiple supply chains to the strategy that is right for each market.

Technology Decisions

Since technology has become the powerful force that extends supply chain visibility across multiple tiers while providing world-shrinking velocity, it deserves serious consideration as an aid to achieving strategic objectives. It's beneficial to weigh the advantages and disadvantages of technology or conduct a benefit-cost analysis. Since technology is expensive to install or lease, sometimes difficult to learn, and, for some, downright threatening, it's important to make informed choices.

There is a lot to choose from, including technology that can increase the velocity and accuracy of information flows, cash flows, checkout processes, inventory tracking, production scheduling—virtually

any process of any length inside the supply chain. Whatever the process you're aiming to improve, technology has become a necessary component of that improvement. But it has to be selected by specialists who know what is current and can guide process stakeholders in choosing the appropriate technology infrastructure at the right initial and ongoing price to conform to overall strategy. The collateral effects of new technology have to be taken into account as well. The theory of constraints tells us that there is no point in buying expensive technology solutions to speed up the flow of information, materials, or payments if they will just be sent speeding into a bottleneck (or constraint) that will stop their progress. Most importantly, each organization needs the right technology applied to the right process by the right people.

Elsewhere we'll look at technology architecture decisions that relate to supply chain design. Other important considerations in this area include

- Determining how frequently data should be transferred and analyzed
- Deciding how data will be cleansed, analyzed, and used
- Determining how to leverage the internet and e-commerce
- Designing and setting up infrastructure internally and between supply chain partners
- Integrating IT and decision support systems into competitive strategy.

Process Decisions and Inventory, Funds, and Information Flows

A supply chain is a set of processes, and these processes can be fine-tuned to suit each customer segment. When planning improvement initiatives, select the processes that are central to the supply chain strategy, measure and benchmark them, and focus your attention on one process or a small manageable number of processes.

The four basic flows in supply chains are the flow of information, the primary product flow, the primary flow of cash, and the reverse flow of products. Customer information flows through the organization and the extended enterprise via orders, sales activity, and forecasts. As products and materials are procured, a value-added flow of goods begins. Understanding how these flows touch many internal and external parties helps supply chain managers determine who will be affected by a supply chain design and thus who needs to be involved in the design effort.

Sourcing

The *Dictionary* defines **sourcing** as "the process of identifying a company that provides a needed good or service." Sourcing involves complex, challenging decisions. Manufactured goods, components, and services can be acquired by purchasing from a company that delivers them by an arm's length transaction or by outsourcing.

The trend in the latter decades of the 20th century and early in this century has been toward contracting non-core activities to supply chain partners. These partners may be located near at hand or offshore. As supply chains grow in length and global dispersion, they can locate each partner in the country or

region best suited by raw material proximity, customer proximity, climate, culture, resources, tax policy, etc., to support each specific activity.

Outsourcing was initially a strategy in manufacturing supply chains. However, advances in computer hardware and software and global broadband networking have enabled global outsourcing of service activities, such as help desks, accounting, and medical testing. Accounting activities, for example, can be carried out across multiple time zones. Working half a world away, a day-shift accountant can perform services during the customer's nighttime hours.

Network Configuration

Supply chain network configuration is a complex strategic decision that concerns the comprehensive organization of suppliers, production factories, distribution centers, and manufacturing resources. Supply chains should be configured to reflect customers' needs and trading partners' capacities. Planning a network that provides an optimal return on all investments requires long-term, strategic thinking. Each decision must be weighed based on its impact on the entire supply chain, not only on the single matter under consideration.

Given information on customer demand, product and service requirements, and supply chain partner requirements, the optimal network configuration needs to consider the following variables:

- Location of plants and production capacities for each product
- Number, location, capacity, and capabilities of warehouses
- Transportation between all facilities

For example, supply chain managers in manufacturing enterprises consider the stocking of distribution centers with an optimal level of the right kinds of inventory and establish transportation links that ensure timely arrival at, and departure from, distribution centers. In the ideal network, raw materials, components, and resources might never be at rest in a warehouse. Instead, they would always be in motion until arriving, just in time, at each location along the chain. One reason this ideal state is difficult to achieve is the fluctuation in demand that occurs all along the supply chain, beginning with the ultimate customer. Unpredictable demand, along with other factors such as accidents and adverse weather conditions, means that maintaining some levels of inventory at various locations along the chain is generally necessary. The supply chain manager's challenge is forecasting future demand as accurately as possible and keeping inventory as low as possible without disruptions in delivery to customers. Elsewhere you will learn more about planning and controlling inventories, the related cost categories, how inventory impacts an organization's financial statements, and inventory management and control.

Another example is warehousing for customer goods. Adding to the number of warehouses may have the benefit of putting goods closer to the customer and thus reducing delivery time. It may also have the drawback of adding to total inventory and increasing the footprint of warehouse space necessary to

store a given amount of goods. Up to a point, putting goods closer to retail outlets or within customer shipping zones tends to benefit the supply chain by reducing transportation costs.

Transportation costs are a function of several variables, including total distance between production facilities, warehouses, retail outlets, or customers; bulk discounts for transport; and types of transportation required. To solve the optimization problem for the entire network, supply chain managers must rely upon the most powerful technology available to them.

As supply chains grow in length and complexity, facilities may be spread out among numerous regions, countries, and continents. A variety of statistics demonstrate how global sourcing and offshore manufacturing can reduce supply chain costs. Employing skilled labor at relatively low wage levels, establishing worldwide or regional centers of competence near major specialized talent pools, savings on materials, and finding new sources of supply are examples.

While global expansion is attractive, offshore expansion requires sufficient due diligence to help ensure success. Specifically, from a logistics perspective, there are many issues related to getting business done and getting a product shipped. This means being aware of local infrastructure issues in the country being evaluated, as summarized in Exhibit 2-1.

Exhibit 2-1: Infrastructure Considerations in Global Expansion

Issue	Considerations
Port facilities, airports	Specific details on the size and quality of port facilities and airports
Highway conditions	The size and condition of roads as well as the extent of the highway system
Rail lines	The availability of routes that will minimize any delay in movement of products

Source: APICS Global Sourcing Workshop Series.

The condition and capacity of port facilities, airports, and roads can be major factors in getting goods and supplies shipped reliably and on a timely basis. Different rail track gauges and capacity issues can adversely affect lead times. Additionally, crossing borders involves high volumes of paperwork.

Topic 2: Business and IT Requirements

Translating business requirements into supply chain design starts with selecting between two basic types of supply chains: efficiency-focused chains and responsive chains. Either type needs to be resilient in terms of its ability to recover from disruption.

IT requirements for the supply chain can include freeing supply chain managers from tasks that can be automated so they have time to improve processes and relationships. Improvements can relate to supply chain velocity, demand volatility reduction, data management, relationship enhancement, and so on. Since cybersecurity is so vital, the NIST Cybersecurity Framework is discussed as a way to set common IT security requirements.

Balancing Efficiency with Responsiveness While Being Resilient

Organizations often need to balance efficiency (least-cost manufacturing and supply chain) with responsiveness. A third element, resilience, is important for either type of supply chain.

Responsiveness implies being responsive to changing customer requirements. This can take the form of investing in customer service and/or agility. Supply chain agility is measured in SCOR® using metrics for flexibility and adaptability, but they basically measure an organization's ability to ramp up or down in production volume without a major impact on cost or organizational disruption.

Since customer focus, flexibility, and adaptability come with a cost, for example, redundant capacity, one cannot generally maximize both efficiency and responsiveness simultaneously. One also cannot ignore either factor entirely. An organization that competes on low cost will maximize efficiency but will still need some amount of responsiveness to mitigate demand risk. An organization that is adaptable to large fluctuations in demand or to disruptions in the supply chain will still need some efficiency or it will go out of business.

The variables that differentiate efficient and responsive supply chains are inventory volume and demand uncertainty. As you review the following descriptions of the two types of chains, you may recognize and associate certain attributes that are integral to the production of different types of products.

An efficiency-focused supply chain may have these attributes:

- Customer demand is stable and does not fluctuate significantly. (There is low demand uncertainty.)
- Forecasting error levels are manageable.
- There is little or no adaptation to changes in structures of markets. (That is, the locations of demand and vendors do not change.)
- There is a long product life cycle.
- Product introductions are infrequent or are planned out well in advance.
- There is limited product variety.

In an efficiency-focused supply chain, the supply chain manager works to proactively manage customer demand and may use time-series forecasting methods to predict future demand. Customer orders are

filled with inventory, and any unpredicted interruptions receive demand management attention to minimize their impact.

A responsive supply chain may have these attributes:

- Customer demand is not stable and can fluctuate significantly. (There is high demand uncertainty.)
- Forecasting error levels can be significant.
- There is adaptation to changes in structures of markets. (The locations of demand and vendors may change.)
- It uses real-time systems for customer data and purchases.
- There is a short product life cycle.
- It may use multiple warehouses for close proximity to customers.
- It may maintain extra or redundant capacity in the form of geographically diversified operations or contracts with suppliers.
- It may use third-party transportation providers for speedy product delivery.
- It may require its manufacturer(s) and suppliers to have a high degree of agility (ramping up or down without cost penalties).

In a response-focused supply chain, the supply chain manager usually develops forecasts based on system flexibility and capacity cushions. (A capacity cushion is extra capacity that is added to a system after capacity for expected demand is calculated. It is also called safety capacity or protective capacity.) Extra capacity may also take the form of redundant manufacturing capabilities at different plants or contractually obligated backup suppliers to safeguard against supply failure risks or to shift capacity in response to demand. From a demand planning perspective, a responsive supply chain that has both high demand variability and sales volumes will probably focus on forecasting parts and components so that it can postpone final assembly until a customer order “pulls” production of the final product.

Being solely focused on either efficiency or responsiveness has proven fatal for some companies. Most supply chains fall somewhere in between the endpoints of the efficient-responsive spectrum. As supply chains strive to improve their performance based on the metrics that are important to their key audiences, they should also evaluate their ability to strike the right balance between efficiency and responsiveness. A supply chain should identify the appropriate level of service. **Level of service** is defined by the *APICS Dictionary,* 16th edition, as

> a measure (usually expressed as a percentage) of satisfying demand through inventory or by the current production schedule in time to satisfy the customers’ requested delivery dates and quantities.

Implementing Efficiency and Responsiveness

How do you determine the best balance of efficiency and responsiveness for a specific supply chain? In the *Harvard Business Review* article “Triple-A Supply Chain” by Hau Lee, the author states that intelligent organizations tailor their supply chains to the nature of the product markets for the optimum

manufacturing scenario and best distribution capabilities. Supply chain management needs to research and identify how to optimize the supply chain based on the types of products or product groups that are manufactured within the chain. What exactly do the customers value in terms of each purchase they make—low price, convenience, customizable features? This question should have been answered during market research.

The success of the supply chains of Gap Inc. is a testimony that tailoring supply chains can be the right solution. Gap Inc., which owns three major brands—Old Navy, the Gap, and Banana Republic—has three separate but overlapping supply chains on three different continents in order to fit each one to the types of products it produces:

- The Old Navy brand targets cost-conscious consumers, and therefore its manufacturing and sourcing are located in China, where labor and material costs are lower.
- The Gap, which caters to more trendy buyers with midpoint prices, has its supply chain in Central America, where speed and flexibility are most important.
- Banana Republic draws customers who want better quality and are willing to pay for it, so its supply chain is located in fashionable Italy, where there's a plethora of finely made fabrics and fashions.

Because it has these three supply chains, Gap Inc. does have higher overhead, lower scale economies for purchasing and production, and higher transportation costs than if it had just one supply chain. Since these brands require different strategies, Gap also uses different supply networks. These networks can provide backup for each other if any experiences a disruption.

Supply chain managers need to determine which type of supply chain is most appropriate for a particular product. It may require some data analysis to do this accurately. Exhibit 2-2 shows how supply chain types can be fitted to products based on volume and demand uncertainty.

Exhibit 2-2: Fit Supply Chain Type to Product

Volume	Efficient Supply Chain	Responsive Supply Chain
High	Make-to-stock products	Assemble-to-order products
Low	Make-to-stock products	Make-to-order products

Low — **Demand Uncertainty** — High

Organizations that focus primarily on efficiency may select a make-to-stock manufacturing strategy (goods are produced and held in warehouse/retail locations before customer orders are placed). Organizations that focus on responsiveness may use a make-to-order manufacturing strategy (goods are manufactured only after customer orders are placed) or an assemble-to-order strategy (product

components or modules are produced based on forecasts and are assembled when customer orders are placed).

In addition to efficiency and responsiveness, modern supply chains also need to be proactive in regard to disruption risks. Making either an efficient or a responsive supply chain agile enough to respond to risk is called making it resilient.

Making Supply Chains Resilient

Once you identify where a product falls in regard to the variables of volume and demand uncertainty, you can research and identify potential changes that will enhance the fit of the supply chain to the product. But some researchers don't think that in itself will be sufficient. Author Lee states that although supply chain efficiency is necessary, it isn't sufficient proof that a company will outperform its competitors. He argues that in order to develop or maintain a competitive edge, supply chains also need to become agile, adaptable, and aligned with other entities in the supply chain. In other words, they need to become resilient. **Supply chain resilience** is defined by the *APICS Dictionary,* 16th edition, as "the ability of a supply chain to anticipate, create plans to avoid or mitigate, and/or to recover from disruptions to supply chain functionality."

Authors Sheffi and Rice echo a similar message in their article "A Supply Chain View of the Resilient Enterprise." They point out that a company's resilience is determined by its competitive position and its supply chain's ability to be responsive to changes or disruptions. Companies that respond successfully to unpredicted disruption will reinforce their competitive advantage and gain market share. They can increase their resilience by building in redundancy or flexibility. Redundancy can also be created by establishing safety stock, using multiple suppliers (even when more expensive), and intentionally setting low capacity utilization rates. To increase an organization's flexibility, mechanisms or indicators need to be put in place that can sense threats and react quickly and accordingly. Efficiency-focused supply chains may have to avoid some of the more expensive resilience initiatives, but they cannot omit all of them.

In summary, no matter what type the supply chain is, if the appropriate metrics and key performance indicators are being used and the supply chain fits with the market and the product requirements for the company, that supply chain has the potential to create a sustainable competitive advantage.

Supply Chain IT Requirements

The *APICS Dictionary,* 16th edition, defines **information technology (IT)** as

> the technology of computers, telecommunications, and other devices that integrate data, equipment, personnel, and problem-solving methods in planning and controlling business activities. Information technology provides the means for storing, encoding, processing, analyzing, transmitting, receiving, and printing text, audio, or video information.

Networking technology also plays a central role in enabling the transmission of information throughout organizations and among supply chain partners.

The information system in a supply chain is not only a collection of data. According to the *Dictionary,* an **information system (IS)** is the

> interrelated computer hardware and software along with people and processes designed for the collection, processing, and dissemination of information for planning, decision making, and control.

This definition's focus on people and processes is the key to getting the most out of any information system. Technology should automate the flow of information and help network people together so they can share their knowledge efficiently and effectively. By using **electronic documents ,** "the electronic representation of a document that can be printed" (*Dictionary*), people and automated systems can easily share data and information of every nature. Technology should help automate, control, and standardize processes so that people can focus more on the "why" and the social elements of transactions or on the exceptions to normal transactions. Finally, information systems not only help turn data into information by putting it in context; they also help share and create knowledge by finding and highlighting new associations between data. These capabilities empower people and processes to continually improve. In other words, the key is turning data into information and then turning that information into action.

Organizations can employ IT to aid supply chain management in many ways, including the following:

- **To increase supply chain velocity, agility, and scalability.** By enabling the efficient transfer of secure information among independent supply chain partners, IT supports the formation of virtual chains. Firms specializing in complementary core competencies can network together temporarily to develop new products and exploit fast-changing opportunities.

- **To provide cost-effective global visibility of data.** Rapid, inexpensive transmission of massive amounts of data through the internet enhances global supply chain visibility. The resulting improvement in sourcing and selling decisions is now a standard that must be met by other companies.

- **To avoid the bullwhip effect.** IT can be used to gather, integrate, and report logistical data to show actual supply chain activity and avoid the bullwhip effect that occurs when partners forecast with incomplete data.

- **To create lean, cost-effective supply chains by replacing inventory flows with information flows and moving from push to pull.** Rapid data streams replace push systems with pull systems, in which real-time data sent from the point of sale allow planners to respond rapidly to actual shifts in demand.

- **To gather, store, and analyze knowledge and share it among supply chain partners.** Efficient networking and integrative technologies give each partner strategic and tactical capabilities that enhance everything from strategic analysis to logistics.
- **To facilitate strategic, tactical, and operational planning and coordination.** By giving all partners the same information, supply chain partners are empowered to improve the overall profitability of the supply chain rather than solely focusing on their own profits.
- **To drive accuracy of data and provide straight-through processing.** Data can be entered once, stored in one place, and used in multiple transactions without reentry errors.
- **To facilitate new relationships.** IT has removed many of the barriers (sometimes called “friction”) that locked organizations into less-than-optimal relationships. Thus it has enabled easier formation of new supply chain partner relationships to exploit emerging global opportunities.
- **To deepen trust in existing relationships.** IT can help create greater trust among supply chain partners using real-time information sharing.

Topic 3: Technology Analysis and Optimization

Technology analysis justifies investments in technology. Technology optimization is a key part of reaching a given stage of supply chain maturity and so is mapped here to the five stages of supply chain maturity. Advice on how to get to higher levels is also provided.

Supply Chain IT Benefit-Cost Analysis

For all the potential uses of technology, IT investments should be undertaken only if they result in a net gain for the organization. As such, the first assumption to make in an IT justification is that this is a business decision, not an IT project. New technology should be matched to the organization’s or supply chain’s goals and should create a strategic supply chain advantage. Note that most IT departments will expect the recipient of the technology to perform such a justification. The IT personnel can be used as expert resources but should not be expected to develop a business case. For supply chain technology, this is the supply chain manager’s responsibility.

If technology is poorly chosen or installed without thorough project management, it can result in a huge financial drain without generating the envisioned benefits. Many organizations have assumed significant financial risk by poorly planning and/or implementing IT projects.

Well-managed capital investments can generate returns in cost savings (in logistics, procurement, software systems, and overhead), greater market share, and new product and market innovations. Successful IT should make a company agile and resilient to change and disruption.

Tangible and Intangible Benefits

Credibility is the key to any cost justification, and past success lends strong credibility to a proposed IT investment. However, the past is not always an accurate predictor of the future. Moreover, making only investments that previously proved successful can stifle creativity and hamper business growth.

Benefits of IT investments can be both tangible and intangible. Tangible benefits can be broken down into direct, day-to-day savings and increases in working capital or available cash resulting from reductions in temporary assets such as inventory and accounts receivable. Intangible benefits are difficult or impossible to quantify, so they may place some strain on credibility.

Exhibit 2-3 displays some tangible and intangible benefits of successful IT investments.

Exhibit 2-3: Potential Benefits of IT Investments

Tangible	Intangible
• Lower maintenance costs • Faster implementation • Increased sales volume • Improved scheduling (fewer changeovers) • Greater financial returns • Lower overhead • Reduced cash-to-cash cycle	• Customer retention • Customer service • Visibility of order status • Workforce redeployment • Employee satisfaction and efficiency

When estimates are required to justify intangible benefits, the best method is to build a consensus rather than use an individual's opinion. For example, IT that promises improvements in sales volume could include points such as

- System visibility of order status increases responsiveness to customers.
- Quality controls result in fewer returns and more customer satisfaction.
- Faster processing increases transaction velocity, reducing lag times.

Note that Exhibit 2-3 lists workforce redeployment as an intangible benefit. Cost reductions promised by the ability to lay off employees should be treated with caution. Besides lowering employee morale, many such estimates prove incorrect; the firm may initially reduce the size of the workforce but eventually increase overall staff. As a consequence, it is advisable to position this predicted benefit as workforce redeployment.

Some nonfinancial benefits to consider include

- Greater customer satisfaction as determined by customer service measures such as number of service calls or returns
- Employee satisfaction measures such as reduced employee turnover (greater retention) and more positive responses to surveys

- Efficiency measures such as increased orders processed per hour
- Collaboration and visibility measures such as reduction of the bullwhip effect without an increase in stockouts.

Tangible and Intangible Costs

On the cost side, tangible, direct costs are straightforward. These include the direct costs of the IT project and ongoing service and maintenance, plus estimates for consulting fees, staff training and change management, resources assigned to the project, and opportunity costs. However, many IT projects are significantly over budget because managers

- Overlook major cost items such as operational support costs.
- Use estimates that assume everything will go according to plan.
- Purposely underestimate costs to secure project approval.
- Fail to invest in change management and/or training, which creates risks of high costs related to quality and deliverable acceptance.

If the initial estimates are optimistic and the project is over budget, both management and external investors will perceive the project as a failure.

The three basic categories of costs are capital expenditures, one-time project expenses, and ongoing support activities. Capital expenditures are amortized over the expected life of the technology. If this amortization period exceeds the actual product life, the costs will be underestimated. One-time project expenses often contain hidden costs such as fees to investigate alternatives, training travel, data conversion, or lost productivity when employees go through a learning curve. Ongoing support costs may include annual license fees or subscriptions, maintenance fees for vendor support, or internal costs for bug fixes, upgrades, taxes on fixed assets, and IT support staff. Analytical software may have additional costs such as the cost of generating mathematical or simulation models once the software is installed.

Just because a salaried employee is a **sunk cost** (according to the *APICS Dictionary,* 16th edition, “a cost…that is not relevant to the decision…that is being made”) does not mean that the cost of reallocating employees to an IT project can be ignored in the justification. Employees should be used when the savings from long-term maintenance using staff are greater than the savings of using a seasoned consultant.

A final cost to consider is the cost of not implementing the project. Sometimes the costs of acquiring a new IT capability are outweighed by the greater (but intangible) costs of not doing so. For example, if a competitor creates a new business model using technology, failure to adapt may risk business failure.

Benefit-Cost Analysis and ROI

Exhibit 2-4 presents a benefit-cost ratio as well as a return on investment (ROI) ratio for an investment. Assume that a company implementing a new version of an enterprise resources planning (ERP) system has estimated total benefits at US$345,000 in tangible and intangible savings and performance increases over five years. The company has also tallied US$259,000 in tangible and intangible costs for five years.

Exhibit 2-4: Benefit-Cost Formula and Example

$$\text{Benefit-Cost Analysis} = \frac{\text{Total Benefits}}{\text{Total Costs}}$$

$$= \frac{\text{US \$345,000}}{\text{US \$259,000}} = 1.33$$

$$\text{Return on Investment} = \frac{\text{Total Benefits} - \text{Total Costs}}{\text{Total Costs}} \times 100$$

$$= \frac{\text{US \$345,000} - \text{US \$259,000}}{\text{US \$259,000}} \times 100 = 33\,\%$$

The benefit-cost ratio example indicates that for every dollar invested in the project over the five-year period, US$1.33 is returned. The ROI shows the same results from the perspective of net value created, which is 33 percent. Analysis time frames should be kept short due to the risk of technology obsolescence.

Technology Capabilities per Supply Chain Optimization Stage

An organization can design optimization into its information system plans. However, optimization requires a dose of reality. An organization's staff may loyally and optimistically assume that the organization is at a high level of development, and this assumption may engender a failure to work toward optimization. Therefore, understanding what constitutes being in a particular stage of supply chain network optimization is critical.

Supply chain network technology optimization can be mapped to the stages of supply chain evolution that exist on a continuum. The range goes from traditional disconnected companies with adversarial external relationships (stage 1) to orchestrated virtual networks of companies (stage 5).

Supply chain optimization stages can be thought of as evolutionary rather than linear. Starting with basic material requirements planning (MRP), a supply chain continuously increases its sophistication in terms of manufacturing resource planning (MRP II) and enterprise resources planning (ERP), internal integration, supply chain planning, production scheduling, external integration, and so on. The top levels also assess process and human resources maturity, such as change readiness. An organization's stage of supply chain optimization is important for benchmarking the supply chain against its competition. Note that different organizational divisions or an organization's different supply chains may be at different levels of maturity. A given organization or area may also be more mature in some capabilities than in others.

Exhibit 2-5 and Exhibit 2-6 characterize the types of supply chain technology capabilities that should exist at a given stage of supply chain evolution.

Exhibit 2-5: Technology Capabilities for Lower Stages of Supply Chain Evolution

Capability	Stage		
	1: Multiple Dysfunction	**2: Semifunctional Enterprise**	**3: Integrated Enterprise**
Internet	Static websites	Online catalogs	Intranets across all functions
Integration	None; no teamwork	Batch	Internal process integration; design teams
Supply chain planning	Little information exchange of any kind	Informal demand planning; inventory reduction; no coordination of initiatives	Formal global demand planning; enhanced warehousing, logistics, forecasting, etc.
Production scheduling	Basic MRP (time-phased order point)	MRP II (manufacturing resource planning)	MRP—ERP
Integration with suppliers	Email/phone	EDI/email/phone; low-price purchasing strategies	Electronic data interchange (EDI) with all large suppliers
Customer delivery	Research	Local inventory	Available-to-promise (ATP)

Exhibit 2-6: Technology Capabilities for Higher Stages of Supply Chain Evolution

Capability	Stage	
	4: Extended Enterprise	**5: Orchestrated Supply Chain**
Internet	E-commerce	Responsive design; cybersecurity
Integration	Supply chain networks; process integration across entity boundaries	Gaps addressed; end-to-end visibility and process automation; blockchain, IoT, etc.
Supply chain planning	Integrated global planning; supply chain vs. supply chain competition	Data-driven using supply chain analytics; cross-organizational teams (technology, people, and change expertise)
Production scheduling	Externally integrated ERP	Automated forwarding of end customer demand data directly to manufacturers and their key suppliers

Capability	Stage	
Integration with suppliers	Vendor-managed inventory (VMI), online requests for quotation (RFQs)	Category strategies drive integration level; supply chain resilience
Customer delivery	Capable-to-promise (CTP)	Automated delivery quotations (e.g., usually ships in X days)

Stage 1: Multiple Dysfunction

At the multiple dysfunction stage, firms may have multiple disconnected legacy MRP systems performing various transactional functions. These divisions follow the departmental barriers within the company. Communication often requires paperwork and data reentry. Note that MRP indicates the simplest process for determining net component requirements—a bill of material, a master schedule, and current on-hand/on-order data, and nothing more.

Drawbacks of stage 1 include multiple system bottlenecks, no supply chain leadership, minimal web capabilities, and little process flexibility. Systems cannot produce timely information, such as order status or lead time. Performance is either not measured, is inadequately measured, is measured but not applied, or is not aligned to company goals.

Organizations at this stage should focus on standardizing internal processes, becoming internet- and mobile-device-capable, and leveraging past continuous improvement efforts. Phased approaches are best, starting with the areas that can generate the greatest savings, such as procurement and logistics, each of which typically generates five to eight percent savings at this stage. Functional areas will resist change, so change management is a must.

Stage 2: Semifunctional Enterprise

At the semifunctional enterprise stage, many companies have completed manufacturing resource planning (MRP II) implementation and can demonstrate cross-functional integration of planning processes involving automated capacity planning. Internal optimization and corporate excellence break down functional silos, leading to interdepartmental trust and cooperation. Some companies have outsourced areas outside their core processes, and these outsource providers are their main external ties.

Stage 2 companies use documented processes and align key performance measures to goals. However, many companies at this stage have not leveraged their web capabilities. At most, they have functionally focused electronic business solutions such as an intranet site or trading in commodities and office supplies.

To move forward, companies at stage 2 should appoint a supply chain leader with experience in external integration. This leader needs executive support and the authority to break down barriers. The leader should start in areas that can be altered without reducing market performance, such as aggregating purchasing across the organization to receive volume discounts. Early successes will help when the leader is championing more painful but necessary process and culture changes. Optimization at this level usually focuses on lean strategies to cut transportation, warehousing, inventory, and equipment costs.

Stage 3: Integrated Enterprise

At the integrated enterprise level, companies have started point-to-point planning integration with the extended enterprise. They share real-time or near-real-time information and collaborate on forecasts between multiple divisions and first-tier customers and suppliers. Interactions with trading partners are usually still on a one-to-one basis. Some share best practices and the risks and rewards of collaboration. They likely use ERP and may use customer relationship management (CRM) or supplier relationship management (SRM) or both. The firm brings functional areas together in processes such as sales and operations planning with a focus on companywide processes.

Getting to stage 3 requires overcoming cultural and technical resistance to change. On the culture and process side, each party may view any ideas from external sources as inferior to internal ideas. On the technology side, many managers don’t know much about the technology enablers and fear loss of key data and the difficulty of linking to multiple different legacy and ERP systems.

To progress to and past this level often requires a visionary leader from a business unit to strengthen the efforts of the supply chain leader and the IT officer in developing these external integrations for the leader’s business unit.

Stage 4: Extended Enterprise

In stage 4, the supply chain becomes more of a supply network. Stage 4 networks engage in e-commerce and have automated and seamless information sharing, linked competitive vision, and common business objectives. They may also use collaborative planning, forecasting, and replenishment (CPFR®) to make plans jointly and may employ vendor-managed inventory for components or finished goods. New products are brought to market faster. Partners in these networks have risk- and reward-sharing contracts and other safeguards to ensure that everyone is motivated toward common goals. End-to-end integration provides total visibility and allows the network to function as a virtual company.

Companies at stage 4 use public or private internet exchanges to buy materials and services from and sell them to multiple sources. Much of the trading is automatic and unattended. They establish more formal partnerships and share talent.

Getting to this level requires sustained executive leadership and development of human and technological supply chain expertise. Another key to sustaining collaboration is a fully integrated performance measurement system that expresses the supply chain strategy and goals and can identify counterproductive elements. Technology links between partners should be seen as a continuous improvement initiative, and adaptable and scalable software solutions should be used when possible.

Stage 5: Orchestrated Supply Chain

In an orchestrated supply chain, talented cross-organizational and cross-functional teams determine a cohesive supply chain technology strategy and use their technical expertise as well as mature processes and well-trained people to ensure that prior and new technology investments are fully leveraged. Change management in particular is well-established, and teams receive the support they need, including through executive championship. The goal is true end-to-end visibility. Automation of repetitive processes should enable people to focus on exceptions, improvements, and relationships. While the prior stage also has many of these integration elements, reaching this stage means that the supply chain is realizing a competitive advantage from its supply chain technology investments, likely because, relative to competing supply chains, its technologies are better integrated and are state-of-the-art (e.g., use of blockchain and the Internet of Things for asset traceability).

For internet maturity, the supply chain's web presence now uses improvements such as responsive design (i.e., site automatically scales to make mobile device use convenient). Comprehensive standards for cybersecurity are followed by all partners.

Integration and supply chain planning now routinely occur at the strategic and tactical levels. At the strategic level, supply chains harness big data and data analytics (especially predictive analytics) to provide decision makers with insights so decisions can be data-driven. These planning improvements also reach the tactical level. For example, many more suppliers now automatically receive end customer demand data so they too can improve their planning horizons and right-size their inventories. Organizations can now also drill down into tier 2 and tier 3 supplier information systems, such as to ensure supply of a difficult-to-source or restricted material. A category strategy can also be used for suppliers; this is basically an assessment of how much you need a given category of supplier and how much they need you. It is used to determine the appropriate levels of relationship and integration. Suppliers who cannot collaborate or integrate at the desired level may be given assistance or be replaced.

Supply Chain Network Optimization Strategy

Many companies become bogged down in their evolution through the stages of optimization. While companies may find it easy to see the value of working toward internal integration, they may be unwilling or unable to make the leap of trust involved in external integration.

Different divisions or businesses within a supply chain may be at different levels. Many companies move one or two business units into the next level and move more of the company or network only if successful. The lowest common denominator in the network may become the bottleneck preventing the system from advancing to the next level. For example, most large organizations now have ERP systems and other supply chain systems such as a warehouse management system, but this alone may not be enough to place an organization at a higher level. Rather, a majority of the items must be present to reach a higher stage of optimization.

To move between stages, companies must continually refine their strategies and develop new technologies. Optimization and innovation are never-ending goals. Competitive analysis may play an important role in motivating continued investments in supply chain network optimization.

As supply chains attain new stages of sophistication, the collaborative capacity of cross-enterprise management teams will mature in proportion to their stage. These teams will be better at soft skills such as building consensus as well as the technologies involved. This maturity cannot be gained except through experience. Because of this, and because of the great complexity involved in the planning and execution required to pass from one stage to the next, supply chains cannot skip stages.

The higher the collaborative capacity, the greater the demand for more enabling technology and new processes such as for transparency. Recognizing and responding to this demand drives further collaboration. It may be that the next opportunity for collaboration lies beyond linking the network and will only be clear when more companies have reached stage 4 (extended enterprise) or 5 (orchestrated supply chain).

Evolving a company into one of the higher stages begins with top management's deciding to permit exchange of pertinent information across the supply chain. The starting point for getting to stage 4 is often one partnership that points the way toward the completely networked system. Internal resistance to change must be broken down. Only then can the company approach prospective partners with an inter-enterprise strategy. If other prospective members are also willing to explore collaboration, they establish a technical infrastructure. Members then work together over time to reach stage 5.

Strategy is set in several steps:

1. Determine the goals and the desired end state of the supply chain.
2. Create cross-functional and cross-business teams.
3. Organize the supply chain's operational processes and IT's mission.
4. Design in change management and training with stringent timetables for all parties. Measure results and provide feedback.
5. Create a conceptual model that will adequately explain the process and all of its elements.
6. Establish technical infrastructure.

Because cross-functional or ad hoc teams will be making more decisions, a culture shift and a shift in individual employee skill sets must occur. Supply chain network optimization requires that centralized and decentralized approaches be mixed to optimize the decision-making process. Teams perform collaborative centralized planning, but execution will be decentralized. Multiple management levels create integrated organizational structures.

Organizations wishing to form a strategy to get to the next stage first need teams to stay abreast of supply chain technology developments. This thinking should include how the technology would benefit them if they had it as well as if a competitor had it first. Second, organizations wishing to move to an inter-enterprise strategy must build a wide and deep knowledge base of all members of the supply chain network. Third, team-building training should stress a holistic viewpoint; that is, they should think of all members of the supply chain as if they were all in the same lifeboat. When cross-functional teams come from different nationalities and cultures, supply chain managers may need to educate team members to show proper sensitivity to cultural differences.

Role of Nucleus Firm and Cross-Functional Teams

Moving between stages is often facilitated or orchestrated by a nucleus firm or channel master. Because the nucleus firm is most likely the best-known name in the partnership or has its name on the products, it is ultimately responsible for customer satisfaction. Therefore, the nucleus firm will champion the cause, contact potential partners, perform a technology audit, and form teams with qualified partners across both functional and enterprise boundaries. This firm must also measure, monitor, and manage the supply chain across companies to make it appear seamless.

Common cross-functional and cross-business teams formed to support a supply chain management initiative include the following.

- **Executive team.** The executive team led by the nucleus firm sets the pace and strategic goals for collaboration and examines mutual strategies for market penetration.
- **Technology team.** The technology team examines requirements for databases, networking, software, and configuration, especially as regards communications and security for safe collaboration. It should be the first team formed, because the team must agree on methods of connecting systems and make these connections before other teams progress past the conceptual stage of network planning. The technology team works with the other teams to find types of information that would build mutual advantage. They analyze existing systems to determine actions to support strategic goals. This team should have representatives from the general IT functional areas (not just supply chain technology specialists) due to the need for cybersecurity and networking expertise.

- **Buying team.** This team examines leveraging combined network purchasing, procurement, and sourcing strategies.
- **Making team.** The making team examines collaborative improvements to manufacturing. Members may feel that their process is already optimal, and incremental steps must be taken to show the benefits of production collaboration.
- **Selling team.** The selling team examines marketing, sales, and customer service synergies to reduce cycle times and optimize order fulfillment and safety stock. Each partner's customer base and segments reveal potential for cross-selling.
- **Inventory team.** The inventory team determines optimal total inventory and inventory turnover to show the benefits of collaboration.
- **Delivery team.** The delivery team examines total space against actual inventory. The team builds a consensus on logistics best practices, total asset use, use of Just-in-Time (JIT) or other inventory strategies, and network safety stocks.

External relationships will start out with collaboration meetings, followed by partial or pilot endeavors, and then standing and/or project-based team development. Relationships will move forward only when the technical foundations are in place and each party is given reasons to trust the others.

Once the initial connectivity project is complete, the network is at the beginning of stage 3 (integrated enterprise). Thereafter, the teams work toward continuous improvement. At stages 4 and 5, teams see the results of their labor, as real-time network communications are actively used by all cross-functional teams.

Section B: End-to-End Connectivity and Visibility

This section is designed to

- Show how IT fits in a comprehensive supply chain management system

- Appraise key application tools for their use in supply chain management, including
  - Enterprise resources planning
  - Advanced planning and scheduling
  - Supply chain event management
  - Warehouse management systems
  - Transportation management systems

- Classify information system infrastructure: databases, networks, software, and configuration

- Understand how the information system architecture is designed at multiple levels: organizational strategy directs information strategy, information content requirements direct information policies and controls, and so on, down to the detailed levels of design and change planning

- Discuss how electronic business enables visibility and information sharing

- Describe various processes for enhancing visibility and information sharing, including distributor integration (DI), vendor-managed inventory (VMI), and collaborative planning, forecasting, and replenishment (CPFR®)

- Discuss the need for timely and accurate master data through the use of master data management over a data life cycle and the use of data cleansing and normalization

- Understand how automatic identification technologies such as conventional and 2D bar codes and RFID help reduce data errors and increase information velocity.

Key technology applications for supply chain management discussed in this section include enterprise resources planning (ERP), advanced planning and scheduling (APS), supply chain event management (SCEM), warehouse management systems (WMS), and transportation management systems (TMS).

Customers and suppliers now expect fast and informed responses to questions and real-time visibility into events, market intelligence, and point-of-sale transactions. Better knowledge of demand has allowed (and required) product life cycles to shrink. Faster life cycles mean that products may enter growth and maturity faster, which will speed the time to profitability, but, conversely, it may also mean that products enter decline sooner and need to be replaced, meaning that organizations must be increasingly flexible. Technology can be a source of competitive advantage for a business.

Topic 1: Supply Chain Technology Applications

Supply chain technology applications discussed here include broad, organization-wide systems such as enterprise resources planning (ERP) and advanced planning and scheduling (APS) as well as supply chain–specific systems including supply chain event management, warehouse management systems, and transportation management systems. First, an overview of these applications is provided.

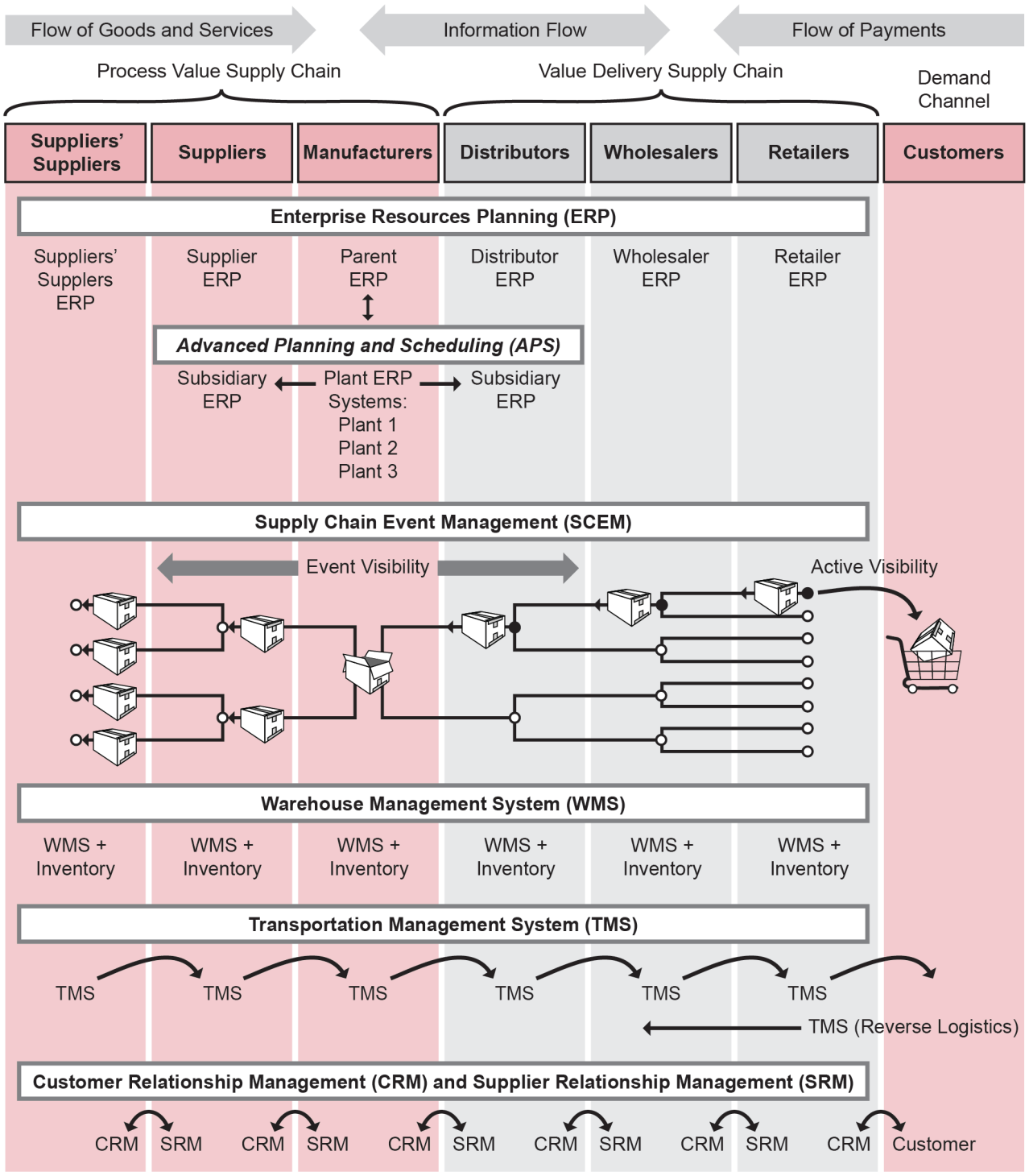
Technology, Connectivity, Visibility/Sharing, and Legal Road Map

A technology road map for supply chain management is presented next, followed by an overview of the other subjects discussed in this area: connectivity, visibility or information sharing, and the legal implications of visibility and information sharing.

Technology Road Map

Exhibit 2-7 provides an overview of a comprehensive supply chain management technology system from the perspective of a manufacturer, focusing on the key application tools as well as on customer relationship management and supplier relationship management. Notice how each partner has their own versions of many or all of the systems.

Exhibit 2-7: Comprehensive Supply Chain Management System (Manufacturer's Perspective)



Many of these systems are also used by other supply chain members, and their supply networks and technologies would appear to be centered on them.

Note the three categories at the top of the exhibit:

- **Process value supply chain.** This part of a supply chain translates demand channel information into products or services. Process efficiency and effectiveness are critical.
- **Value delivery supply chain.** This part of a supply chain is configured to deliver the service component of a product-service package as defined by what the demand channel values. Some chains will have more or fewer partners as strategy demands.
- **Demand channel.** From an IT perspective, the demand channel exists to collect, analyze, and disseminate market intelligence and information on actual customer demand.

Rather than thinking of a supply chain as a monolithic entity, technology has allowed supply chains to continually reinvent and regenerate themselves by forming new chains for different products or

customer segments. Viewing a supply chain as a set of modular components helps demonstrate this flexibility. A **modular system ,** as defined in the *APICS Dictionary,* 16th edition, is

> a system architecture design in which related tasks are grouped in self-contained packages. Each package, or module, of tasks performs all of the tasks related to a specific function and advances in functions can be implemented without affecting other packages or modules because of the loose coupling with other modules. One example is a multitiered architecture in which application business rules are separated from the data management rules. Another example is a client-server architecture in which user interface tasks are separated from the application software.

Connectivity Road Map

Connectivity is enabled by the organization's and its supply partners' information system architectures. This includes databases, networks, software, and their configuration choices (such as a cloud). Supply chain managers need to know how these elements can help or hinder the goal of better connectivity among partners. It is also important to know how these elements can be designed to enable the organization's supply chain strategies to succeed.

Visibility and Information Sharing Road Map

Enhancing visibility and information sharing is how supply chains become more mature and integrated. In addition to solving the technical hurdles, supply chain managers need to sell the idea to the persons involved, both within and external to the organization. Building up trust is critical.

Legal Requirements Road Map

Visibility and information sharing create risk. This includes risks of supply chain disruptions, risks of loss of intellectual property, data privacy risks, data residency rules (the nation in which the data resides, which is especially important for cloud systems), and risks related to cybersecurity. Trade disruption and cyber insurance are options. Getting supply partners to adopt common standards is another response.

ERP Systems

The *APICS Dictionary,* 16th edition, defines **enterprise resources planning** (ERP) as a

> framework for organizing, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage. An ERP system provides extensive databanks of information including master file records, repositories of cost and sales, financial detail, analysis of product and customer hierarchies, and historic and current transactional data.

ERP software is a modularized suite of business applications that are seamlessly integrated to provide automated interactions and a common source of data. ERP systems are built around a large database

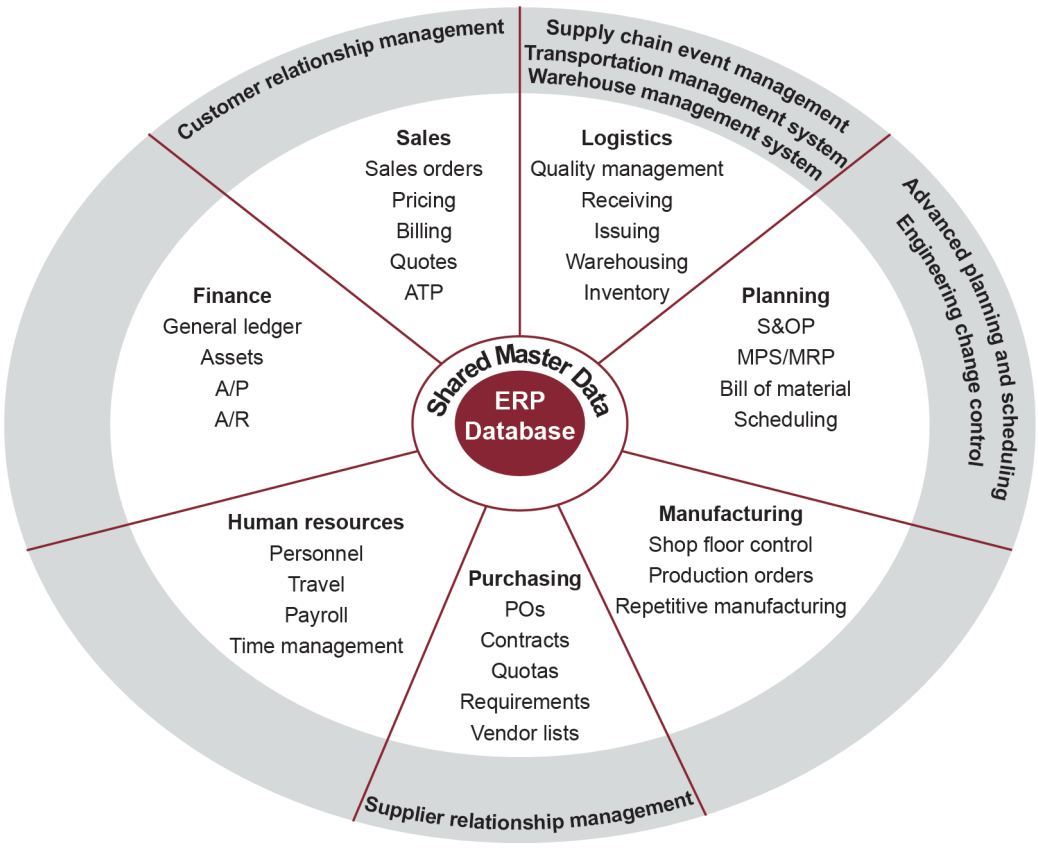
with shared access to data and include a number of transactional modules (for example, planning, manufacturing, purchasing, human resources, finance, sales, logistics).

ERP systems are common in large and mid-size companies and are being adopted by smaller firms. Even in companies already set up for enterprise resources planning, however, there is room to enhance the system's capabilities and to add new modules. Moreover, there is the evolving challenge of linking the ERP systems of supply chain partners.

Without vision or direction, ERP is just a set of applications; with them, ERP will provide the visibility and efficiency needed to see where the business is going and where it can be steered.

Exhibit 2-8 shows how an ERP system supports multiple business functions and can be extended to include more advanced systems such as advanced planning and scheduling.

Exhibit 2-8: ERP System Functionality



ERP Database and Shared Master Data

A key feature of ERP systems is a shared central database. ERP databases provide a single storage location for all types of data. This minimizes data redundancy and enables the various modules to create, access, and modify the same data. The ERP data warehouse contains a number of files or categories of data; the following are relevant to supply chain management:

- Customer files contain all information on individual customers, including terms of sale, records of transactions, and customer service notes.
- Product-price files contain all data on the firm's products and services, including quantity discounts, standard costs, and physical characteristics.
- Supplier files list all suppliers for the organization, allowing the organization to consolidate suppliers and find economies of scale.

- Open order files contain all current or potential product orders from multiple channels, including special shipping or handling requests.
- Purchase order (PO) files are all open orders to suppliers, including MRO (maintenance, repairs, operations).
- Bill of material (BOM) files list product components and raw materials.
- Inventory files show, by location, all available raw materials and finished goods and forecasts of when work-in-process (WIP) inventory will be available.
- Order and PO history files show past purchases and sales for forecasting and budgeting.

These master data are shared among the transactional modules. For example, information in a vendor master file may be used by purchasing, finance, and planning. Material master information may be used by purchasing, planning, and logistics. Location information may be used by planning, purchasing, logistics, sales, human resources, and others.

ERP Transactional Modules

The ERP transactional modules are where all user interactions with the system occur, such as placing orders, moving inventory, billing customers, or paying suppliers. These modules are numerous, and companies can implement one, many, or all of them and may implement them sequentially or all at once.

Decision makers use the ERP planning module to gather input data and analysis when developing tactics aligned with strategy. For the supply chain, this includes research and development, funding and required returns, product line decisions, and marketing strategies. Analytical and forecasting tools in this area use ERP data as well as external market intelligence. The strategic goals set in this area are translated into department-specific goals. Sales and operations planning is a key tool that works to synchronize supply with demand, allowing strategic plans to be regularly adapted to current circumstances. (S&OP is discussed in more detail elsewhere.) S&OP decisions feed into master production scheduling, material requirements planning, bills of material, scheduling, capacity, and other planning methods. The results of S&OP are also fed into other modules, including sales, manufacturing, purchasing, finance, and logistics.

Each of the other modules shown in Exhibit 2-8 will have a range of functions from the strategic to the transactional. Review the exhibit to see some of the functions of these transactional modules.

ERP System Evolution to Advanced Systems

Most ERP systems originated as material requirements planning (MRP) systems that grew over time to include manufacturing resource planning (MRP II) functions and then continued to add modules. Therefore, these supply planning functions are often described as the core of ERP.

The outer ring of Exhibit 2-8 shows that ERP systems are continually evolving and adding new functionality such as CRM, SRM, SCEM, TMS, WMS, engineering change control (ECC), or APS. ECC, also called engineering change management or engineering change order, is a way to ensure that product designs follow a change authorization procedure.

Advanced systems may be part of the same ERP system, but often they exist within separate systems. These systems will link back to the ERP system and leverage the shared ERP data. They may send instructions back to the ERP system for processing. For example, an APS system may determine an optimized production plan/schedule, but it will not execute that plan; it will send the plan back to the ERP system to process.

Even older ERP versions provide value, such as automating processes to increase efficiency and reduce errors. ERP systems incorporate best practices in their conceptual models, which enables process improvements but also means that an upgrade is required to use innovations such as moving from a product-oriented push model to a customer-oriented pull model. More advanced versions shift the focus from internal optimization to external relationships and efficiencies such as collaborative commerce and supply chain management.

With advanced versions of ERP software, supply chain partners are able to

- Make better decisions by relying on data transformed into business knowledge
- Link management pay to supply chain performance through built-in performance measurement tools
- Adopt operational methods such as build-to-order, direct-to-customer, and lean manufacturing
- Connect one ERP system to others in the supply chain and use web-based, open, and component-based systems to regularly adapt the business model
- Provide global access to operational data for all supply chain partners
- Free up capacity and resources to pursue new business opportunities
- Perform collaborative planning using cross-industry and industry-specific ERP systems.

ERP Versus Best-of-Breed Systems

There are several ways to construct an ERP system. All modules can be purchased as a package from one vendor, some modules can be purchased from one vendor with other modules added, or “best of breed” modules can be bought from multiple vendors. When an application is available from both a best-of-breed vendor and an organization’s ERP vendor, which should be chosen?

The advantages of using a module from the ERP vendor include the following:

- Simpler and better integration
- Leveraged ownership of enterprise data
- Shorter user training
- Fewer vendors to work with
- Included in existing support contract

- Lower total cost of ownership (most of the time)
- Vast development resources, including large development (industry-specific) staffs

On the other hand, many best-of-breed vendors have come up with industry-specific or otherwise highly tailored and cutting-edge solutions with the following advantages:

- Faster to market with innovative functions and services
- Targeted industry expertise
- Niche market applications (e.g., oceangoing vessel management)
- May have more expertise in a specific functional area such as warehousing, while an ERP vendor may have little expertise in this area and their module's functionality may reflect this shortcoming

The best-of-breed companies will likely have the most innovative technologies first, and if the company is looking to use the technology to create a competitive advantage, such a purchase can differentiate the company until the technology becomes mainstream (by ERP adoption). Also, if the business case requires a niche application, a more generic alternative offered by an ERP vendor may not suffice. Ultimately, the selection should come from a detailed analysis of the needs of the business versus each option's capabilities.

Upgrades, New Releases of ERP, or New Modules

When a technology audit reveals a gap between current and required technology, the company may be able to get to the desired supply chain stage by implementing an upgrade or new release of its ERP system or by purchasing a new module from the ERP vendor. Any of these changes has significant costs and should be justified by a positive return-on-investment analysis proven with measurable results.

If the upgrade supports the top issues that the company would like to address and if it satisfies key profit, performance, functionality, integration, time to market, and human resources criteria, then the upgrade will likely be a good investment.

Other indications of a worthwhile upgrade include providing the following:

- Better open architecture than the current system, easing supply chain communications and the process of later upgrades or add-ons (Unlike a proprietary architecture, an open architecture is software coded using certain standards to make its parts more interoperable and interchangeable.)
- Better business information or metadata (data about data) such as not only knowing in-stock inventory but also lead time for new stock, stock locations, and capable-to-promise
- Faster learning curve and user-friendly abilities to speed acceptance
- Full integration with currently disjointed systems
- Increasing cost of maintaining old versions (lack of vendor support)

Upgrades take longer when the system infrastructure is heterogeneous and multiple duplication of effort is required for each different system. Multisite coordination is also a factor in the speed and complexity of the process. Upgrading only the sites that will benefit from the change is an option, especially if communication between the versions is already part of the plan.

Tracking the cost of each subsequent upgrade or release allows companies to assess the lifetime cost of the system. This cost should be measured by spending as well as time to delivery. ERP upgrades that can come into service quickly provide the most differentiation from competitors. An alternative to purchasing ERP software and periodically updating it is to use software as a service (SaaS). Many companies are starting to offer SaaS directly to their customers.

Another advanced feature that organizations may want to add through the use of upgrades is cloud computing. Cloud computing would allow a geographically dispersed organization to maintain servers and databases in multiple locations while having them function as a single virtual system and database that can be accessed from anywhere. Note that cloud computing may use an SaaS model or purchased software.

Configuration Versus Customization

For a software purchaser, configuration is adjusting system parameters from a process view without reprogramming the software's code. Configuration is typically a necessary step that results in entry fields and lists being populated with the organization's cost centers, transaction codes, customer codes, and so on. Configurable software is flexible and cost-effective but has limitations, so the software must still be a close match. Customizing is reprogramming the software's code or adding on to the software's code to get the application to do what it was not originally designed to do.

ERP vendors create systems by interviewing thousands of firms and, in general, design the systems to cover the top 80 percent of requested functionality. Costs tend to rise quickly if software is selected below the 80 percent threshold level, partly due to the increased need to customize the software.

Customized ERP systems are inflexible, and customization beyond a few minor and necessary adjustments has many costs and pitfalls. Customization to meet the remaining 20 percent of strategic goals can be worthwhile but should never be applied to the 80 percent that does fit. Customization should be used only to enable meeting indispensable business requirements, and, in practice, far less than 20 percent of a system should be customized. A firm is generally better off upgrading current hardware, databases, software, and business processes to best-practice standards rather than customizing ERP to fit existing systems. A similar argument against customization could be made for many types of software.

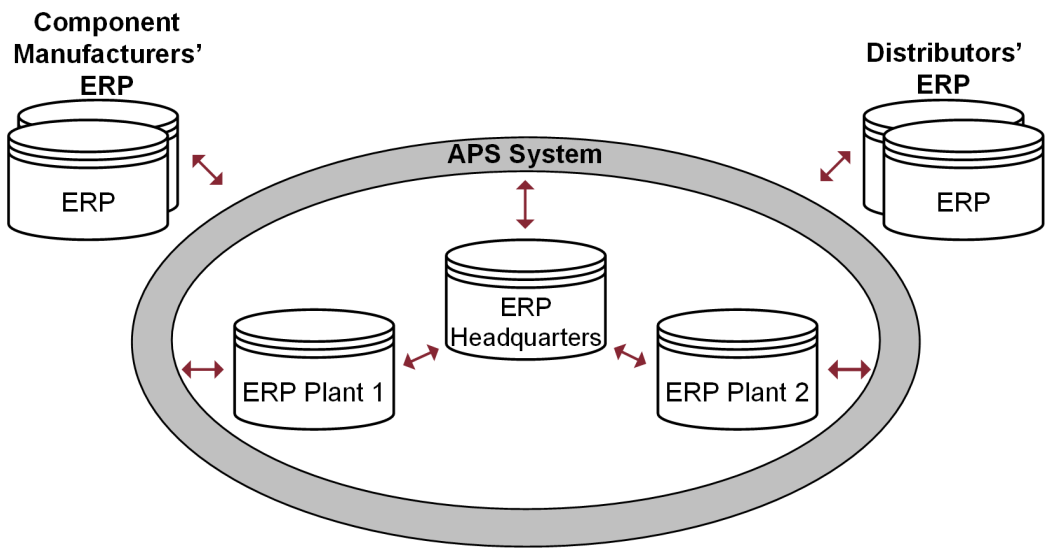
Advanced Planning and Scheduling Systems

According to the *APICS Dictionary,* 16th edition, **advanced planning and scheduling (APS)** refers to

techniques that deal with analysis and planning of logistics and manufacturing over the short, intermediate, and long-term time periods. APS describes any computer program that uses advanced mathematical algorithms or logic to perform optimization or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others.

The key use of APS is to help make sourcing and timing decisions when multiple facilities are available to provide the supply required to meet demand. As Exhibit 2-9 illustrates, APS is an intermediary to enterprise resources planning (ERP) systems that feed it.

Exhibit 2-9: Advanced Planning and Scheduling Systems



APS applications use analytical tools such as modeling, optimizing techniques, and simulations. APS usually includes user-friendly planning tools such as interactive scorecards and drag-and-drop functionality in its interfaces. These advanced tools help plan at the strategic, tactical, and operational levels:

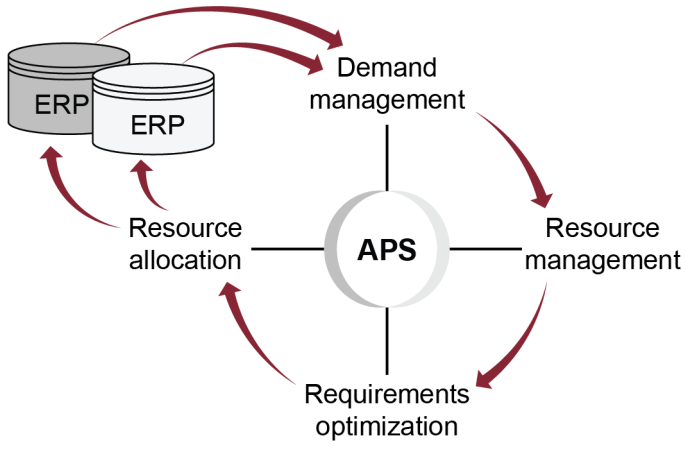
- The strategic level is where high-level decisions and system design occurs. At this level, APS systems may perform logistics supply chain network design. For a manufacturing company, this would involve determining the location of factories, warehouses, and distribution centers, including which aspects of the supply chain will be owned and which will be contracted from a third party.
- The tactical level is where strategy is refined into discrete plans and optimization occurs. At this level, APS helps optimize production, distribution, and inventory across the supply chain.
- The operational level is where plans are refined to the most granular level and then executed. At the operational planning level, APS creates demand forecasts, demand plans, inventory plans, transportation plans, and optimized daily production schedules. For example, at this level it may include finite scheduling software that sends optimized work order loads to manufacturing equipment.

Note, however, that while APS supports planning at each of these levels, it does not execute transactions itself.

Exhibit 2-10 shows how APS systems have four modules that take data from the ERP systems, provide planning and optimization, and then provide the results back to each ERP system's master production

schedule.

Exhibit 2-10: Advanced Planning and Scheduling System Modules



The four modules comprising APS are described as follows:

- **Demand management.** This module takes data on actual orders, order history, customer data, seasonality, and scheduled marketing events and performs organizational or extended supply chain forecasting for production and transportation.

- **Resource management.** This module coordinates the capacities and constraints of resources across the supply chain. Inputs include planning objectives, demand management output, system constraints, customer data such as location, and costs, descriptions, and physical characteristics of products and resources.

- **Requirements optimization.** This module analyzes demand and resource management results and generates and evaluates multiple planning options. It considers customer service and cost, recommending the optimum systemwide solution for procurement, manufacturing, transportation, and storage. It also allows planners to simulate the effect of changes in demand, capacity, etc.

- **Resource allocation.** Once planners review and release the optimized requirements, this module sends requirements to each ERP system's master production schedule. It also provides sales/customer service decision support, such as

  - **Available-to-promise (ATP) .** Information on the visibility of uncommitted finished goods inventory plus work-in-process inventory allows sales channels to quote reliable delivery dates. *The APICS Dictionary,* 16th edition, further explains ATP as

    > the uncommitted portion of a company's inventory and planned production maintained in the master schedule to support customer-order promising. The ATP quantity is the uncommitted inventory balance in the first period and is normally calculated for each period in which an MPS receipt is scheduled.

- **Capable-to-promise (CTP) .** If supply chains are fully linked, the availability of materials for production can be added to ATP data to quote a reliable delivery date.

  The *Dictionary* defines CTP as the

  > process of committing orders against available capacity as well as inventory. This process may involve multiple manufacturing or distribution sites. Capable-to-promise is used to determine when a new or unscheduled customer order can be delivered.

- **Profitable-to-promise (PTP) .** This combines CTP with a profitability analysis to determine how profitable a particular order would be after all costs are considered.

The optimized supply chain master plan feeds a detailed sequence of events to the transactional systems. It ensures the availability of materials and capacity and synchronizes their flow using scheduling.

Feedback from these plans helps continuously improve supply chain planning.

APS Benefits

APS systems remove pressure from bottlenecks in systems. In a multiplant environment, when the same item can be manufactured at different facilities, APS optimizes and accelerates the use of available materials, labor, and plant capacity. At the same time, it satisfies business objectives to create schedules for what should be produced, when and where production should occur, and the sequence of events that should occur. APS creates holistic supply chain plans that incorporate long-range aggregate planning and short-term detailed scheduling.

APS also makes tradeoffs between conflicting objectives as determined by the strategic priorities of the firm. One such tradeoff is performing mass customization while keeping costs down.

The combination of several ERP systems with an APS system makes the most of current ERP investments while opening up a new stage of supply chain development for a firm. The APS system derives an optimal solution for the supply chain network and provides each ERP system with production requirements and optimal start dates for production runs, and it leaves the ERP system to work out the details of how it will meet this high-level plan. Note that the benefits of APS systems can only be achieved if input data are complete and accurate.

Supply Chain Event Management

The *APICS Dictionary,* 16th edition, defines **supply chain event management (SCEM)** as

> a term associated with supply chain management software applications, where users have the ability to flag the occurrence of certain supply chain events to trigger some form of alert or action within another supply chain application. It can be deployed to monitor

> supply chain business processes such as planning, transportation, logistics, or procurement. SCEM can also be applied to supply chain business intelligence applications to alert users to any unplanned or unexpected event.

The alerts mentioned in the definition are often called exception reporting.

SCEM software simulates, controls, and responds to unplanned events and exceptions to planned events. It uses supply chain visibility to link the extended supply chain and track inventory movement. It can help reduce or eliminate customer service errors such as late deliveries or incomplete orders by inputting data into performance management systems so that the root causes of the errors can be seen and corrected. In other words, it shows why a problem occurred.

SCEM also allows users to set parameters based on business rules that trigger notification to the appropriate parties when events in the system occur or when exceptions to those events occur. Managers set workflow-enabled business rules and can spend their time on exceptions instead of sifting through events. Decision makers using SCEM are able to quickly develop and possibly even automatically implement alternate plans. Therefore, SCEM helps mitigate business risk, makes processes more harmonious, and enables collaboration.

Use of SCEM will help a supply chain reach the highest stage of development by enabling interactions between their functional systems such as ERP, advanced optimization tools, and trading exchanges.

SCEM can also trigger downstream activity. For example, when a surgeon writes an order (prescription) authorizing a specific procedure, this event may trigger a number of activities at the hospital, such as allocation of nursing resources, operating and recovery room space, pharmacy needs, and meals.

Active Visibility

SCEM provides active visibility, meaning it can perform the following functions:

- **Monitor** events such as demand, shipments, orders, production, fulfillment, and inventory and distribute the information throughout the supply chain.
- **Measure** events against key performance indicators to improve forecasts and decision making.
- **Notify** decision makers when exceptions occur, such as a shortage, so they can make alternate plans in time to avoid costly consequences.
- **Simulate** real or projected exceptions to gauge their impact and recommend solutions.
- Help **control** events by providing timely and simple methods for reversing previous system choices when an exception indicates that a change could prevent a problem or be less costly (e.g., ship from an alternate source).

Active visibility in SCEM means providing real-time data to internal users and external supply chain members by capturing data from each supply chain partner and dynamically updating distributed databases across the extended supply chain. With SCEM visibility, customers using the company's

website can see dynamic order status or get the same information from an email, call center, or salesperson. These systems usually save the company money in customer service because an email to customers makes them less likely to call about the status of their order, saving call centers for more complex issues.

For managers, the system may include global track and trace functions and may provide data not only on picking, packing, shipping, transit, and delivery status but also quality reporting and performance data. Instead of making calls to find the status of an incoming order, managers simply check the system, at a much lower cost per transaction. Active visibility may also benefit other systems, such as transportation management or warehouse management, for example, when optimizing or making available-to-promise quotes.

Visibility provides SCEM the ability to measure and report on supply channel performance, including information on customer demand patterns, shipments, order location and lead time, and inventory levels by location. SCEM collects information from external sources to add to business intelligence.

For demand management, SCEM provides the ability to manage supplier stockouts or delays. It helps buyers and sellers plan for seasonality and promotions and quickly update demand forecasts with the latest information.

For supply planning management, SCEM supports dynamic inventory allocation and postponement. Sourcing can be sorted into multiple tiers for various levels of speed versus price. Global supplier shipments can be redirected at the port of entry rather than sorted at a central distribution center.

SCEM Benefits

SCEM benefits include the following:

- Faster response times to changes in supply and/or demand
- Ability to receive exception notifications on portable devices
- Earlier marketing and sales demand reaction (less waiting for systems analysts)
- Improved order accuracy, tracking, and cycle time
- Less management time devoted to shipping and receiving
- Reduced inventories and safety stocks across the supply chain
- Greater labor efficiency and productivity
- Better forecasting and business planning for a flexible response to demand
- Reduced total supply chain costs
- Enriched collaboration by allowing it to occur in a decentralized way
- Increased customer responsiveness and decreased product returns
- Improved real-time communications with ad hoc partners

Use of SCEM in Trading Exchanges

Some online trading exchanges provide SCEM capabilities as software as a service (SaaS). They coordinate procurement or sales activities and manage documentation and information distribution needs. On the buy side, exception alerts can notify appropriate personnel of a need to buy a type of good, or the system can be set up to automatically bid for items based on constraints such as cost and supplier rating. On the sell side, shortages in supply can dynamically influence trade exchange demand, such as by promoting an alternative item.

Warehouse Management Systems

As defined in the *APICS Dictionary,* 16th edition, a **warehouse management system (WMS)** is

> a computer application system designed to manage and optimize workflows and the storage of goods within a warehouse. These systems often interface with automated data capture and enterprise resources planning systems.

WMS software takes the output from the enterprise resources planning (ERP) systems and order entry and executes the daily operations of the warehouse or distribution center, performing tasks in an ordered sequence based on predefined parameters.

To gain productivity improvements, the WMS, the warehouse layout, and all enabling technologies for automating data capture and inventory movements should be thoroughly mapped in advance. For example, if mobile devices for scanning bar codes are to be located on forklifts, this needs to be included in the mapping. While WMS was initially only for warehousing, its role has expanded to include areas such as light manufacturing (postponement) and transportation, labor, and order management. This functional overlap makes selection more complex and integration more challenging. However, a WMS selection should hinge on three key areas: directed picking, directed replenishment, and directed put-away. WMS performs these tasks by tracking and analyzing item, quantity, location, unit of measure, and order data.

WMS Functions

A WMS incorporates feedback to improve workflow by continuously simplifying and optimizing operations, especially with warehouse personnel and equipment. It directs management attention to anticipated or existing problem areas in warehouse activity by continuously profiling performance and then creating exception reports for activity levels, productivity, warehouse order cycle time, storage density, and shipment and inventory accuracy. WMS should perform continuous cycle counting for inventory.

The WMS should have a flexible location system, including definable put-away and storage logic methods such as zone logic (defined storage zones), nearest location, fewest locations, or pick-to-clear (using smallest quantities first to maximize space).

Specific WMS functions include the following:

- Receiving—automatically matches and routes POs with advanced shipment notifications (ASNs) and blind or traditional receipts; notifies staff of incoming ASNs and upgrades backorders or rush orders
- Storage location management and optimization—creates put-away algorithms and determines location by type, size, volatility, and velocity
- Cross-docking—allows for opportunistic or planned truck-to-truck transfers, including timed merging of items for a customer's order
- Inventory control—performs cycle counting and creates audit trails to track the time, person, and place of movements, inventory levels, and lead times
- Quality control—tracks items by batch or lot, notifies management of quality issues, places rejects on hold, and ensures quality compliance
- Order selection and task management—forms a pick plan by picking type, allocates items for specific orders, and shows order status
- Automated replenishment—automatically creates a shipment order when an internal or external partner's system signals the demand
- Security—interfaces with security by requiring WMS records for all releases at controlled points, rotates work assignments, etc.
- Returns—manages reverse logistics for repairs, returns, and recycling

Today's WMS supports automatic identification technologies and wireless data collection devices to make the warehouse manager's job easier, more efficient, and less prone to error. Automatic communication and presentation devices such as radio frequency data communications, synthesized voice, pick-to-light, carousels, sortation systems, virtual displays, and other pick signals tell warehouse staff what needs to be moved where without creating paper records.

WMS Interfaces or Portals

Some vendors offer WMS with web-based interfaces or portals. Portals allow visibility and control because users can push data and inventory to supply chain members or they can pull the data and inventory themselves. Such portals can be available as purchased software or software as a service (SaaS).

WMS interface functions include merge-in-transit and cross-company sharing of warehouse space, freight consolidation, or complementary commodities. The web can provide real-time visibility to these collaborative activities such as by providing warehouse status or brokerage clearance data.

Benefits of WMS

Implementing a quality WMS can significantly improve productivity and reduce the frequency of errors or fraud in comparison to traditional methods. In traditional systems, stock pickers may find the wrong item in a location or may find that an item is out of stock. Salespersons with old data may promise what

is unavailable, leading to rush orders. Special orders may wait instead of being cross-docked. Fraud or theft may occur (e.g., deliberate over-picking).

Other WMS benefits include the following:

- Offers competitive advantage, such as faster cycle times through cross-docking or automated checking replacing manual checking
- Satisfies retail requirements such as by adding automatic identification technologies
- Improves accuracy by automating put-away and pick location verification
- Supports high transaction processing capacity for global e-commerce
- Satisfies complex international handling needs
- Increases distribution efficiency, for example, coordinating pallet sizes and bulk discounts (e.g., 80 items per pallet = 80-item order for discount)
- Reduces safety stocks
- Optimizes use of space
- Provides for system design, selection, training, and change management that can mitigate risk

Transportation Management Systems

As defined in the *APICS Dictionary,* 16th edition, a **transportation management system (TMS)** is

> a computer application system designed to manage transportation operations. These systems typically offer modules focused on specific functions, such as intermodal transportation, import/export management, fleet service management, and load planning and optimization.

Transportation management systems automate the planning and operations involved in moving goods between any points in the supply chain, including shipper and mode selection, optimizing routes and loads, and fleet maintenance. TMS has become an integral part of supply chain management partly because of the impact of e-commerce on order size and frequency. Online procurement favors the lowest bidder. Both businesses and consumers are finding it cost-effective to have smaller, more frequent orders. Business models such as Just-in-Time and build-to-order, direct-to-customer also require smaller shipments with tighter lead times. Thus the profit margins are still tight, but the expectations for shipping to manage capacity, costs, and congestion are growing. In such an environment, TMS must be able to optimize transportation across the entire supply chain.

Transportation costs amount to a significant percentage of a company’s total expenses. Furthermore, organizations commonly use thousands of transportation suppliers. Transportation optimization has room to leverage cost savings by using key partnerships with a smaller number of suppliers for most activity and transportation marketplaces for exceptions.

Any TMS package must be able to provide the following:

- **Visibility.** Gives transportation managers, salespersons, customers, and shipping personnel access to timely information.
- **Centralized control over shipment planning.** Holistically optimized routes and shipping modes, freight cost, lead time, and customer service levels.
- **Integration between transportation planning and order fulfillment.** Increases cost control, customer service, and automation.
- **Execution control.** Ensures that the plan is being followed.
- **Automation.** Increases efficiency and reduces errors, e.g., integrating TMS with conveyor belt systems, automatically marking billed loads, or converting documentation to PDF format for international shipments.

TMS Functions

TMS generally includes the following functions.

Transportation Network Design

This strategic phase maps out the transportation network using tools and optimizers. This process would be completed when starting a company or undergoing a major shift in strategy such as collaborating with supply chain partners in transportation network design or determining distribution center locations.

Shipment Planning

Shipment planning optimizes the transportation network using modeling and simulation. At the tactical level, it evaluates routes and carriers. At the operational level, it optimizes daily transportation plans. Shipment planning includes carrier capacity planning, which matches capacity from a supply plan with demand from a demand forecast. Planning takes into account national regulations such as hours-of-service limits to prevent driver fatigue.

Routing

Routing must be able to deal with various transportation modes. For example, truck shipments are shipped by truckload (TL) and less than truckload (LTL). Mode-switching tools optimize the movement of goods across multiple modes, such as air-to-ground, parcel-to-LTL, or courier-to-air-to-courier. Routing guides allow users to define rules for shipment routings, and the TMS can automatically select carriers. Dynamic routing services can interface with global positioning (GPS) devices to avoid traffic congestion.

Specialty applications exist for modes such as routing containerships.

- **Private fleet management.** Private fleets can be managed using tools such as dynamic routing and real-time dispatch. Fleet management dispatches the least number of routes over the least distance

to maximize capacity. A vehicle maintenance module schedules maintenance and tracks costs.

- **Carrier selection.** Multiple carriers such as owner-operator trucks, common carriers, agents, and package services can be managed and selected using transportation procurement applications and transportation marketplaces. Both methods can electronically distribute and collect data from requests for quotation (RFQs) on price and capacity. The systems also track carrier broker profiles and contracts.

Load Matching and Optimization

TMS provides better visibility to the resources available so that the system can find optimal locations from which to fill orders based on availability and inventory and delivery costs. Common load matching/pooling functions include cross-docking and LTL consolidation. Load optimization includes handling of special materials (e.g., refrigeration, hazardous materials). Special applications exist such as for bulk replenishment (e.g., gasoline tankers).

Freight Rating

Rate tariffs can be entered, and loads will be automatically rated by cost and reliability. The selection process uses carrier service level ratings that are updated based on past performance measurement of cost, on-time delivery, and number of errors or damaged goods. Each owner's tariff is used to calculate demurrage (payment for delay to load or unload) and per diem rates.

Manifesting

Manifesting is the process of creating all required shipment documentation. TMS automates the process, printing shipping labels and pick slips.

Load Tendering and Delivery Scheduling

Each load lists carriers in order of preference, and each carrier is attempted in order until coverage is obtained. The delivery is automatically scheduled if the location is set up to receive advanced shipment notifications (ASNs).

Shipment Tracking and Settlement

Managers can view the actual cost of shipments based on actual charges through real-time updates of proof of delivery, freight bills, and import/export documentation. The TMS generates invoices and bills of lading. For global shipments, managers can view certificates of origin, global settlement and billing information for freight, and customs information. Settlement includes auditing of freight bills, minimizing payment errors, and automating payment.

Visibility Tools

Visibility tools allow companies and their suppliers and customers to view inbound and outbound shipments, in-transit inventory levels, and exceptions to expected shipments. These tools improve customer service because they provide the same information to all channels, including self-service channels, make replenishment cycles more reliable, and help supply chain members reduce safety stocks by showing sources of stock and delivery times.

Post-Shipment Analysis

Managers can print reports on freight bills, total landed cost, and loss and damage claims and their filing status.

TMS Interfaces or Portals

Transportation management systems often have web-based interfaces or portals that allow centralized control and automate information distribution across multiple sites. Portals are available in purchased software or as software as a service (SaaS). They have dynamic databases of transportation information that can immediately be used for optimization of transportation methods, such as by allowing carriers on the network to indicate their availability to ship to a particular location or accept backhauls from a location.

Many SaaS TMS applications have thousands of carriers and thousands of TMS subscribers in their networks, meaning that there are no compatibility issues between network members and that automated requests for proposal (RFPs) can be sent to a large selection of carriers. For example, Ace Hardware used its SaaS network to send an RFP to almost 500 carriers, helping it save US$3.9 million or approximately 4 percent of its transportation costs.

Since shipment and fuel costs; road maps and routes; carrier availability; road, traffic, and weather conditions; and many other transportation factors change dynamically, it makes sense for data of these types to be located in a web-based environment where they can be updated in real time. Managers can use web-based TMS to change destinations on shipments while in transit and receive a notice of consignment and statement of revised charges.

Global Track and Trace

Common carriers and private fleets can install global track and trace using cellular-enabled GPS. Global track and trace allows tracking of shipments by location and by receiving status from booking to proof of delivery. Concerned parties can check the information on a dynamically updated website. Global track and trace can also be used to manage field personnel and keep fleets in constant communication, such as finding the best time to pass a toll if the rates change by time of day. The ability to measure driver performance and efficiency allows shippers to manage these factors. Therefore global track and trace systems are a key element in any effort to optimize transportation routes.

When web-based transportation information services are coupled with automatic identification technologies, this information can automatically keep the TMS up-to-date on the status of a shipment without any manual intervention. Because the TMS gets near real-time updates on order shipping status, the system can be proactive in planning next steps and notifying appropriate parties of information such as pickup requests or claims status. Shipments have unprecedented visibility because the TMS allows access by container, bill of lading, PO, order, and other numbers.

Collaborative Transportation Management Principles

Collaborative transportation management has become possible because of robust web-enabled technologies such as use of transportation marketplaces for collaborative shipment management. Shippers and carriers can collaborate on load planning, optimize costs, and consolidate shipments for lower overall transportation costs. Members of a collaborative supply network can optimize all network assets such as by matching loads with multicompany internal assets before resorting to common carriers.

Benefits of TMS

Benefits of TMS include reduction of overall transportation costs by reducing deadheading, demurrage, and time spent waiting to load or unload. Companies can aggregate volumes between locations or companies to reduce freight costs. Capacity procurement reduces cost variability by anticipating demand and making better use of all internal and contractual transportation resources. Linking of communications reduces billing errors and gives networks more time to strategically plan shipments.

In general, a TMS should

- Minimize transportation costs
- Communicate with carriers, vendors, and others using web-based tools
- Make faster and better transportation decisions
- Enable intelligent sourcing decisions by sharing accurate, real-time costs
- Reduce shipment delays from paperwork, errors, or capacity bottlenecks
- Centralize operations to reduce administrative and support costs
- Create distributed data access to reduce information bottlenecks
- Increase supply chain visibility.

Topic 2: Connectivity, Visibility/Sharing, and Legal

Connectivity involves getting the organization’s information systems (IS) to talk to the information systems of the organization’s partners. Understanding connectivity requires understanding how the IS architecture needs to be designed to enable this connectivity. Prior to addressing design, there is a discussion of IS architecture components to clarify the basics of an information system. Next, we

address what connectivity provides: visibility and information sharing capabilities. Finally, legal and regulatory requirements related to information sharing are addressed.

Information System Architecture Components

The *APICS Dictionary,* 16th edition, defines the **information system architecture** as

> A model of how the organization operates regarding information. The model considers four factors: (1) organizational functions, (2) communication of coordination requirements, (3) data modeling needs, and (4) management and control structures. The architecture of the information system should be aligned with and match the architecture of the organization.

The core technologies of the information system architecture can be summarized as databases and their management systems, networks, software, and configuration.

Database and Database Management

The core of information system architecture is the **database,** which is a structured repository of data serving a specific need, such as a transaction record or an employee file. When enterprise resources planning systems are used, they provide a pre-built database structure that can be leveraged. Databases require a **database management system (DBMS) ,** which is defined by the *Dictionary* as

> software designed for organizing data and providing the mechanism for storing, maintaining, and retrieving that data on a physical medium (i.e., a database). A DBMS separates data from the application programs and people who use the data and permits many different views of the data.

Related terminology includes **data manipulation language** (e.g., structured query language [SQL]), which is the language used to query and manipulate a database, and **data dictionary ,** which, as defined in the *Dictionary,* is

> (1) a catalog of requirements and specifications for an information system; (2) a file that stores facts about the files and databases for all systems that are currently being used or for the software involved.

Networks

The *Dictionary* defines a **network** as

> the interconnection of computers, terminals, and communications channels to facilitate file and peripheral device sharing as well as effective data communication.

Linkage between computers and servers is usually through a local area network. The *Dictionary* defines these terms as follows:

> **Server :** A computer, or software package, that provides a specific kind of service to client software running on other computers.
>
> **Local area network (LAN) :** A high-speed data communication system for linking computer terminals, programs, storage, and graphic devices at multiple workstations distributed over a relatively small geographic area such as a building or campus.

Wireless LANs use radio waves to transmit data. Wireless systems are less expensive to set up since they require no wiring, but they do require higher security to prevent unauthorized interception and use of data.

Companies use wide area networks to share information between geographically dispersed facilities. The *Dictionary* states that a **wide area network (WAN)** is "a public or private data communication system for linking computers distributed over a large geographic area."

A virtual private network (VPN), a low-cost internet-based secure transmission method, can allow secure communications with individuals and organizations in various locations. VPNs use encryption to ensure secure communications. External VPN users see the system as if they were in the facility using the LAN.

Two other network terms from the *Dictionary* are intranet and extranet.

> **Intranet :** A privately owned network that makes use of internet technology and applications to meet the needs of an enterprise. It resides entirely within a department or company, providing communication and access to information, similar to the internet, with web pages, and so on for internal use only.
>
> **Extranet :** A network connection to a partner's network using secure information processing and internet protocols to do business.

Software

Software describes programs that create, display, modify, process, and analyze the data in databases in various ways. Types of software include operating systems and applications.

- According to the *Dictionary,* an **operating system (O/S)** is

  > a set of software programs that control the execution of the hardware and application programs. The operating system manages the computer and network resources through storage management, disk input/output, communication linkages, program scheduling, and monitoring system usage for performance and cost allocations.

  Familiar operating systems include Windows, Unix, Linux, and the Mac O/S.

- Application software is controlled by an operating system and fills various computing needs such as to plan, make, source, account for, deliver, and return products and services.

Software can be judged by its relative cost, its reliability (failure rate), its relevance (usefulness and time until obsolescence), its scalability (bandwidth or number of users it can accommodate), and its maintainability (relative cost to create, configure, or upgrade).

In the conventional software application model, the user purchases a software package and license, paying a one-time or annual fee. The user owns the software, and the vendor or developer provides support and updates according to the terms of the licensing agreement, which may require paying an annual maintenance fee or separate fees per upgrade. An alternative to this is **software as a service (SaaS) ,** defined by the *Dictionary* as

> computer services…provided by a third party that keeps all of the software and hardware in its place of business and the company using the services accesses them via the internet.

With SaaS, the software is not downloaded to the user's computer or server. The organization effectively rents the software; SaaS software licenses are still used to indicate the number of authorized users and so on, but the license is in force only so long as the subscription (usually monthly) is kept current.

SaaS eliminates time required for installations and upgrades. For example, Google's word processing and spreadsheet tools fulfill the basic criteria of a SaaS application:

- A vendor (Google)
- Logic and data stored in a central location
- End-user access to data and software, run and used over the internet

This example can be classified as one broad category of SaaS—customer-oriented services. Business-oriented SaaS applications are often "lines of business services," or business solutions for processes such as supply chain management, customer relations, and others.

Exhibit 2-11 summarizes some basic advantages of SaaS for users and vendors.

Exhibit 2-11: Key Advantages of SaaS

User Advantages	Vendor Advantages

User Advantages	Vendor Advantages
• Lower initial costs—no large licensing fee reduces barriers to use; no IT investments • Immediate use—no long implementations • Upgrades are automatic—the vendor makes improvements and fixes to the active version • Smaller storage requirements—storage is the SaaS provider's responsibility • Fewer personnel—reduced need for internal IT people for installation, monitoring, maintenance, and updates	• Continuous stream of income—ongoing subscription fees typically exceed the traditional one-time or annual software licensing fee • Usually only one active version to support (Some vendors deliberately maintain older versions.) • Reduced software piracy and unlicensed use as well as fewer losses associated with such activities

Certainly SaaS does not come without challenges. Vendors must constantly reaffirm that SaaS solutions are lighter, simpler, more intuitive, and more agile. Users are looking to vendors to facilitate easier deployments and provide more robust integration strategies that recognize the heterogeneous environments that most customers now run and will run in the near future. Application areas where functionality is fairly standardized and commoditized (such as customer relationship management, security, sales support, and the IT help desk) are thus far the most prevalent uses for SaaS. Gaps in customization and integration capabilities make SaaS less appealing in areas requiring specialization or complex, real-time integration.

Configuration

Configuration from an information system architecture standpoint refers to how the actual hardware, operating system, application software, and networks are arranged.

The most common configuration is a client/server system, where the clients are personal computers (PCs) or devices and the servers may be mainframe systems. The operating system runs the clients and the servers. The client/server concept involves distributing processing tasks so that the client takes care of local, low data demand tasks and the server/mainframe performs general, high data demand tasks for the company.

The extended chain of suppliers and customers operates primarily over the internet, which is a distributed form of the client/server structure, or a network of networks in which the web browser is the client connected to a web server.

Another option for configuration with supply chain partners or other internal offices is **cloud computing**, described in the *Dictionary* as "an emerging way of computing where data is stored in massive data centers that can be accessed from any connected computers over the internet." Cloud computing

allows authorized members to have virtual access to a network of remote servers, databases, or software no matter their actual location. It is a network of data centers enabling computing resources to be accessed and shared as virtual resources in a secure and scalable manner.

Cloud applications are accessed on a web browser and are offered as software as a service (SaaS), or users can purchase or develop software and upload it to the cloud. Similarly, organizations can eliminate their owned platforms or infrastructure and lease platform as a service (PaaS) or infrastructure as a service (IaaS). SaaS providers may be PaaS customers, and PaaS providers may be IaaS customers. That is, while cloud computing is often advertised as a way to connect with external service providers, it can also be used internally as a way to focus on core capabilities and outsource technology management.

Standards and high adoption rates have made cloud computing mainstream. (In a 2020 Statistica survey cited in an article by Hunter Lowe, 87 percent of organizations indicated they used a hybrid cloud strategy.) An example of a cloud computing standard is ISO/IEC 17788:2014. (This standard was reviewed in 2021 and needed no update). It provides an overview of cloud computing and its terminology. Many SaaS cloud-based systems can interface with an organization’s enterprise resources planning systems. Many ERP systems have enhanced their delivery methods using cloud- and web-based access, and cloud-only ERP systems such as NetSuite or Plex also exist.

Supply chain software lends itself well to cloud-based applications due to the need to integrate so many partner systems. According to a Supply Chain News article by Bridget McCrea, the cloud portion of the supply chain management software market grew 2.5 times faster than the overall market in 2019, a year in which cloud software represented 34 percent of supply chain management applications. Supply chains want to use clouds both to reduce costs and to increase agility.

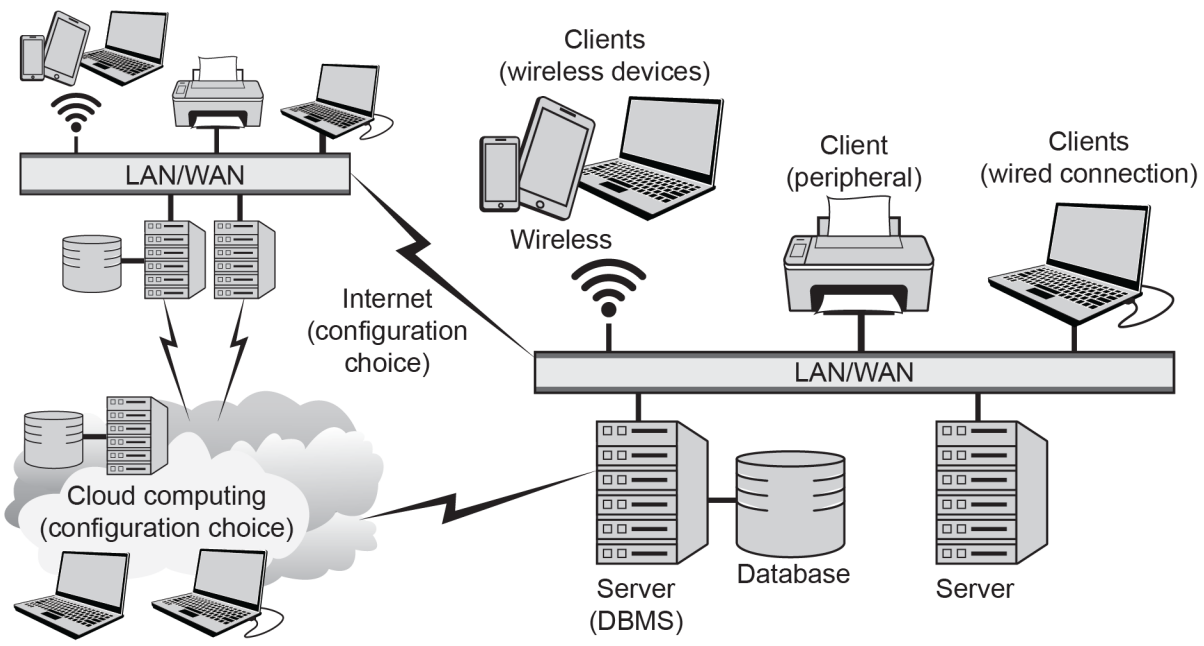
Here are some other benefits of using cloud versions of supply chain management software from the Lowe article:

- Supplier quality management can track the same metrics across the chain and help ensure that specific materials are used by providing bill of material visibility/control.
- Delays or early completion data can be shared automatically with supply chain partners to reduce cycle times.
- Metrics on overall equipment effectiveness (OEE) and availability can be more easily integrated into higher-level decisions, not just the shop floor.
- Some regulatory forms can be automatically created, such as a device history record required by the U.S. Food and Drug Administration on batch, lot, and unit data.
- Real-time track and trace is more achievable and scalable with cloud-based partners.
- Application programming interfaces (APIs) are becoming more common and the cost of integration is falling, allowing existing applications and specialty clouds to be leveraged quickly rather than reinventing them.

- Cloud-based warehouse management systems can automatically aggregate inventory at various network levels.
- Pricing/quoting, customization requests, and approvals can be automated, reducing errors.
- Some systems can integrate early life cycle tools such as for new product introductions into production planning systems to provide readiness reviews.

Exhibit 2-12 shows the technology components of information system architecture, including the connection to external system(s) over the internet or via cloud computing.

Exhibit 2-12: Information System Architecture Components



Information System Architecture Design

Information system architecture is like any type of architecture in that it consists of the detailed plans, drawings, and standards that carefully define the structure of the things being designed. An information system architecture maps out the specifics of how information is gathered, stored, shared, used, and updated/retired. A well-designed architecture enables a high velocity of information. The velocity of information is the ease and speed involved in creating, compiling, transferring, understanding, analyzing, and using information. Poor velocity of information constrains the degree of efficiency and effectiveness a supply chain's functions can achieve.

The definition of the information system architecture states that it should reflect the architecture of the organization. This implies that if the organization wants to change its basic architecture, say, from a department focus to an extended process focus, its information system architecture will also need to change. If it does not, older technology architectures could prevent the changes from succeeding. Therefore, supply chain managers review an organization's information system architecture at a high level so they can assess if it needs to be changed or upgraded to facilitate a specific supply chain strategy.

Supply chain network design and configuration include information flow design and major sourcing decisions. A key goal of network design and configuration is to promote efficiency. This is done by positioning and managing inventory effectively and using resources appropriately. Since the information system architecture enables various departments and external partners to become a unified whole, supply chain information system architecture design is addressed here at the big picture or “road map” level. A technology road map is a brief document (or white board) that sets out overall priorities and high-level plans for a given large-scale process such as supply chain design. The various elements can be reprioritized or changed as needed. Some road maps include graphical representations showing the current state and the future state. Specific parts of the road map then are enacted using project management.

Since information strategy is closely tied to overall network design and configuration, we will show how organizations may go in different directions with their information systems depending on whether their competitive basis is efficient (i.e., cost-basis or lean), responsive, customer-focused, and/or some other mix of priorities.

Information System Architecture

Exhibit 2-13 provides a road map of how the elements of the information systems are designed in parallel to the organization’s strategic and tactical plans for the organization and extended supply chain.

Exhibit 2-13: Organizational and Information System Architectures

Organizational Architecture	Information System Architecture
Organizational strategy	**Information strategy**
♦ Mission, vision, strategy ♦ Core competencies ♦ Segmentation Extended supply chain strategy ♦ Efficient, effective, flexible system ♦ Partner core competencies ♦ Levels of trust and integration	♦ Commitment, principles, goals ♦ Priorities: efficient, responsive, customer-focused ♦ Vision of information system structure Extended supply chain information strategy ♦ Vision and model of extended architecture ♦ Gap analysis
Information content definition	**Information policies and controls**
♦ Data entry, accuracy, and how long to store ♦ Where to store, who can access, how to access ♦ How it is used and analyzed to make decisions Extended supply chain business model ♦ Strategic model of technology integration ♦ Market segment and product/service goals ♦ Financial goals/measurements, profit allocation ♦ Distribution strategy (logistics and integration)	♦ Specific policies and controls, including governance methods and standards to ensure data integrity and system usefulness Extended supply chain communications ♦ Required level of networking and communication enabled by each channel partner ♦ Integration of partner policies, work processes, and tasks and roles
Information infrastructure design	**Database, networks, software, configuration**
♦ Database design ♦ Networking ♦ Software ♦ Configuration (e.g., hardware, client/server) Extended supply chain process model ♦ Details of daily external processes ♦ Which partner does which processes ♦ Degree of process interaction (e.g., virtual organization)	♦ Specific database/cloud choices ♦ Networking specifics (e.g., data communications) ♦ Specific software ♦ Configuration specifics (e.g., interfaces) Extended supply chain networking, etc. ♦ Technology prerequisites ♦ Interfaces to bridge technologies ♦ System reengineering and change management
Information infrastructure change	**Action plan, schedule, prioritization**
IT change requirements Extended supply chain IT requirements	IT action plan Extended supply chain IT action plan

Let’s look at each of the categories in Exhibit 2-13 more closely.

Organizational Strategy

Like all other parts of the supply chain, supply chain design for all information systems and technology should be based on, and align with, the organization’s overall strategy. If a company’s focus changes, the information system architecture should then be changed or upgraded to facilitate the new supply chain strategy.

Information Strategy

The information strategy translates the organization’s strategy into commitments to treat information systems as strategic investments, and it sets guiding principles, priorities, and common goals for network design. The results of the information strategy are reflected in a high-level end-to-end vision of the information system structure. Similarly, the extended supply chain strategy is translated into a strategic vision for the extended supply chain. A gap analysis is performed with key willing partners to compare the existing systems of supply chain partners with what is envisioned, and a model for the extended enterprise is developed in consultation with partners to resolve existing gaps.

Information Content Definition

Information content definition involves making decisions on what data need to be collected, how they will be collected, how their accuracy will be maintained, and how they will be stored, accessed, controlled, analyzed, and retired. For the extended supply chain it involves business modeling, which maps the dynamics and interactions of each supply chain partner. Extended supply chain business modeling includes decisions such as what market segments are being targeted, how performance will be measured, how profits will be shared among partners, and how products will be distributed.

Supply chain infrastructure is evaluated based on these decisions; this includes determining

- The appropriate number of facilities (warehouses, plants)
- The size and location of each facility
- The allocation of space for products within the facility
- Sourcing requirements
- Distribution strategies.

Information Policies and Controls

Information policies and controls are the agreed-upon methods to be used in information infrastructure design, daily operations, and continual improvement initiatives to ensure that the organization’s data and software systems perform as expected. Information systems use data and cost collection to see if the supply chain is an efficient channel for product or service distribution. Controls provide oversight against system misuse and assist with auditing. Governance of information systems and policy compliance will require training and ongoing management support.

For the extended supply chain, the issue is enabling the desired levels of communications and security. Collaboration between partners involves coming to agreement on how networking and data sharing will occur by settling on common information policies and work processes. It also involves determining the roles of partners in establishing data repositories and communications methods. Plans should be designed to be reviewed and adapted as situations change.

Information Infrastructure Design

Information infrastructure design involves determining how to translate policies and controls into a cohesive and cost-effective information system that minimizes data duplication and errors, provides access to information at all necessary internal and external points, and supports effective analysis and efficient transaction processing. This is the level at which detailed decisions are made on how to perform networking, what software to use to best achieve strategic goals, and how to configure the hardware and software for optimum flexibility and growth. Decisions may include how to leverage existing systems; analysis of the costs and benefits of leasing versus purchasing, upgrading, or replacing software; and decisions on the use of interface devices and communications tools.

Databases, Networks, Software, and Configuration

Specific decisions on databases/clouds, information networks, software, and configuration are made following design approval, including use of existing systems, decisions to upgrade or add technologies, specific vendor search and selection, etc.

Decisions on databases and database management systems (including clouds) are critical to the ability of the organization to maintain the integrity, availability, and usefulness of data for decision making. Data for extended supply chains must allow fast access while remaining synchronized. Depending on how databases are designed, they can enable or hinder internal and external integration and external collaboration. Quality data repositories can be a true source of competitive advantage; poor data or poor access can cause users to distrust and discredit otherwise useful systems.

Similarly, networking, software choices, and configuration decisions should be selected to fulfill business requirements while providing a positive return on investment.

Information Infrastructure Change

Supply chain network design should include plans for continual system change and improvement for the internal and extended supply networks.

Action Plan, Schedule, and Prioritization

The results of regular strategy update sessions, tactical system improvement sessions, and operational gap analyses should result in IT action plans for both the organization and the extended supply chain. These plans should prioritize development efforts and expenditures, create projects and tasks, and

include feedback mechanisms to assess project success. Specific cross-functional teams should be responsible for these plans.

Data Communications Methods and Middle End

Data communications methods are the computer languages and methodologies that enable systems to intercommunicate and act as a seamless whole.

Ideally, communications between supply chain partners have two features: They should be easy to link or unlink, and, when linked, they should be tightly integrated. The more tightly integrated the communications are between supply chain partners, the more the supply chain can act as though it were a virtual organization. The value of communications methods that enable efficient interbusiness links depends on how businesses make use of the data. If they manage the process properly, they can increase the visibility and accuracy of information, speed transactions, and reduce duplication of efforts. These efficiencies can reduce cycle times, inventories, and capital expenses and increase return on investment and customer service.

While the communications themselves need to be tightly integrated, the method of achieving that integration should be easy to create, change, and maintain. This is accomplished using a middle end that resides between the user interface and the back end server and database systems. Here we cover two types of middle end systems, middleware and application programming interfaces (APIs). Middleware is more complex and requires more investment in programming but can connect to multiple tools, while APIs are direct one-to-one connections that are easier to develop. First, we clarify where the middle end fits in the overall information system architecture.

Front End, Middle End, Back End

Front end, middle end, and back end are ways of describing conceptual roles of software as well as areas of specialization for software developers:

- **Front end.** This is the user interface, and, in a client-server scenario, this would be the software on the client end. A web browser and web pages are another example. Front end programmers are concerned with the quality of the user experience, minimizing data entry errors, and accommodating various use cases.

- **Middle end.** This is the “glue” that holds the front end together with the back end. It is essentially a translation service for various applications to enable them to converse. Middle end programmers are concerned with automating data requests or data transmissions, and the key is to ensure that the interface is simple to program, simple to document, and simple to modify or scale upward. An example of scaling upward is that the middleware does not become the bottleneck when the front end and back end could handle more traffic.

- **Back end.** This is the server and the database (which could be in the cloud). Back end developers are concerned with ensuring fast access to the right data and for keeping that data accurate, well organized, and secure.

Here we take a closer look at the middle end. These systems are intended to overcome a major obstacle that stands in the way of creating visibility and automated transactions between supply chain partners: getting incompatible hardware and software to communicate automatically and securely without great expense or development time.

The middle end is important because it helps to integrate the supply chain, enables systems and companies to share information, eliminates duplicate and inconsistent data, and breaks down organizational silos—in short, it enables an optimized and collaborative supply chain. The middle end also enables secure transactions through authentication (preventing unauthorized users from gaining entry) and authorization (users can only perform authorized transactions or access their own data).

Middle end systems are often needed because some software systems may be inherently incompatible or reside on different hardware platforms and thus require a middle end to share their functionality. They may also use different operating systems, database types, or computer languages. Sometimes legacy systems may be involved that are no longer supported and may be virtually impossible to modify. A **legacy system** is defined in the *APICS Dictionary,* 16th edition, as

> a computer application program that is old and interfaces poorly with other application but is too expensive to replace. It often runs on antiquated hardware.

While many of the methods discussed next are becoming dated through the continual advancement of the field, the expense of upgrading to newer methods means that many organizations are still relying on some of these older methods.

Middleware

Middleware is “software that interconnects incompatible applications software and databases from various trading partners into decision-support tools such as ERP” (*Dictionary*).

Subtypes include content-level middleware (i.e., electronic data transfer), data-oriented middleware, and process-oriented middleware.

Content-Level Middleware: Electronic Data Transfer (EDT)

Content-level middleware specifies a shared format for standard forms and each of the data fields. The parties involved must agree upon the shared format that will be used. Each may need to translate their data to work with this common format. It is more like an electronic version of sending someone a paper invoice or other document without requiring data reentry. It cannot automate multiple system interactions. Content-level middleware is also called electronic data transfer (EDT).

EDT refers to any transfer of information using electronic means. Originally, EDT could take place only through proprietary electronic data interchange and electronic funds transfer (EFT). **Electronic data interchange (EDI)** is “the paperless (electronic) exchange of trading documents, such as purchase orders, shipment authorizations, advanced shipment notices, and invoices, using standardized document formats” (*Dictionary*). EDI and EFT systems were effective in sending data between two locations if each location was set up using the same standards. Distributed, open standards for EDI plus the internet have enabled much more fluid EDI transfers. Funds transfers have their own standards and are necessarily very restricted. (EFT is vital for supply chain payments but is outside the scope of this text.)

EDI is primarily internet-based today, including via mobile devices. Newer EDI methods should take these cellular device needs into account by providing fast, simple data transfers in self-contained small packets that keep interruptions from corrupting the data. Also, because wireless transmissions are easier to intercept, data security is paramount.

Messages can be sent through a private network or a web-based EDI. (The latter type is much less expensive.) Under either method, EDI requires that special software (proprietary software or some type of middleware) be installed at each end of the transaction or that a third-party value-added network manage the transaction for a fee. The *Dictionary* defines a **value-added network (VAN)** as “a network, often supporting EDI, providing services additional to those provided by common carriers.” ERP systems may also perform this service.

EDI data standards include internationally agreed-upon extranet protocols for transmitting data between companies. In this way, EDI can connect systems that do not run the same applications or ERP systems.

While newer methods to be discussed shortly have replaced EDI in many cases, EDI remains a common method of connecting supply chains for basic transactions such as customer orders, advanced shipment notifications, and invoices. Because of the expense of implementing EDI, the fact that it often needs to be batch-processed, and the need to agree on one of the various EDI data formats, newer web services–based offerings (discussed below) or cloud native formats are taking over this space. Many of the more complex messaging requirements involved in supply chain management such as supply chain event management (SCEM) are too complex and too expensive to implement with EDI.

Data-Oriented Middleware

Data-oriented middleware involves large system-to-system linkages that require extensive customization. Each connection usually requires a great deal of configuration, as all the shared data fields must be mapped out one by one. For example, when one system sends information with a “product number,” the receiving system knows that “product number” is what it calls “Finished Good

ID#.” If you decide you now want to link to a third application, or upgrade to a new version, you have to start from scratch. Therefore, this option is expensive and can become obsolete fast.

Process-Oriented Middleware

Another approach to middleware is process-oriented middleware, also called business process management software. The *Dictionary* defines **business process management (BPM)** as

> a business discipline or function that uses business practices, techniques, and methods to create and improve business processes. BPM is a holistic approach to the use of appropriate process-related business disciplines to gain business performance improvements across the enterprise or supply chain. It promotes business effectiveness and efficiency while striving for innovation, flexibility, and integration with technology.

Process-oriented middleware is smart middleware that manages entire conversations. The linked businesses first map their processes; then the process-oriented middleware runs the processes and sends the data to the relevant systems as dictated by the process map. Once the process is mapped out, different companies with various types of ERP, legacy, and best-of-breed applications can apply the process map to their systems and communicate effectively without attempting to make systems congruous. It requires businesses to focus on processes and therefore has a side benefit of process simplification. However, process-oriented middleware may not be as simple to integrate with existing systems as advertised.

Other features of process-oriented middleware include

- Firewalls between partners
- Customized processes for each partner
- Internal integration preceding external links
- Integration with automatic identification technologies.

Application Programming Interfaces (APIs)

An application programming interface (API) is middle end programming code that resides nearer to the front end systems than middleware. It enables simple one-to-one interactions with the back end. Internet traffic from other systems, IoT devices, and mobile devices are sent to the API, which translates the data into a format useful to the web server and ultimately to its database. Data returned from these queries (requests for information) is translated back into the format required for the other application. The API enables an authorized system to query the database automatically and frequently. Newer forms of APIs (e.g., JavaScript Object Notation [JSON]) are lightweight, meaning they are easy to create and update. APIs are developer-friendly, platform-independent, and easily scalable. APIs are also used for large-scale applications such as ERP systems that need to talk to their back end systems. APIs can be for public use, for specific partner use only, for internal use only, or a combination. They can enable real-time transactions and real-time analytics.

APIs are typically used with software architectures that break the software into small modules that can be programmed independently of one another. (Older systems were monolithic.) Each module is one software function, such as a credit card processing function. This type of framework is called web services. The *Dictionary* defines **web services** as

> a common internet or intranet framework that enables the movement of data from one application to another, without the requirement for a direct connection between two supply chain applications and without regard to the underlying operating system for those applications.

The standards are open, meaning that all developers can access and use the same standards and communications can be performed across operating systems, application platforms, and computer languages.

The advantage of web services is that they save time and money by cutting development time, especially for integration. For example, if an airline develops its flight check-in software using web services, it could build the application using the best available database search engine from one vendor, the best seat assignment application from a different vendor, and their own pricing application. Web services make use of only the specific data elements that are made available for sharing. The components would work together as one application, but just a portion of the application could be upgraded independently.

Two types of APIs are SOA and microservices.

SOA

Service-oriented architecture (SOA) is an approach to software design ("architecture") in which applications are assembled from reusable components ("services") to allow for widespread and flexible sharing of supply chain partner services. A service could be a credit check or matching an invoice with a purchase order, or it could be more elaborate, for example, a rule to reroute trucks automatically based on traffic data.

SOA has two main goals: to achieve loose coupling among services and to separate applications from their data so they achieve universal functionality. The loose coupling of modules could be compared to the round connectors on Lego® building blocks that make them easy to reconfigure. Universal functionality requires that all messages contain all data necessary to complete processing (rather than assuming that the data can be looked up). This allows the best service provider in each area to offer its service without offering the whole package.

A consequence of loose coupling is that services can run anywhere on a network without being restricted to a specific hardware or software platform or programming language. In contrast, tightly coupled systems have interoperability issues.

The results of using SOA are a dramatic decrease in application development time because many portions of an application can be reused. Applications are by nature more adaptable, interoperable, and scalable.

Microservices

Microservices are newer cloud-native interfaces that require the same loose coupling of services as SOA. While SOA is used to help multiple applications talk to each other, microservices help various services within a single application talk to each other. There are a number of other differences from SOA that are of interest to programmers related to ensuring the efficiency and resilience of the code, but the gist is that while similar to SOA, microservices are a different programming style.

One model used in microservices as well as in some other types of middleware is called publish/subscribe messaging. In this model, the publisher creates one or more categories of interfaces or other types of messages and publishes them. Any number of organizations or persons could then subscribe to receive these publications as soon as they are released. The publisher is in effect creating some standard templates, and it is up to the subscriber to get their end to communicate with the given template.

Optimizing Visibility

Visibility means being able, figuratively, to see what's happening in the supply chain. The *APICS Dictionary,* 16th edition, defines **supply chain visibility** as

> sharing information throughout the supply chain to create transparency among supply chain partners. For example, the ability of supply chain partners to access demand and production information from trading partners.

In traditional, functionally oriented companies, silo walls obstruct "horizontal" visibility outside one's own department. ("Vertical" visibility also tends to be limited. Management may be able to see downward to activities at the tactical level, but visibility upward may be limited to information framed as directives and performance reviews.) The more visibility supply chain partners have to see through functional walls and also upstream and downstream into the activities taking place in other tiers of the supply chain, the greater the chance they all have of synchronizing their operations to produce value for the customer.

For example, with global positioning, satellite communications, and the Internet of Things (IoT), logistics managers can track individual items as they are shipped across the world to customers in foreign countries. In fact, anyone in the supply chain with the necessary technology, including the customer, can be given access to this information. This real-time visibility into customer shipments gives logistics managers the ability to react to difficulties long before they could have just a few years ago.

One obstacle to visibility along supply chains has been the unwillingness of partners to share information. Consequently, implementing process improvement requires building trust across the functions and partners who are party to the process involved. A small-scale pilot project can be helpful in demonstrating trust and honest communication. Once partners see that data sharing can work to their advantage, they are more willing to provide that all-important visibility into their operations.

And, most appropriately in the present context, data used to measure supply chain performance against key indicators can be made much more easily available to continuous process improvement teams. Visibility is one key to successful improvement initiatives.

Information Sharing Using E-Business

Information sharing typically takes the form of e-business these days. **Electronic business (e-business)** "is conducting business processes on an electronic network, typically the internet" (*APICS Dictionary,* 16th edition). E-business is a collection of business models and practices enabled by internet technologies that network customers, suppliers, and productive capabilities in order to continually improve supply chain performance.

Electronic commerce refers to that part of e-business that has to do with conducting electronic transactions. The *Dictionary* defines **electronic commerce (e-commerce)** as "the use of computer and telecommunication technologies to conduct business via electronic transfer of data and documents."

There are several electronic business models: business-to-consumer (B2C), business-to-business (B2B), consumer-to-consumer (C2C), consumer-to-business (C2B), and business-to-business-to-consumer (B2B2C). All are considered to be types of e-commerce. Since the focus of electronic business is on improving the information sharing performance of the extended enterprise, our focus is on the B2C and B2B models.

Today, some level of electronic business is required for almost all organizations, and not only B2C but also B2B companies engage in e-commerce (e.g., industrial products) to extend their supply chains. Not all organizations will be able to sell their products or services on the internet, but almost all should engage in brand awareness and marketing using at least a website, even if the site is just informational rather than interactive. Modern websites use responsive design, which detects the type of device the user is using to access the site and then automatically reformats the information for optimal display on a phone or tablet, in addition to enabling touch-screen capabilities as needed. In addition to this, some organizations will benefit from developing a downloadable app.

The goal of all supply chains should be a network that functions as if it were a single well-run company. The boundaries, even when geographically dispersed, should be invisible to the customer. The internet has made this feasible, if still challenging.

Internet-enabled supply chains—those in which all partners share data through the internet—have specific characteristics that distinguish them from less advanced supply chains. They exhibit these characteristics in different degrees, depending upon the sophistication of their strategy and use of internet technology.

An internet-enabled supply chain realizes the following benefits:

- **Visibility and efficient, responsive networks.** Internet-enabled supply chains can realize the benefits of integration.
- **Global reach.** Instantaneous communication through the internet eliminates distance and time-of-day constraints on buying and selling.
- **Improved financial position.** The internet provides increased revenue and profit margin through global sales with fewer intermediaries, increased customer loyalty through personalized contact, speed to market, and reduced costs.

Exhibit 2-14 shows how the traditional and electronic business supply chains differ.

Exhibit 2-14: Traditional Versus Electronic Business Supply Chain

Characteristic	Traditional Supply Chain	Electronic Business Supply Chain
Ownership model	• Own the supply chain. • Vertically organized. • Mergers and acquisitions.	• Own the core capabilities. • Virtually organized using collaborative processes and IT. • Outsourced business processes.
Competitive advantage	• Big dominate the small. • Barriers to market entry: high market share and many physical assets.	• Fast dominate the slow. • Physical assets become barriers to change and are tied-up costs. • Agile companies find new business models that dominate industry.
Who is channel master/nucleus firm?	• Firm closest to customer: retailer for consumer goods, manufacturer for industrial goods.	• Firm with most brand equity and most efficient model: even small firms get global reach from internet.
Trading interaction	• Rivalry; each party seeks the best deal at the expense of the other. • Terms dictated by channel master. • Much friction in interactions.	• Collaborative arrangements that share the risks and rewards. • Terms set by mutual agreement. • Fluid interactions.

Characteristic	Traditional Supply Chain	Electronic Business Supply Chain
Working with competition	• No interaction with rivals.	• Same party can be buyer, supplier, rival, and/or trading partner, depending on mutual gain. • Where no mutual gain can be found, rivalry still exists.
Production focus	• Economies of scale and scope.	• Engineering competitive supply chain.
Collaborative stage	• Internal organizational silos. • Cross-functional cooperation. • Proprietary, expensive networking. • Batch processing.	• External trading partner silos. • Cross-company cooperation. • Open, inexpensive networking. • Real-time and batch processing.
Suppliers	• Fixed industry structures: number of suppliers limited by buyer relationships, e.g., over the phone. • A few long-term partnerships and a moderate number of commodity and/or adversarial relationships.	• Open competition via electronic marketplaces and auctions. • Collaboration allows faster partner integration, so firms have many continuously reconfigurable relationships at every level.
Customer service	• Purely reactive, narrow view. • Narrow product/service offerings. • Little feedback used.	• Proactive, broad view. • Segment-specific product/service. • Better use of feedback.
Intermediaries (brokers, distributors, freight forwarders, dealers)	• Fixed, often vertically integrated relations.	• Business models may avoid some intermediaries entirely. • Some reintermediation as these channels find way to add value.

B2B and B2C Strategy

B2B and B2C are defined in the *APICS Dictionary,* 16th edition, as follows:

> **B2B—Business-to-business commerce :** Business being conducted over the internet between businesses. The implication is that this connectivity will cause businesses to

transform themselves via supply chain management to become virtual organizations—reducing costs, improving quality, reducing delivery lead time, and improving due-date performance.

B2C—Business-to-consumer sales : Business being conducted between businesses and final consumers largely over the internet. It includes traditional brick and mortar businesses that also offer products online and businesses that trade exclusively electronically.

B2B commerce includes exchanges and direct collaboration technologies. Exchanges are intended to decrease the costs of procurement, resource management, and fulfillment by providing access to a larger market and by lowering transaction costs through automation.

Objectives of B2C are to create a wider customer and revenue base, build customer loyalty through tailored offerings and shopping experiences, and create an ever-expanding source of customer information. B2C focuses on retail sales and includes things such as banking, shopping, product downloads, travel, and insurance. It may also simply include providing corporate information to customers or collecting information on customers through incentives such as surveys, product samples, games, or prizes.

Business-to-business-to-consumer (B2B2C) is a collaborative e-commerce model that involves two or more B2B companies each collaborating to provide enhanced value to the end consumer. A common example is of two organizations that share sales leads with each other and cross-promote each other’s products to consumers. The Amazon Marketplace is another example.

B2B, B2C, or B2B2C may include virtual service providers, a broad category of companies that own no assets but direct the actions of many companies and may provide capital as needed to produce, transport, and/or sell goods or services. Virtual hybrids own a relatively small number of assets. Often what these companies provide is expertise in supply chain coordination for those with a particular core competency.

Electronic business was initially so popular that it gained market support even without financially sound business models. Eventually, businesses unable to sustain profits failed. A primary cause of this failure was lack of a valid business strategy and a valid electronic business strategy. Both must exist and must be tightly integrated, and they must be guided by a realistic vision communicated and accepted throughout the extended supply chain by involving these partners in strategic planning.

The electronic business strategy should enable collaboration with the extended supply chain, including integration of customers and suppliers. Traditional business strategy still needs to be robust to allow the efficient sourcing, manufacturing, and fulfillment of orders that satisfy actual customer needs. Company and e-business strategy needs global reach.

E-business strategy indicates how the firm intends to connect with partners. The link between business strategy and e-business strategy is enhanced by optimization, visibility, and shared planning tools.

Potential Costs and Challenges with E-Business

Implementing e-business solutions requires a formidable investment of time and money for the ongoing discovery of IT capabilities, contract and request for proposal development, benefit-cost analysis, infrastructure costs, training, change management, consultant fees or opportunity costs for staff time, customization, configuration, and ongoing maintenance. Some of the necessary costs of doing e-business include the following:

- **System security.** Security maintains an agreed-upon level of access, authentication, and identity management. The firm must determine what information will be shared.
- **Increased outbound transportation costs.** While inbound transportation can be optimized or centralized, outbound transportation volume and cost increase because some customers no longer pick up the goods, requiring shipping (often smaller quantities of a wider variety of products more often) anywhere in a short window.
- **Increased materials-handling costs.** Handling costs are higher because actions typically performed by the customer now must be performed by the company (e.g., product returns, picking orders from shelves, unique packaging or labeling). E-business analysis tools weigh the risk of a lost sale against decreased profitability.
- **Reliance on outside suppliers.** Companies may need to rely on other suppliers to perform actual delivery. Late deliveries directly affect customer satisfaction. Reliability has forced many virtual models to adopt hybrids that include physical distribution centers.
- **Global reach requires global localization.** The company will need to tailor its offerings to each country or region. While it may not need infrastructure in each country, it does need to translate its web offerings to accommodate local languages, culture, and currencies and local and national regulations, laws, and commercial practices.
- **Accessibility and ease of use.** Significant effort must be made to advertise and to provide easy methods of searching for e-business services. A website can have a much greater variety of goods for sale than a typical retail location, but if the site does not provide an easy way to find what is needed, such as by intelligent product recommendations, this variety becomes cumbersome.

ROI Justification for Electronic Business Initiatives

Justifying a particular e-business strategy requires consideration of its costs and benefits. External factors, such as the economic environment, market turbulence, and the competition’s capabilities and stage of supply chain sophistication, must also be examined.

Comparison of the cost of maintaining old technology plus the opportunity cost of lost capabilities versus the cost of implementing a new technology can help make the choice clear. In general, if an electronic business strategy increases competitive advantage, it will tend to decrease inventory, facility, and transaction costs while increasing transportation and technology costs.

Another choice is whether to outsource the e-business technical functions or to maintain the IT internally. The cost of monitoring an outside arrangement must be added to the direct cost of outsourcing.

Failure is a real possibility if the balance between benefits and costs tips the wrong way. However, some level of investment in e-commerce is now a required cost of doing business. Strategy should focus on finding the investment level that is appropriate for the organization and the supply chain.

No project will succeed unless it has cost controls in place. Management must also incorporate a review process to improve future project budgeting.

Examples of E-Business Ventures

The global COVID-19 pandemic has changed consumer behavior related to the likelihood of using traditional versus online channels. While e-commerce has been a priority for most organizations for a very long time now, the pandemic forced many organizations to make immediate e-commerce investments to survive at all. A *Harvard Business Review* article by Kathy Gramling et al. indicates that the pandemic has resulted in a lasting shift in B2C consumer behavior, with significantly more people still planning to shop online for things they traditionally purchased in retail stores. Many retail stores themselves turned into miniature distribution centers for online sales. The article cites research by the EY Future Consumer Index that indicates the retail locations likely to re-engage consumers and get them back in physical spaces are those that offer consumer experiences, not just products. Being price-competitive with online-only competitors is also vital as is an option to buy online and pick up in store.

In these tumultuous times, different industries and business models have experienced different levels of success from the use of electronic business. Three companies have historically used it to spur incredible growth: Amazon, originally just an online bookseller; Dell, a pioneer in direct sales of assemble-to-order computers; and Alibaba, owner of several Chinese e-commerce juggernauts. This discussion describes their origins and the direction they each have taken in terms of their use of e-business.

Amazon was founded in 1994 by Jeff Bezos.

- It went online in 1995 as Amazon.com and originally sold only five product types: compact discs, computer hardware, computer software, videos, and books.
- Its original supply chain started out longer than that of traditional brick-and-mortar book retailers.

- It invested heavily to maximize its servers' capacity to handle peak traffic during holiday shopping periods.
- It added its own distribution functions across North America, Latin America, Europe, Africa, and Asia.
- It has its own software development centers. (Some are run by an Amazon subsidiary.)
- It located its automated fulfillment centers in select cities around the globe, often near airports.
- It turned its first profit at the end of 2001—one cent per share.
- It is now the largest online retailer, with net sales in 2020 topping $386 billion, a $100 billion increase over the prior year, making it a pandemic success story.

Dell, originally a maker of personal computers, was founded in 1984 by Michael Dell, a college freshman at the University of Texas.

- It designed and built its first computer in 1985 and differentiated itself with risk-free returns and next-day at-home product assistance.
- It manufactured the industry's fastest-performing PC and opened its first international subsidiary in the U.K. in 1986.
- It debuted its online website in 1996 and sold $1 million of product per day within six months after the site was launched.
- It climbed onto the Fortune 500 list in 1992.
- It provided customers with at-the-time innovative online technical support via the internet.
- It sold $40 million a day of online product, which made it one of the highest volume e-commerce sites in the world in 2000.
- It expanded its product portfolio to include printers, projectors, and consumer electronics.
- It launched free product recycling and a blog, Direct2Dell, enabling fast two-way communication with customers, in 2006.
- It created an investor relations blog and participated in social media.
- It offered its customers high-tech end-to-end IT services and cloud-based enterprise solutions.
- It became a privately held company again in 2013 and offered enterprise-class IT capabilities to small businesses and remote offices.
- It established Dell Ventures, which supports new businesses that align with Dell's expertise and future vision for the cloud, big data, next generation data centers, storage, mobile, and security.

Alibaba is the dominant e-commerce site in the world's largest e-commerce market, China. Its largest website, Taobao.com, can be thought of as a giant Chinese bazaar that is part B2C with direct deliveries like Amazon, part middleman like eBay, part PayPal with its Alipay payments processing (it also protects buyers if sellers fail to deliver), and part Google with its fees for advertising and promoted search results (it doesn't charge sellers to list merchandise). You can even buy real estate on the site. Its Tmall.com website is for larger retailers, such as Gap, Nike, and Apple. It also supports B2B e-commerce, connecting manufacturers with overseas clients, which was actually its primary purpose when it was founded in 1999.

Other companies have had slower starts. Mega-retailer Walmart's online sales accounted for only two percent of its U.S. revenue in 2012. However, Walmart grew online revenues at 79 percent for its fiscal year 2021, and for Q4 of that year e-commerce made up 6.2 percent of its comparable sales growth, excluding fuel. It has also been competing with Amazon Prime with its Walmart+ e-commerce membership.

So what does it take to be successful in e-commerce?

Requirements for Success in E-Business

E-business must maximize the efficiency of all channels. Retailers must be prepared to serve customers across all channels even when they seemingly may compete against each other, such as sales of televisions via the web versus an in-person visit to a traditional retailer.

Other requirements for success in e-business include

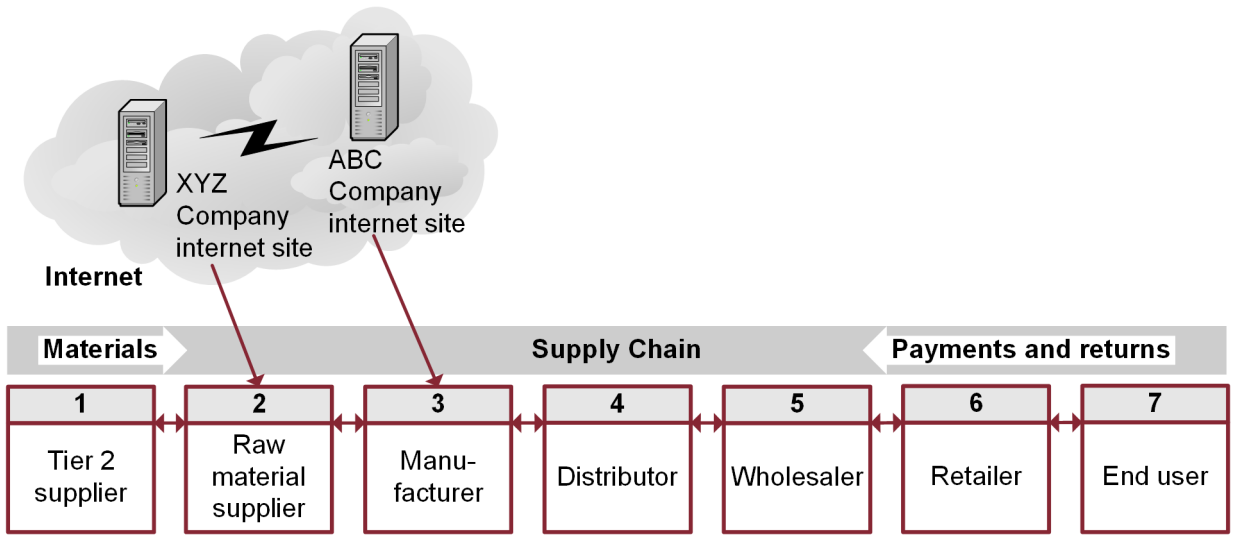
- Order visibility that extends to the customer to reduce inquiries and complaints about fulfillment status
- Shipping methods consistent with profitable sales (using a transportation management system [TMS])
- Sensible warranty and return policy (customers cannot see merchandise until received)
- Reevaluation of wholesale or retail locations on the basis of site profits

Information Sharing Using E-Commerce

E-commerce was born when websites could be made interactive rather than static. This enabled internet transaction processing and payment acceptance. B2B (business-to-business commerce) is characterized by automating traditional business transactions such as formal sourcing, so it took off when the internet became viable for automated data transfer in two directions instead of only one and when smaller businesses could participate due to the low cost of the internet.

Exhibit 2-15 shows how B2B commerce facilitates faster and cheaper links in the supply chain.

Exhibit 2-15: Business-to-Business Commerce (B2B)



E-commerce software includes sell-side, buy-side, content management, and B2B collaboration applications. Prior to addressing these types, the layers of B2B and B2C e-commerce are introduced.

Layers of B2B and B2C E-Commerce

The internet structure can be seen as a series of layers (based on a study sponsored by Cisco). The layers can show where investments are needed.

- **Foundation layer.** The foundation layer includes all physical means of transmitting data over the internet plus all necessary networking and interface devices. This layer also has security systems such as firewalls. It includes assets both in and out of the company's control.

- **Application layer**. The application layer includes all web-specific applications and tools for creating interactive websites. Applications include **web directories** ("a list of web pages structured hierarchically," *APICS Dictionary,* 16th edition), catalog builders, web shopping carts and billing, multimedia tools for streaming audio or video or virtual classrooms, search engines, and web development tools. Many of these tools simply enable internet commerce. Therefore, companies that outsource their web development can outsource all of these costs, too.

- **Aggregation layer.** The aggregation layer consists of applications designed to take information and services from various locations and package them for easier access and consumption. This layer includes portals and intermediaries such as brokers and service providers. Hosting is generally expensive, and many companies have formed consortia to control costs and form a user community.

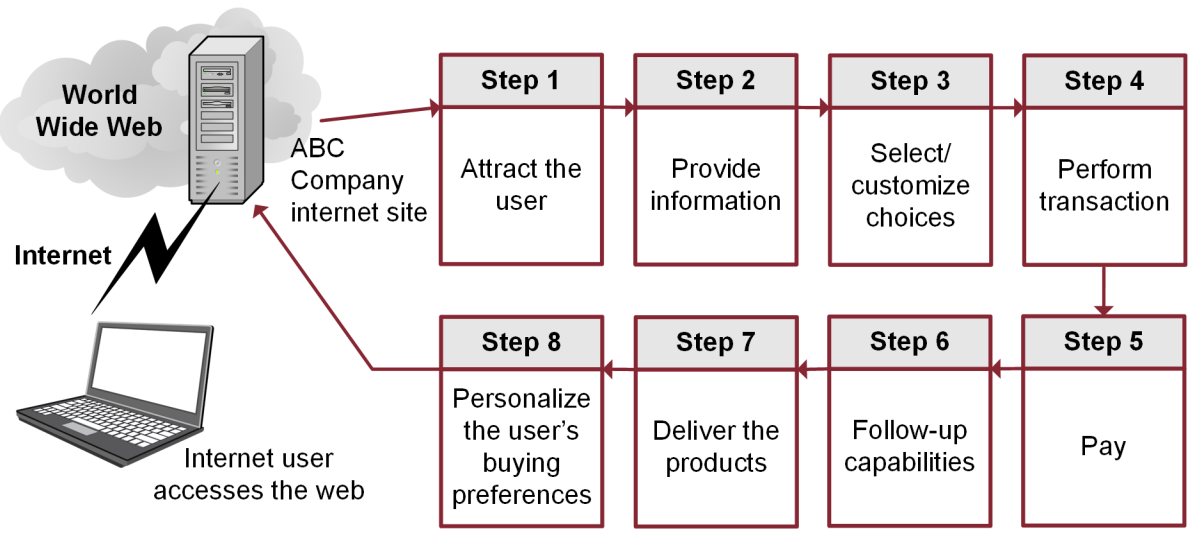
- **Business layer.** The business layer includes all exchanges and involves all buying and selling activities over the internet. If the level of sales is expected to be quite large, a huge investment in both setup and maintenance at the foundation layer is required to handle the traffic. Therefore, many businesses become members of an exchange or they outsource its creation and management to specialists such as via the cloud.

Sell-Side E-Commerce

Sell-side e-commerce applications and services help sellers present their products and automate sales and customer relationship building. These applications must include presentation (right product at the right time to the right audience), automation (order entry, tracking, and settlement), and administration (nontechnical staff can maintain the site).

Exhibit 2-16 shows the steps of an adaptive sell-side e-commerce website.

Exhibit 2-16: Adaptive Sell-Side E-Commerce Website



Note that sell-side e-commerce and customer relationship management applications are often offered as a single system or cloud-based service.

Buy-Side E-Commerce

Buy-side applications help firms purchase goods and services. These applications save employee procurement time, especially in the request and approval process. They generally automate the categorization, requisition, sourcing, negotiation, and contract phases as well as supply and payment.

Open exchanges provide access to the worldwide market; this can, however, lead to risks involving unknown suppliers. Membership-based exchanges (often on an extranet) prescreen members to mitigate risks. B2B can be performed globally, which has helped to create the process of supply chain management.

Content Management E-Commerce

The *Dictionary* defines **content management applications** as follows:

> Supports the evolutionary life cycle of digital-based information and makes information dynamically updatable online; includes the ability to publish content to a repository and support access to digital-based content.

Content management applications can include, for example, catalogs for product data, databases for customer data, contract information, and advertising content.

Buyers want to see only items specific to their strategic sourcing needs and restrictions, so these applications stress content repurposed by buyer or seller perspective while preserving brand image, pictures, and other content.

B2B Collaboration

As supply chains grow more complex due to flexible supply chain configurations, virtual organizations, outsourcing, and virtual service providers acting as intermediaries, collaboration acts as the glue that binds the network.

B2B collaboration facilitates the multiple connections necessary in a real supply chain. Exchanges (also called B2B marketplaces) provide a common place to trade and exchange information. Hundreds of separate links are replaced by a single hub with spokes going out to each node. One example is the popular QAD supplier portal for the automotive vertical.

Supply Chain Integration Methods

Quick-response programs, distributor integration, continuous replenishment, vendor-managed inventory, and collaborative planning, forecasting, and replenishment are powerful business tools. These inclusive supply chain management methodologies each integrates point-of-sale (POS) data and forecasting in its own way to reduce lead times, lower inventory costs, and smooth out the bullwhip effect. Note that each also requires building partnerships—and trust—along the supply chain. Partners must be willing to share information (and do it quickly). This could mean collaborating in developing a single forecast and agreeing to carry out their supply functions according to the forecast. The goal is to replace estimates with data reflecting customers' buying patterns.

Quick-Response Programs

Simply sharing information between customer and supplier is one of the earliest and most basic types of supply chain alliances. This is often called a **quick-response program (QRP) ,** defined by the *APICS Dictionary,* 16th edition, as

> a system of linking final retail sales with production and shipping schedules back through the chain of supply; employs point-of-sale scanning and electronic data interchange and may use direct shipment from a factory to a retailer.

In a QRP, the customer still typically submits the individual orders. The supplier uses the POS data as the basis for scheduling production and determining inventory levels to improve synchronization of supply with actual demand. Simply having the same information as the retailer doesn't necessarily mean that the supplier's forecasts will be the same as the retailer's. That requires another level of cooperation. Nevertheless, the QRP can achieve significant reductions in lead times.

Distributor Integration

Distributor integration (DI) occurs when distributors are integrated using information systems so the expertise and inventory located at one distributor are available to the others, such as sometimes exists between auto dealerships. Distribution systems can be integrated for better inventory control and customer service.

In inventory-related DI, each distributor can check the inventories of other distributors to locate a needed product or part. Distributors gain flexibility without having to carry excess stock. The total system inventory is lowered, and a side benefit is that customer service levels are also raised. Examples include

- Participants that share connectivity, warehouse order entry, and integrated demand management systems to improve supply chain efficiencies
- Companies that work to facilitate multicurrency capabilities.

In service-related DI, individual distributors build expertise in different areas. When a customer request comes in, it is routed to the distributor with the most expertise (application support, assembly, etc.). The experience improves the customer's perception of the distributor's ability. An example in this area is restaurant services where procurement systems and strategies are automated.

An obstacle to DI is ownership of inventory. When the distributors are all owned by the same company, there is no problem. However, when distributors are independently owned, there may be no existing relationship between them and they may not want to provide access to the information. A solution is to allow the manufacturer to act as a middleman to the independent distributors. For example, beer manufacturer Sam Adams has access to its independent distributors' inventory levels. Sam Adams then brokers deals between distributors when inventory shortages or surpluses occur.

Another challenge to creating a DI alliance is that distributors may doubt the benefits of participating in such a system. Service-related DIs may shift certain responsibilities and areas of expertise away from some distributors and concentrate them in a few. The excluded distributors may feel marginalized or may worry about losing these skills and abilities. Distributors must feel certain that the DI is a long-term alliance. Organizers must work hard to build trust among the participants. The manufacturer may have to provide pledges and guarantees.

Continuous Replenishment

Continuous replenishment (CR), or rapid replenishment, also relies on sharing of POS data by retailer and supplier. According to the *Dictionary,* **continuous replenishment** is

> a process by which a supplier is notified daily of actual sales or warehouse shipments and commits to replenishing these sales (by size, color, and so on) without stockouts and without receiving replenishment orders. The result is a lowering of associated costs and an improvement in inventory turnover.

Suppliers are notified daily of actual sales or warehouse shipments and commit to replenishing inventory without allowing stockouts or needing to receive replenishment orders. The supplier uses the POS data to prepare shipments at intervals determined in partnership with the customer.

The goal of this strategy is continuous reduction of inventory levels at the store as the forecasts become more accurate. Lost sales due to stockouts are avoided, and inventory turnover is improved. These forecasts can be based on complex formulas that correct for demand variations such as in-store promotions, seasonal swings, and longer-term trends.

Vendor-Managed Inventory

In the vendor-managed inventory (VMI) model, the vendor, through mutual agreement, has access to the customer's POS inventory data for items they supply. The vendor is responsible for maintaining the inventory level required by the customer and performs actual resupply. The inventory is counted, damaged or outdated goods are removed, and the inventory is restocked to predefined levels. The vendor obtains a receipt for the restocked inventory and accordingly invoices the customer.

Procter & Gamble, for example, took over management of the inventory of P&G diapers at Walmart to straighten out the bullwhip effect in their supply chain. Although this successful partnership is now a part of business history, the VMI concept continues to expand as other supply chains adapt it to different situations. Manufacturers of snack chips, bread, and soft drinks now routinely send their representatives to stock items at grocery and convenience stores.

Specific VMI Functions

In the traditional relationship, the customer stocks its shelves with products bought from a supplier, basing orders on demand forecasts. The customer controls all decisions relating to the storage, display, sale, and replenishment of goods. The supplier, in turn, bases its forecasts and inventory levels on past customer orders; once it sells the products, its responsibility ends.

In a VMI arrangement, by contrast, the supplier takes over multiple inventory functions. For instance, the supplier may do all or some of the following:

- Determine how the inventory will be stored and displayed.
- Provide the bins, vending machines, or other storage units.
- Replenish the inventory on a schedule it determines based on POS data.
- Maintain inventory records.
- Handle the delivery, receiving, stocking, and counting functions.
- Provide a permanent vendor representative at the customer's premises (e.g., automotive plant) to perform the resupply and reorder functions.

Vendors can also use historic data and predictive models to forecast stocking demands. The accuracy of the forecasts is carefully monitored and compared with actual data so that the forecasting model can

be refined. Inventory levels may be based on sophisticated models that change the appropriate level based on seasonal demand, promotions, or changing consumer demand. Forecasts of demand guide the creation of the master production schedule and the material requirements plan. Work orders are released from the master production schedule to meet the projected demand plus safety stock.

Who Owns the Inventory—and Who Benefits?

In early instances of VMI, the customer continued to purchase goods but the supplier took over inventory management in whole or in part. As the VMI strategy has evolved, some partners have adopted a VMI-consignment arrangement in which the supplier continues to own the inventory as well as manage it.

Consignment in relation to inventory is defined in the *Dictionary* as “the process of a supplier placing goods at a customer location without receiving payment until after the goods are used or sold.” Consignment is sometimes called vendor-owned inventory (VOI). There are four possibilities of how VMI and consignment can be combined, as shown in .

Exhibit 2-17: VMI and Consignment Combinations

Consignment? \ VMI?	Yes.	No.
No.	Supplier decides on replenishment. Replenishment goods are immediately invoiced. Buyer owns inventory.	Traditional: Organization owns and manages inventory or sells it to independent distributors who order and manage their own inventory.
Yes.	Supplier decides on replenishment, but only sold inventory is invoiced. Supplier employs restockers, e.g., Frito Lay pays restockers per bag of chips sold to promote proactive restocking.	Seller wants/needs items on site but may not be fast-selling, e.g., hospital controls stock of pacemakers owned by supplier. When one is used, one is sent to replenish inventory and invoice is sent for the used one.

In the traditional relationship, the customer has an incentive to keep inventory lean by placing small, frequent orders. To ensure that it maintains an acceptable fill rate with its customers, it may expect the supplier to bear the costs of maintaining larger inventories of safety stock to respond to unexpected demand. When the customer enters into a consignment or VMI-consignment relationship, it benefits from reduced inventory costs or inventory management costs by transferring one or both to the supplier. On the other hand, with either type of VMI, it loses some degree of control over the inventory —such as deciding the amount and frequency of orders.

When the supplier takes over management of inventory in its customer’s location, its incentives also change. The supplier now determines the size and frequency of orders, and if the customer buys inventory upon transfer it may be tempted to transfer as much inventory to the customer’s stockroom or shelves as possible. In this way, it keeps its own inventory costs low and, not incidentally, takes up

space that might otherwise fill up with a competitor's products. Conversely, consignment arrangements may tend toward optimal inventory since the supplier owns the inventory no matter its location. However, as more total inventory is owned, ordering and carrying costs of inventory will be higher for the supplier.

Consignment ownership of inventory (raw materials, components, finished goods, etc.) in a VMI partnership may be required to compete for business. Large retailers, for example, may represent so great a percentage of a supplier's revenue that they exercise considerable control over the relationship. In some cases, the retailer may want to share some of its own cost savings with the supplier as an incentive to enter a VMI partnership.

Getting Started

Setting up a VMI relationship can be done in various ways. The customer and the supplier may go directly into a full-scale VMI alliance, or they may take it a step at a time. At the beginning, the customer may exercise thorough oversight of the process, accepting vendor policy changes only after careful review. The ultimate goal of many VMI arrangements, however, is for the supplier to control the ordering process.

Steps in the process include the following:

1. Contract negotiation to decide such matters as when to transfer ownership of the inventory, terms of credit, and performance metrics
2. Integration of information systems between the partners to ensure quick, complete, and accurate transmission of data
3. Joint development of replenishment logic
4. Development of a shared forecasting process
5. Development of logistical support tools to coordinate transportation, management of inventory, and so on
6. Hiring or training personnel to manage the system effectively

Measuring VMI Success

Adopting VMI involves a tradeoff between control and inventory management costs for customer and supplier. The metrics for tracking the success of a VMI relationship should reflect its potential benefit to both parties, not just one. Some customers develop VMI supplier certifications. Specifically, the partners should track the following measures of success:

- Reduction or elimination of the bullwhip effect
- Reduced inventory costs in the supply network as a whole
- Reduction or elimination of stockouts or spoiled product on shelves
- Reduction of lead times for deliveries and more on-time deliveries
- Increased inventory turns

Collaborative Planning, Forecasting, and Replenishment

Collaborative planning, forecasting, and replenishment (CPFR®) is a way to integrate the components of demand management among supply chain partners. CPFR® is an evolving set of best practices, process standards, organizational standards, and technology recommendations.

The *APICS Dictionary,* 16th edition, defines **collaborative planning, forecasting, and replenishment (CPFR)** as

> (1) 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. Collaboration encompasses business planning, sales forecasting, and all operations required to replenish raw materials and finished goods. (2) A process philosophy for facilitating collaborative communications.

CPFR® Model

shows the activities and tasks in the CPFR ® model. The activities are Strategy & Planning, Demand & Supply Management, Execution, and Analysis. The collaboration tasks appear in the center column; the enterprise tasks appear in the left column (manufacturer tasks) and the right column (retailer tasks). The model can be expanded to include other partners, such as distributors, who can play the buyer or seller role. The idea is to formalize collaborative tasks while reducing redundant work by specifying what work is best done by each supply chain partner. For example, market planning is the responsibility of the manufacturer, while the retailer takes care of category management.

Exhibit 2-18: CPFR Model

Manufacturer Tasks	Collaboration Tasks	Retailer Tasks
Strategy & Planning		
Account Planning	Collaboration Arrangement	Vendor Management
Market Planning	Joint Business Plan	Category Management
Demand & Supply Management		
Market Data Analysis	Sales Forecasting	POS Forecasting
Demand Planning	Order Planning/Forecasting	Replenishment Planning
Execution		
Production & Supply Planning	Order Generation	Buying/Re-buying
Logistics/Distribution	Order Fulfillment	Logistics/Distribution
Analysis		
Execution Monitoring	Exception Management	Store Execution
Customer Scorecard	Performance Assessment	Supplier Scorecard

The model starts with strategy and planning, where the primary tasks are to decide on how collaboration will proceed and to develop a joint business plan. The joint business plan identifies

significant events such as promotions, inventory policy changes, store openings and closings, and product introductions.

The model proceeds in the other three activity categories in similar fashion, with joint sales forecasting being an important part of demand and supply management. Again there is a division of labor as the manufacturer analyzes market data and conducts demand planning while the retailer forecasts POS numbers and does replenishment planning to determine order and shipment requirements.

The execution activity, also known as the order-to-cash cycle, involves placing orders, preparing and delivering shipments, receiving and stocking products at the retail site, recording transactions, and making payments. The manufacturer does production and supply planning, while the retailer conducts the activities associated with buying. Both parties conduct logistics and distribution on their ends.

In the analysis activity, the supply chain partners monitor planning and execution activities to identify exceptions. They also aggregate results and calculate key performance metrics, share insights, and adjust plans as part of continuous improvement.

Technology

CPFR® is not fundamentally a technology solution. Rather, CPFR® is at heart about developing effective business processes to synchronize supply chain operations across enterprise boundaries. Nevertheless, the success of CPFR® depends upon willingness to work with shared data efficiently in real time. CPFR® software solutions might go by various names but include systems that allow enterprise partners to

- Share forecasts and historical data
- Automate the collaboration arrangement and business plan
- Evaluate exceptions
- Enable two-way, real-time conversations, revisions, and commentary.

These solutions must be able to function on any existing enterprise software and hardware. CPFR® is generally described as internet-based, with each enterprise feeding data into shared servers for immediate joint web-based access. This allows for low-cost connections even with very small trading partners.

CPFR® Scenarios

CPFR® scenarios are case studies of the experiences of enterprises using the CPFR® model. Examples of some of the scenarios that can be found on the GS1 US website through our Resource Center include ways to collaborate on retail events, distribution center replenishment, retail store replenishment, and assortment planning.

CPFR® Challenges

Instituting CPFR® may require meeting several predictable challenges.

- **Increased costs.** There may be costs in money and time required to acquire and train users on the technology to share data externally.
- **Resistance to data sharing.** CPFR® needs a single, jointly developed business plan that incorporates one set of shared forecasts. Although there are risks, without shared data, there is no CPFR®.
- **Bridging internal functions.** Successfully establishing CPFR® requires the partners to build bridges between internal functions so as to speak with one voice to its trading partners. Yet this internal challenge cannot be underestimated.

Legal and Privacy Requirements for Information Sharing

Information sharing can result in exposure to risk. Liability, data privacy, and cybersecurity risks and protections are addressed more next.

Legal Liability and Protections

Information sharing with the extended supply chain or with government entities creates risk for organizations, and some of these risks could leave the organization liable for damages sought by other supply chain partners, customers, or investors. Here are some of the risks related to information sharing along with some potential responses in the form of insurance:

- Trade disruptions caused by information system failures could be mitigated using trade disruption insurance for lost profits, continuing and expediting expenses, and contingent losses. (Trade disruption insurance is broader than business interruption insurance, which addresses the loss of use of physical property.)
- Political risk from government expropriation of intellectual property can also be addressed to some extent using trade disruption insurance.
- Customer or trade partner liability risk can come from failure to adhere to privacy laws related to the collection or use of data; this is addressed more below.
- Cybersecurity risks can create liability from breach of data. Cyber insurance or use of a cybersecurity framework can help, as is also addressed more below.

Data Privacy Risks and Laws

While privacy refers to the right to be left alone and free from surveillance by various parties, data privacy instead relates to an individual's right to have a say in how one's personally identifiable information is collected, used, and handled. This includes control over who can access the information and how it can be amended, changed, or deleted (including the right to be forgotten).

Personally identifiable information (PII) is a legal term. For example, the U.S. Department of Labor defines it as follows:

> Any representation of information that permits the identity of an individual to whom the information applies to be reasonably inferred by either direct or indirect means. Further PII is defined as information:
>
> - (i) that directly identifies an individual (e.g., name, address, social security number or other identifying number or code, telephone number, email address, etc.) or
> - (ii) by which an agency intends to identify specific individuals in conjunction with other data elements (e.g., indirect information). These data elements may include a combination of gender, race, birth date, geographic indicator, and other descriptors. Additionally, information permitting the physical or online contacting of a specific individual is the same as personally identifiable information. This information can be maintained in either paper, electronic, or other media.

Cybersecurity is particularly important for data privacy due to the potential for sensitive information being acquired. Health records, financial information, legal records, information on membership in organizations (e.g., churches, unions, political parties), and racial or ethic group membership all require higher levels of protection. Big data or data analytics systems have additional privacy implications because data from multiple sources is being aggregated.

Data privacy laws and regulations exist in numerous jurisdictions. While these laws apply to those jurisdictions, an organization wishing to have data on customers in those locations will need to abide by those restrictions for its customers in those locations even if the organization does not otherwise operate in those jurisdictions. Also, since adherence to different regulations for different customers can be cost-prohibitive, many organizations adopt the most stringent set of data privacy laws or regulations for all of their customers as a gold standard. Examples of more stringent data privacy laws include the California Consumer Privacy Act (CCPA) in the U.S. and the General Data Protection Regulation (GDPR) in the European Union. For example, the GDPR gives individuals the following rights over their data:

- Right to be informed of how organizations are using their data, such as through a privacy policy
- Right to access one’s personal data
- Right to correct errors in one’s personal data
- Right to be forgotten (deletion of personal data)
- Right to get a copy of personal data (data portability)
- Right to opt out of future data collection

Similarities and differences exist in various data privacy laws, so legal review is needed. For example, in the GDPR, the organization or its embedded third-party processors needs to obtain prior consent for the collection and use of EU citizens’ data, including the purpose, extent, and duration of the data processing (which is why websites now commonly ask you to accept cookies prior to using this information to personalize ads and more). The CCPA does not require this but does allow people to opt out.

Another issue with data privacy laws is data residency, or requirements for storing data within the physical borders of the country that passed the law. While the GDPR does not address data residency, many other laws do. Germany's Data Protection Act, for example, requires data residency for the accounting data of German organizations and individuals filing taxes in Germany. Laws of this sort have implications for clouds, as the data could conceivably be stored anywhere. Such laws have led to national clouds, where the cloud guarantees data residency within the jurisdiction.

Cybersecurity Risks

Maintaining certain standards for cybersecurity may be a regulatory requirement in certain jurisdictions, and it also creates reputation and liability risks for the organization related to breach of personally identifiable information. It can also be a form of trade disruption. For example, a ransomware attack shut down a key U.S. East Coast pipeline in May of 2021 and resulted in panic buying of gasoline by consumers, as discussed in the *New York Times* article by Michael D. Shear et al., "Colonial Pipeline Paid Roughly $5 million in Ransom to Hackers."

Cyber insurance is one option for addressing cybersecurity risks. This form of coverage is basically a type of trade disruption coverage. The impact of cyber risks on suppliers and customers one or more tiers out may also need to be considered when negotiating this type of insurance.

IT requires robust security due to the numerous cyber threats that exist, and this is especially the case for supply chains that integrate with numerous partners, since this creates more attack vulnerabilities. One way supply chains can reduce these risks is by getting all parties to agree to use a common security framework. Two examples are the NIST Cybersecurity Framework and the MITRE ATT&CK® framework.

NIST Cybersecurity Framework

The National Institute of Standards and Technology (NIST) is a U.S. government agency and a contributing member to the ISO. The NIST Cybersecurity Framework, version 1.1 (2018), has been well accepted in the U.S. and internationally as a foundation for developing cohesive cybersecurity processes and policies intended to provide information systems with resilience. The framework outlines cost-effective best practices that can be tailored to the need and properly prioritized. The framework includes

- **A framework core.** The core presents cybersecurity activities called functions, their expected outcomes divided into categories (e.g., for the "protect" function, one is identity management and access control) and subcategories (e.g., "Remote access is managed."), and informative references (e.g., relevant standards). The following functions operate as a cyber risk management life cycle:
  - **Identify:** Business context, resources needed, risk identification, and risk management strategy
  - **Protect:** Preventive controls including training and maintenance
  - **Detect:** Continuous monitoring and anomaly detection and related processes

    - **Respond:** Planning and communicating responses and improvements
    - **Recover:** Plans for resilience and recovery after failures

- **A set of implementation tiers.** These are maturity levels for implementation of cybersecurity that go from partial, to risk informed, to repeatable, to adaptive.

- **A framework profile.** This area provides guidance on generating a cybersecurity road map aligned with the given industry, organizational strategy, best practices, and legal or regulatory requirements. An organization with several supply chains may have separate road maps per chain. The profile includes an “as is” and a “to be” state for gap analysis.

MITRE ATT&CK® Framework

The MITRE Adversarial Tactics, Techniques, and Common Knowledge (MITRE ATT&CK®) framework is a curated framework that categorizes adversary behavior and maps out the life cycle of cyber attacks. It provides a common frame of reference for types of attacks and presents related defenses. There are three versions, one for enterprise (Windows, Mac, Linux, and clouds), one for mobile devices, and one for “pre-exploit” adversarial behavior, such as reconnaissance.

Categories of adversary tactics include resource development (command and control of attacks), reconnaissance, initial access (e.g., phishing), execution, persistence (trying to stay in the system), privilege escalation (getting higher levels of access), defense evasion (detection avoidance), credential access (stealing user IDs and passwords), discovery (determining what they can control), lateral movement (gaining access to other systems), collection (determining what data to steal), command and control (using seemingly normal traffic to communicate with the compromised network), exfiltration (data theft), and impact (a malicious attack such as ransomware).

Topic 3: Supply Chain Master Data

Supply chain master data include static files such as customer master files. Maintaining these master data is vital to the efficiency and effectiveness of supply chain networks. After discussing master data and their management, we address data acquisition and management, including automatic identification technologies and point-of sale systems, data analysis, and maintenance and cleansing of data.

Master Data and Their Management

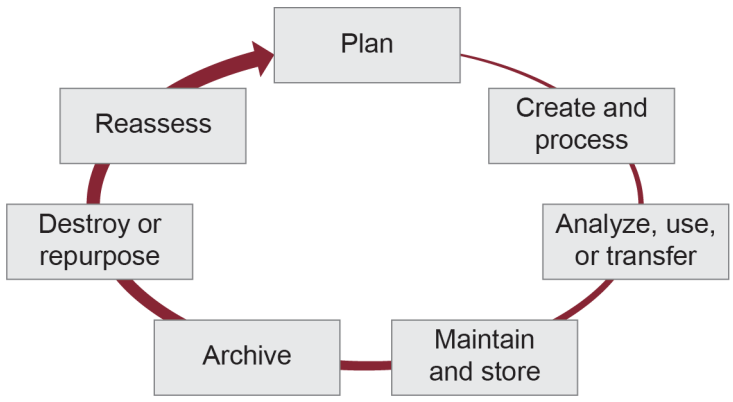
Master data are a type of data (other types include unstructured data, transactional data, metadata, and hierarchical data) that describe the organization’s core business elements, including customer data, supplier data, product or item data, engineering data, and logistics data. Each of these categories has many subcategories. Master data also include reference data, which are data that help place master

data into categories, link them to transactional data, or relate them to external sources of information. Unlike transactional data, master data do not change frequently. They are static information (though they can be maintained). However, they are referenced in transactional data. Without accurate and timely data, no other aspect of supply chain management can be achieved.

Master data management (MDM) is a discipline that works alongside the IT discipline to coordinate the creating, updating, cleansing, and retiring of master data across an organization's systems or the systems of an extended set of entities to ensure stewardship, accuracy, consistency, completeness, and timeliness of those data among all parties. It involves governance (oversight), methodologies (process specifications and metrics), policies, procedures, and related technologies.

The concept of a life cycle can be applied to master data management to help organizations be holistic in how they govern and manage their data. There are numerous master data life cycle models, and the steps differ among them. Exhibit 2-19 shows one example of a master data life cycle.

Exhibit 2-19: Example of Master Data Life Cycle



In the plan phase of this cycle, the organization determines what master data it needs, how the data will be created and processed, and any policies, processes, procedures, and technologies that need to be in place for each type of master data. This step often can leverage a common data model, which is a best-practice model that offers standards for how organizational master data should be approached. Major database, enterprise resources planning, and cloud vendors offer such models. The last step, reassess, is a continuous improvement step where gaps in the master data management methodology or any feedback on specific issues are addressed. The steps that need to be done more frequently are reviewed next:

- **Create and process.** The expected use of the data should be a primary driver of the data to be collected. This step can include manual data entry, automated data capture through organizational devices or systems, or acquisition of data created outside the organization. Processing can include manual data entry restrictions or checks and automated formatting steps to get the data ready for their intended use.

- **Analyze, use, or transfer.** The data are put to their intended uses, which can include support for transactions, analysis to generate business insights, or analysis to find potential new uses of the

data. Data can also be shared outside the organization. An audit trail is a vital control for this step. It tracks who made what changes and when they occurred. The audit trail itself needs very high security.

- **Maintain and store.** Maintenance and storage includes ensuring security in transit and in storage, cleansing the data (such as removing duplicate records), providing security, and backup and recovery processes.

- **Archive.** Data that are not needed for current transactions can be put into long-term storage if they need to be maintained for regulatory compliance or other reasons. The data are no longer subjected to regular maintenance but are secured.

- **Destroy or repurpose.** Data that are no longer needed and are slowing down the system or that must be deleted for legal or regulatory compliance (e.g., compliance with data privacy laws) need to be systematically purged from every system within which they reside. Destruction typically occurs mainly to data that has been archived for a time (such as to comply with records retention regulations). Repurposing involves finding a new use for a type of data.

Types of Master Data Important to Supply Chain Managers

The types of master data used will vary between department, company, supply chain, and industry. The most important master data for analysis include

- Customer and supplier master files
- Product/item/stock keeping unit (SKU) master files
- Manufacturing master data such as bills of material or standard costs/time (a “should cost” amount or time period for things like direct materials or direct labor)
- Purchase orders for raw material cost and spend analysis
- Orders for demand analysis, customer profitability, and customer service
- Inventory data for economic order quantity calculations (e.g., annual demand volume, unit value at cost, inventory carrying cost percentage, ordering cost, and partial or full load transportation costs), working capital, customer service costs, and obsolete or excess inventories
- Logistics data, including shipment data for network optimization, transportation spend analysis, carrier performance analysis, and transportation rate negotiations
- Engineering data.

Master data exist for every department and area of a company. For example, customer data include the customer master file. (Related transactional data include customer order history or point-of-sale data.) From these basic sources, one analysis might query sales by customer and customer location, further broken down into sales by pallets, cases, or pieces or by weight, cube, product lines, or frequency. Similar queries could be run for sales by SKU or other measures. Such information results in customer activity profiles, SKU activity profiles, customer by SKU profiles, and customer order profiles, each

broken down by sales amounts and volume. From these data, managers can determine customer segments, better classify SKUs, set customer response measures, and determine an optimal customer service strategy for each customer segment.

For engineering data, a key data element is an effectivity date, or the date upon which an old engineering document is superseded by a newer version. The bill of materials (BOM) or product structure includes effectivity dates, both “from” and “to,” to indicate when the information is valid. This allows engineering changes to be proactively scheduled. Material requirements planning (MRP) notes these dates and plans accordingly. In the event that a BOM is changed—for example, a new component with a new number is introduced—an engineering change notice can alert the MRP when to shift from the old part to the new part. This allows production to use up existing inventory first if this is feasible/allowed.

Creating Data

Cost-effective processes need to be set up to capture and transmit data to the database accurately. Once set up, data capture is primarily a tactical or operational problem, but the setup of methods, policies, and procedures for capturing data is a strategic decision.

Considerations in Data Capture

Specific considerations in data capture include the following:

- **Data volume.** Depending on how sophisticated the company’s data capture processes are to start with, the volume of data captured may vary. Incremental improvements may be the best policy, because each increase in the amount of data captured can immediately be put to use in improving the bottom line. An accurate inventory system is a good place to begin. Many companies have moved to cycle counting—counting inventory periodically, several times a year. Done correctly, this improves the accuracy of the inventory. Working with accounting, this can avoid the annual physical inventory counting.
- **Having partial data is better than having no data.** Even if a company’s strategic goal is to have complete visibility across the supply chain network, it has to start somewhere. Partial data can provide incremental improvements and the ability to see what data are necessary for the next improvement in analysis.
- **Capture at the source.** When possible, capturing data at the source is far better than entering them later.
- **Data capture tools: manual versus passive.** Passive or automatic data capture increases productivity, is more likely to occur every time, and is more likely to be accurate than manual processes.

- **Capture ancillary data when possible.** In a networked supply chain, it can be difficult to know what data will be important. Data mining and decision support systems can find hidden patterns if enough data are available. If a particular type of data is deemed important in the future, it is many times more valuable if those data have been captured continuously since some point in the past. Systems design should acknowledge the desirability of capturing ancillary data.

  However, as the term “big data” implies, organizations can become overwhelmed by too much data. More data than are needed may simply hinder analysis or hide the true indicators of change. Therefore, even when the additional data are stored, use cases for data should be developed to indicate how the extra data could help prior to their being included in metrics or analysis.

- **Real-time versus batch data.** Engineering true real-time access to data can be many times more expensive than engineering near real-time access. Sometimes using near real-time data has no real impact on usefulness. For example, transmission of production counts each minute rather than each second does not make the data less useful and saves considerable expense. Oftentimes an organization has both a transactional system for real-time data checking as well as a reporting system for when near real-time or historical data are sufficient.

Data Capture Challenges and Possible Solutions

Fast-paced, hostile, or multilingual environments pose a particular challenge to accurate data capture:

- **Fast-paced environments.** Local management may be resistant to adding any steps that would slow a process down, so the best solution may be to incorporate hands-free data capture such as a bar-code or radio frequency identification (RFID) reader. Package shipping companies use multiple readers from different angles so packages passing on conveyor belts can be quickly read.

- **Hostile environments.** Dangerous, noisy, hot, crowded, or otherwise physically hostile environments require special solutions. It should be determined where measurement is required in the process so that a minimum number of durable sensors can be used.

- **Language or training issues.** Employees who do not speak the same language as their managers or are illiterate or technically illiterate need simplified environments such as those that use bar-code work cards with multilingual or pictographic instructions.

Data Capture Methods

Data capture methods include automatic identification and point-of-sale systems.

Automatic Identification Systems

The *APICS Dictionary,* 16th edition, defines an **automatic identification system (AIS)** as “a system that can use various means, including bar code scanning and radio frequencies, to sense and load data

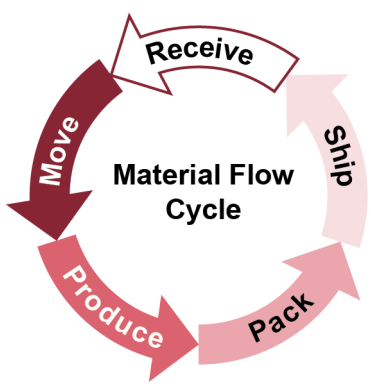
in a computer.” Devices used for an AIS are sometimes called automatic identification and data capture (AIDC) devices. These devices identify items and track the movement of goods across the supply chain automatically, leaving employees to handle just the physical movement of goods. The key benefits of an AIS are faster information visibility and increased transaction accuracy and processing speed.

AIDC devices have two key features: automatic classification and automatic identification. The automatic classification process applies the object’s class to some of the numbers in an identifier, reducing the complexity of the numbering process and increasing identification speed. An item that can communicate its class allows optimization of groups of objects. In the warehouse, these items can be stored in optimal locations. In transportation, available shipping space can be planned. In retail, shelf space can be planned. Automatic identification means that unlike just having a serial number on an object, an AIDC device can communicate the object’s presence.

Instead of trying to keep all product data on a tag, or even in a static database, the product data can be stored on the internet so that classification and identification occur on a network.

Global identification requires that the identifiers for objects be unique so the internet will yield only one match per item. Bar codes do this to a certain degree, but radio frequency identification (RFID) is more thorough. Both, however, can be used to update the transactional database when changes occur. Automatic identification systems are used in many places where the physical world must connect with the world of data, as shown in Exhibit 2-20.

Exhibit 2-20: Automatic Identification System (AIS) Interface Points



The cost of purchasing, implementing, and maintaining automatic identification technologies should be offset by the benefits, especially if paperwork can be eliminated. The movement from paper-intensive activities to automated data capture systems improves productivity. Workers spend less time looking for and processing paperwork, writing numbers, and entering data. These devices reduce errors by eliminating numeric transpositions, missing or incomplete information, and lost or damaged paperwork.

Bar-code and RFID scanners can now be embedded or attached to cell phones for real-time data input at any location. Wireless POS devices with cellular technology can accept immediate customer payments. Handheld scanners allow workers to concentrate more on moving items. RFID devices are even better, because workers don’t have to place items with their bar codes in a particular alignment.

These systems improve customer service levels by reducing stockouts, especially when dealing with promotional or advertised items. The inventory database is more accurate, and supply is matched more closely to demand, leading to added profits because fewer sales are lost and variability is reduced. Enriched product information also benefits the consumer because such data will be more easily available from multiple synchronized sources. Even consumer data can benefit, such as an affinity card showing a pattern of buying certain products in a supermarket on certain days.

Automated replenishment signals can occur when inventory is tracked accurately. Accurate inventory reduces shrinkage from employee theft, lost inventory, or spoiled goods and enables functions such as vendor-managed inventory. In other words, automated data capture significantly improves inventory visibility. Visibility and dynamically updated product data help plan space in warehouse and retail locations more effectively. Finally, quality assurance can be improved by tracking where problems have occurred.

The following content looks at automatic identification technologies including warehouse automation systems, bar codes and bar-code scanners, RFID, smart cards, magnetic stripes, and vision systems.

Warehouse Automation Systems

Warehouse automation systems are physical devices that interface with warehouse management systems (WMS) to provide information to distribution center employees on how to pick or put away items while they are on the move. These devices may be handheld, hands-free, mounted on a forklift or other vehicle, or built into the warehouse floors or racks. The key benefit of these devices is that they can be integrated with optimizing applications to ensure employee efficiency. Hands-free devices are especially good because they do not hinder manual tasks.

Warehouse automation systems include the following:

- **Wireless radio data terminal (RDT).** This data interface device involves a display, an input mechanism such as a keyboard with special function keys, and either a bar code, an RFID reader, or both. The RDT receives commands from a WMS and directs the actions of the employee for picking or put-away.
- **Synthesized voice.** A WMS directs this hands-free synthesized voice system to tell an operator what to do. The operator may wear a microphone to indicate when a job is finished. These systems require little training.
- **Pick-to-light.** These systems highlight a path through the warehouse and/or an item to be picked using physical indicator lights or lit alphanumeric displays installed at each inventory location or on a carousel.

- **Heads-up displays.** Heads-up displays present a virtual image of the warehouse over the employee's actual view for hands-free direction.

Bar Codes and Bar-Code Scanners

A bar code is a machine-readable code that identifies, at a minimum, the product manufacturer and the stock keeping unit (SKU). Some bar codes may also contain lot and batch information and/or a serial number. Bar codes assist in the correct identification of products and also operators/staff, store shelves, pallets, and pallet racks. For example, warehouse orders can be picked and placed in reusable baskets, each with a bar code. The operator scans the basket's code, and the warehouse system indicates what to put in the basket.

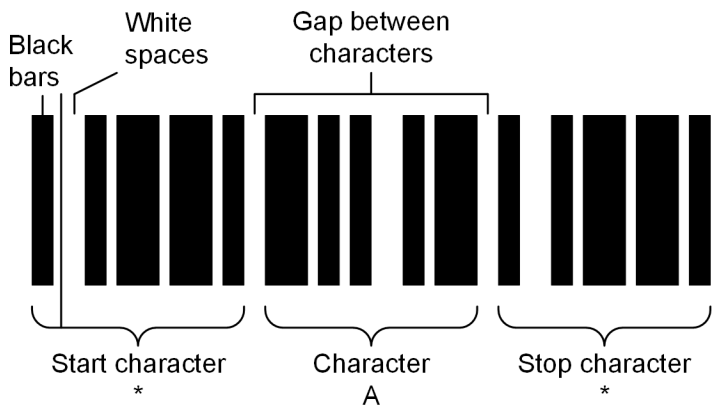
The bar-code system is heavily integrated in all areas of the supply chain. It will continue to coexist with other methods of data scanning such as RFID because bar-code labels are very inexpensive compared to RFID tags. Most RFID labels have a bar code on the outside of the tag for use with either system. RFID and bar codes can be complementary; when an RFID tag has interference, the bar-code tag can be scanned.

Components of a bar-code system include

- Bar-code printers
- Bar-code labels
- Bar-code readers (portable or stationary)
- Hard-wired or radio frequency (RF) communications links between the bar-code readers and an application (enterprise resources planning [ERP], transportation management system, WMS, or point-of-sale capture)
- Applications to process the data collected.

shows a typical bar-code label.

Exhibit 2-21: Bar-Code Label



Bar-code labels list data in a format of bars with intervening spaces of varying thickness. A reader shines lasers at the bar code and captures the reflection in an optical scanner. The scanner takes up to 100 looks at the code to measure the width of the black bars and the white spaces. Each group of black

bars and white spaces represents a character (letter or number). Start and stop characters tell the scanner which direction it is reading from and allow the reader to read information omnidirectionally. Large industrial scanners can read bar codes in a wide viewing field for high-speed sorting. shows only a single character; a complete bar code would include a number of characters to identify the manufacturer, etc.

A very common bar-code standard is the Universal Product Code (UPC), one type of which is shown in , representing the number 123456789012. (A 12-digit number is the maximum information for this type.) This number is typically used to identify the manufacturer and SKU only; it does not normally identify a product by its serial number or other unique identifier. UPC codes are heavily used for checkout at cash registers.

Exhibit 2-22: UPC Bar Code (UPC-A)

There are a large number of other bar-code standards, many of which do support identification down to a unique identifier. Some may use the 12-digit UPC code as the unique identifier. Once the UPC code is scanned, the unique identifier can be run through a WMS, TMS, or POS to link to and retrieve an abundance of data—SKU, date made, location in a warehouse, ERP system part number identifier, and all possible combinations of data captured in a data collection system. Most readers are designed to read multiple bar-code formats.

A popular type of bar code is the 2D code. A 2D bar code can be scanned by mobile devices for automatic redirection to mobile-friendly websites. 2D bar codes include standards such as the QR (quick response) code and PDF417, a code found on the back of every U.S. driver’s license. shows an example of a QR code. The chief advantage of such a code is that it stores data both horizontally and vertically rather than just in one direction, so more data can be stored in a small space without sacrificing scanner readability. 2D codes can identify an item by its serial number.

Exhibit 2-23: 2D Bar Code (QR Code)

Bar codes are not smart tags. They are simply a hard-coded number or alphanumeric information that identifies a product, a website, or other information. When the type of bar code used does not identify a

product down to its serial number, this can be an issue for product defects and quality assurance, especially for medicine and packaged foods. In some cases, one or more additional bar-code blocks (not using UPC coding) carry the serial number, lot number, or other scannable data. In other cases, a single bar code (e.g., a 2D code) contains the manufacturer, SKU, and serial number.

Bar-code data are often batch-processed, for example, when a mobile scanning device is placed back into its cradle, which is linked to the network. According to the *APICS Dictionary,* 16th edition, **batch processing** as it relates to computer processing is “a computer technique in which transactions are accumulated and processed together.” For example, in a warehouse, the operator will be given a series of tasks to perform, and, when these tasks are finished, the operator will send the information to the system in a batch before receiving a new set of commands. While batch processing is low in cost, the advantages of a real-time bar-code system include better data for salespersons quoting availability, on-the-fly correction of operator errors, and systems that can add or change tasks during a job.

RFID

The *Dictionary* defines **radio frequency identification (RFID)** as “a system using electronic tags to store data about items.” The electronic tag is a tiny microchip with an antenna whose signal is automatically picked up by a reader/interrogator. The reader can be combined with a cellular/GPS device for in-transit updates. The information on the tags is more robust with RFID than with other forms of AIDC. Associated data are stored on the internet, data capture is entirely automatic, and tags can be read even when the item is under other packages.

A significant feature of RFID tags for supply chain applications is that the tags are available in a read/write configuration that allows tag and reader to communicate back and forth. The information on the tag can, in other words, be altered from a distance, unlike with bar codes. Applications for the supply chain could include updating the tag with its current location to provide a chain of custody for a pharmaceutical drug or dynamically changing the description of an item as value is added during manufacturing.

EPCglobal’s **electronic product code (EPC)** is the most widely accepted set of standards for RFID tag data and has been mandated by numerous retailers. The *Dictionary* defines EPC as “codes that are used with RFID tags to carry information on the product that will support warranty programs.” The EPC has the same manufacturer/SKU information as a UPC bar code, plus a unique serial number and a link to interactive transaction data. The item’s creation location, distribution points, and point of sale can be known down to the specific cash register and salesperson.

EPCglobal’s EPC Generation 2 (Gen 2) interface protocols specify how information is communicated between tags and readers. EPC Gen 2 is recognized by the International Organization for Standardization (ISO) as the ISO 18000-6 class of standards.

The EPCglobal Network is a standards-based method of locating and verifying EPC codes. It creates an intelligent value chain for products. Trading partners use the web-based network to locate EPC codes and view the manufacturer's secure item website for additional product data.

EPCglobal tag data standards add security. For example, drug companies can use the network to track their products through the supply chain and guarantee that nothing was illicitly introduced, guard against counterfeits, and issue targeted product recalls. Although a counterfeiter could make a tag with someone else's company and product SKUs, only the EPCglobal's object naming service can issue tag headers. Because the product identifier is checked against this online registry, counterfeit tags would be immediately detected. Gen 2 also has password capabilities to lock portions of a tag.

There is a vast variety of types and costs of RFID tags. Simple and cheap tags are used to record an EPC, while more sophisticated tags are used as a mobile database (e.g., recording temperature, pressure). A chip can also control a process on an assembly line. Some tags are for single use only, while others can be updated and reused. Tag types include active, passive, and semipassive:

- An **active tag** is "a radio frequency identification tag that broadcasts information and contains its own power source" (*Dictionary*). Such tags can transmit data to a reader at long ranges and are the most expensive type of tag. They are often used to tag containers or pallets.
- A **passive tag** is "a RFID tag which does not send out data and is not self-powered" (*Dictionary*). The radio frequency energy from the reader temporarily powers the tag. Passive tags can transmit data at short range and are cheap if purchased in bulk. Readers must typically be installed at gateway entry and exit points, on equipment such as a forklift, or be handheld.
- A **semipassive tag** is "an RFID tag that sends out data, is self-powered, and widens its range by harnessing power from the reader" (*Dictionary*).

Companies will likely use a mix of active and passive tags, for example, placing active tags on high-value assets and whole containers and passive tags on boxes full of merchandise. The cost of tags is a limiter in the expansion of RFID, since, in comparison, the cost of a bar-code label is practically negligible.

Printers burn an RFID tag and may simultaneously print a label with a bar code. Printer cost, reliability, and throughput may be the most relevant issues.

Interference (a distorted radio signal) can be a problem with RFID. A signal can be affected by variables such as antenna size, reader power level, frequency used, and other radio frequency emissions (e.g., machinery white noise). Some liquids absorb reader/tag signals, and some metals reflect signals. Reading multiple boxes on a pallet is not foolproof; reading singular cases on a conveyor system is very reliable.

Common adjustments to improve read rates include

- Placing readers in locations with less interference
- Placing a buffer or shield between the tag and the interfering object
- Adjusting the position and angle of the RFID antennae on readers
- Changing reader or tag type/manufacturer to suit the facility or product.

The absence of human intervention in the process makes data acquisition with RFID extremely cheap and fast. However, many RFID users indicate that some human intervention is still needed to verify that the tags have been read, raising the cost and error rate of the system and reducing efficiency. Reader maintenance and testing must be included to verify promised reliability. For example, a major airline tested RFID and found that it could increase the accuracy of luggage read rates to more than 90 percent, but the airline would need to change how its operators loaded baggage into the metal luggage carts to get that accuracy level.

Because RFID generates vast amounts of data, the data must be brought into a usable state prior to sending them to ERP or analytical systems.

Before implementing RFID, companies should be at a high stage of supply chain maturity. Implementations at lower stages will lead to an inability to use the gathered information (i.e., all the costs and none of the benefits of RFID).

RFID's value comes in when process discipline cannot be advanced with other technologies and human interaction has reached the limit of its efficiency. For example, a refrigerated goods company saved 25 percent in energy costs by using RFID to make refrigerated doors at their warehouse open and close automatically at the arrival and departure of trucks.

The costs associated with RFID can be difficult to estimate because they include not just individual RFID tag costs but also infrastructure changes and capacity increases for filtering, storage, processing, and analysis.

A full implementation may be hard to justify, so a limited project may be the best way to add RFID, such as a plant area where items need careful tracking.

The business case should drive RFID selection. The organization should target a supply chain process that has sufficient room for improvement and will provide a strategic advantage, such as collaborative product life cycle management, continuous demand management, reduction of stockouts, asset management, fulfillment and distribution, aftermarket sales, or reducing counterfeiting or theft.

Other Types of AIDC Devices

Other types of AIDC devices include the following.

- **Smart cards.** A smart card has an embedded microchip with a unique identifier. Companies give employees smart cards to regulate physical and computer access and create an automatic time log. Smart cards are also used for vehicle identification at tollbooths or in warehousing for a picking tour.
- **Magnetic stripes.** Magnetic stripes are used for credit and ID cards to automate number entry. Data on the magnetic stripe can be changed. Because the stripe must be read by contact, it can't be used for high-speed sorting.
- **Vision systems.** Vision systems use cameras along with computers to interpret the images. These systems are relatively expensive and can distinguish changes at moderate speeds with great accuracy in a controlled environment. A vision system may be used to identify incoming items that have only text labels.

Point-of-Sale Systems

The *Dictionary* defines **POS** as "the relief of inventory and computation of sales data at the time and place of sale, generally through the use of bar coding or magnetic media and equipment." A related term in the *Dictionary* is **point-of-sale information ,** "information about customers collected at the time of sale."

These two terms provide a great deal of information about the benefits of capturing data at the point of sale. Transferring information from the POS to the organization's information systems in real time allows the organization to

- Capture data on product SKU, price, promotion, and inventory
- Replace a push system with a demand-pull system based on actual customer orders and improve sales forecasting
- Deduct inventory from the books immediately at the time of sale
- Immediately forward accounting information to finance
- Collect information about individual customer purchasing habits (either through a credit card or through a voluntary affinity card program)
- Reduce the bullwhip effect if the data are shared immediately throughout the supply chain
- Reduce data errors by collecting data at the source rather than later entry
- Update POS systems at reduced cost, simplifying returns, coupons, special orders, layaways, etc.

A retailer may, for example, send information from the point of sale to suppliers each time a customer purchases an item to trigger production or shipment of a replacement. Large retailers may summarize the POS results in a data warehouse and provide all vendors with access to it through a vendor web portal. Such portals may include an application programming interface (API) to enable automated retrieval of the data.

In addition to linking cash registers to POS data collection systems, field systems such as wireless credit card readers, wireless POS scanners, tablets, and cell phones can be used to collect POS data. Self-service POS terminals such as at a grocery store or an ATM also exist. POS data can be collected through manual entry or as part of a bar-code or RFID system.

Many types of buyer-supplier partnerships, such as vendor-managed inventory, require that the retailer provide POS data to the supplier. Business portals allow individuals to see exception-based information and forecasts based on POS data. The data are presented on a dashboard that allows users to configure what items are tracked. For example, Walmart shares POS data by broadcasting to all suppliers on a security-restricted basis using their own portal network.

Consider the following case study of a company that has realized the benefits of capturing and communicating point-of-sale data in a retail setting.

A small company designs and creates high-quality running shoes and apparel. It distributes goods through three outlet stores. For several years they have had trouble managing their outlet store inventory because they have no way of viewing inventory levels. They have resorted to sending the same quantities of inventory to each outlet no matter what the current inventory is, resulting in large excess inventory at stores. They have also had great difficulty in changing prices. These changes have to be sent via messenger service.

Their problem is that their data are static but need to be dynamic and real-time. They decide to solve their issues by implementing a retail management system with real-time POS data transfer. The system allows them to view inventory levels at the outlet stores so they can optimize products by local demand. The company can determine what products are selling at what locations and customize shipments accordingly. Headquarters can also change prices dynamically at each location, saving the company several days worth of labor per month. The system reconciles sales reports with actual sales for better reporting at the store level. This reconciliation feature also saves the outlet stores time and money by allowing faster nightly shutdowns and price change reconciliations. The company is more profitable and efficient.

Analyzing Data

Analysis turns data into business information, or information that is actionable, relevant, reliable, and placed in context. Analysis should reveal the best way to allocate scarce resources. A holistic analysis of the extended supply chain should reveal the optimal use of assets for each partner. Analysis occurs at the strategic, tactical, and operational levels, such as determining the location and number of distribution centers or calculating which centers to ship certain goods from during seasonal demand fluctuations. Analytical systems should be flexible enough to enable shifts in strategies, such as weighing the pros and cons of moving from distributed warehouses to a centralized warehouse.

Collaboration with key supply chain partners is a primary goal of organizations wishing to reach more mature stages of supply chain development, and sharing the results of data analytics or sharing data with supply chain partners so they can do their own analytics are key ways to promote this maturity. Sharing data can help globally optimize the supply network, enable sharing both risks and rewards with partners, and promote collaborative forecasting and active visibility.

When analyzing data, both the data and the models used need to be validated. Some degree of data aggregation is usually also needed. After discussing these concepts, decision support systems, big data, and data analytics are addressed.

Model and Data Validation

When analyzing results, both the predictive model and the data used must be validated, or tested against actual results. The first step in analytical model validation is to put historical data into the model and see if the results are as expected. If they are, the model is run again using current data, and the output is compared with expected results for reasonableness. When either of the above validation tests returns unexpected or wildly inaccurate results, both the model and the data are explored to find errors, bugs, outlier exceptions, or incorrect or unrealistic assumptions.

If the results differ by too much, the model and/or the data must be modified until the model accurately predicts actual results within an acceptable margin of error. Then the model and the data are put to use in actual business decisions. They are, however, periodically reviewed to ensure that they continue to reflect actual usage.

Because models often use aggregated data, the amount of error related to the level of aggregation should be estimated. If the error is within limits, it is considered acceptable. Finally, if the model makes intuitive sense and the data are consistent with actual results or if any anomalies in the data can be fully explained, then the model is ready to be used.

Data Aggregation

Due to the large amount of data collected—especially in retail, where large numbers of different products are sold—data are usually aggregated, or grouped into like categories.

Aggregation is “the concept that pooling random variables reduces the relative variance of the resulting aggregated variable” (*APICS Dictionary,* 16th edition). In other words, the peaks and valleys in the data are smoothed out when they are combined, which allows averages and trends to be more obvious. In addition to reducing variance, aggregation is useful because massive amounts of data can be difficult to interpret when viewed at a granular level. For example, sales by SKU by store will have a large amount of confusing variation. Looking at sales by SKU by region will reduce variation and provide better insights. Further aggregation could be done with meaningful groupings of SKUs per region (e.g., all sizes of the same shirt).

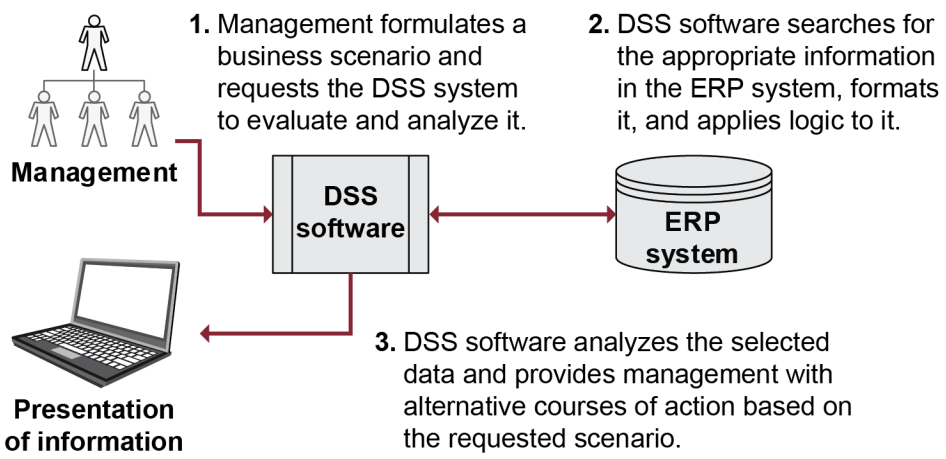
The aggregated data are used in data modeling and analysis, such as by using a decision support system.

Decision Support Systems

A **decision support system (DSS)** is "a computer system designed to assist managers in selecting and evaluating courses of action by providing a logical, usually quantitative, analysis of the relevant factors" (*Dictionary*). DSS is a broad term for any software application used to help management make better decisions. A DSS generates analytical models that are based on mathematical algorithms, simulations, or hybrids of the two. Analytical models are simplified versions of a real situation, event, or transaction. A good model will have just enough information to help guide a decision without including details that would confuse the issue. Models may not always be purely mathematical versions because a DSS may be needed to help management make tradeoffs between qualitative objectives.

As shown in Exhibit 2-24, basic DSS components include an input database, a set of data analysis tools, and a set of database and spreadsheet presentation tools to display results.

Exhibit 2-24: Decision Support Systems (DSS)



Analysis tools also include **data mining**, defined in the *Dictionary* as follows:

> The process of studying data to search for previously unknown relationships. This knowledge is then applied to achieving specific business goals.

Data mining commonly uses a data warehouse (a batch-updated database kept separate from the transactional database for use in analytics) or a shared interorganizational database.

Presentation tools filter the massive data output of a DSS analysis into role-specific information using "dashboards" that allow users to customize the information to suit their needs. For example, a dashboard could show a marketing manager the simulated results of a sales campaign but omit manufacturing simulation results.

Input data to a DSS for supply chain management might include, among many other specific data items, the following:

- Static and semistatic data such as customer order history; locations of suppliers, warehouses, and retailers; weight; volume (cube); holding cost; and shelf life (maximum and minimum) of products
- Dynamic data, such as point-of-sale data and sales forecasts; current capacity and transportation costs to distribution centers; retailer inventory levels; delivery status; and product sales forecasts
- DSS queries, such as sales by customer, segment, or SKU; purchasing by supplier, SKU, etc.; on-hand inventory and inventory forecasts; orders by value, lines, units, etc.; and demand variability

Strategic-level DSS can afford to be detailed and relatively slow because the decisions are long-term and need to be performed only periodically. Such systems often use the most extensive historical data available. Tactical decisions require a balance between speed and sophistication. Operational DSS must be able to provide fast decisions and so are generally simpler models that use current data for short-term planning.

Big Data and Data Analytics

The *Dictionary* defines **big data** as “collecting, storing, and processing massive amounts of data for the purpose of converting it into useful information.”

“Big data” is a buzzword term that describes the massive amount of both unstructured and multistructured data that is hard to process using traditional database and software techniques. Big data comes from different sources—web, sales, customer contact, social media, mobile data, and so on. Many companies process millions of manual/automated transactions per day. A vast amount of data that can be used for numerous purposes is produced. Many frame the discussion of big data using volume (the amount of data), velocity (the speed of information generated and the flow of it through the supply chain), and variety (the kind of data available). However, the term may also refer to the technology that an organization requires to handle the large amounts of data.

Data analytics tools and big data are two elements that can help businesses identify problem areas within a supply chain before those areas actually do damage. Companies need to think about how they will use big data to improve their supply chain:

- **Data collection.** Deciding how much data to collect and how they will be analyzed.
- **Technology usage.** Separating insights from useless data and presenting the insights in a way that is instantly understandable.
- **Leverage results.** Incorporating insights into the decision-making process.

In a strategic example, in determining the optimal distribution network, data can be collected on customer, retail, distribution center, and manufacturing locations; product sales by weight and cube; special transportation requirements; and forecasted demand. In a tactical or operational example, two uses of big data are demand sensing and demand shaping. Demand sensing is used to detect changes in demand from consumers in near real time; demand shaping is then used to alter demand plans to reflect the best current information on demand.

Data acquisition and communication tools are methods of collecting, storing, and sharing data among areas in the organization and with members of the extended supply chain. The primary goal of data acquisition and use is to create a seamless link between all points of production, distribution, purchase, and service. This goal can be broken down into the following components.

- **Collecting information.** Information should be collected at each point at which a good is handled or a service is rendered. Since these points occur within and between many companies, from raw materials companies to manufacturers and assemblers to distribution centers and retailers (plus transportation between each point), there are naturally many individual databases. This information may or may not be shared between supply chain partners.

- **Providing timely access to data.** Data are considered timely if they are received by the relevant system or decision maker within the time needed to execute the relevant transaction or make the decision. Some data are needed instantaneously, while other data can be sent in batches or subjected to intermediate steps such as analytics and still be considered timely.

- **Controlling access to relevant data.** Access to relevant data, especially data regarding the status of material, products, and services, is the basis for making efficient supply chain decisions. The goal of data access is to allow each information user access to a uniform set of role-specific data from any point of contact. For example, a sand supplier should get the same information about a customer's sandpaper sales or rejection rates whether inquiring by phone, ERP, or internet exchange. Likewise, regardless of the means used, the sand supplier should not see the sandpaper manufacturer's labor rates or profit margins.

- **Reducing visibility gaps.** Depending on organizational strategy or the stage of supply chain development a company has achieved, data may or may not be shared. At the earliest stage, even internal information between divisions may not be shared, or it may have to pass through bottlenecks, making it less relevant when shared. At higher stages of development, the company may share data among its internal and perhaps even external partners in real time using straight-through processing (no reentry needed). Visibility implies not only tracking materials, products, and services but also providing active alerts to each affected party of upcoming actions and exceptions to planned events so alternate actions or methods can be devised.

- **Improving planning effectiveness.** A forecast or model is only as good as the data used to create it. Since the sales forecast is the basis of almost all of the other budgets for a traditional manufacturing or service company, improving the data used in planning has a direct effect on a company's planning effectiveness and ultimately on profitability. Improving forecast accuracy is primarily a function of accurate, timely data, measuring and reducing estimate error, and product lead time.

- **Ensuring and maintaining data accuracy.** Ensuring and maintaining data accuracy are critical to the perceived and actual usefulness of any technology system.

Data Maintenance

Ensuring and maintaining the accuracy of data is a major issue and an ongoing concern. Data collection must be as automated as possible; however, with or without humans in the process, data can become compromised or erroneous. In an extended supply chain there are many more potential sources of error.

Data errors can come from sources such as the following:

- Each time data are manipulated (Software bugs can introduce errors.)
- Numeric transpositions, typos, and missing or incomplete data
- Older or not fully integrated databases with multiple versions of a record
- Redundant databases in the network or different tags for the same objects

In addition, delays in data collection can mean that the data arrive too late to be relevant.

Ensuring data accuracy requires resources for validating the data and correcting errors. Companies should use multiple methods to reduce and prevent errors. Without accurate data, advanced analysis will be ineffective and transactional systems will be inefficient. Data accuracy is especially relevant for planning systems. For example, when a transportation management system calculates how to load trucks, if the cube and weight data are wrong or missing from even a small percentage of items to be shipped, the system could recommend overloading the trucks. If this occurs too frequently, workers and managers may stop trusting in the integrity of the system.

In another example, a customer could submit an address change, and the customer master data file is updated. However, if there is a separate shipping and billing address in the system, if the billing address is not also updated or is updated incorrectly, the customer may not receive the bill and could end up being delinquent by accident, be sent to collections, and so on. Even if the problem is eventually discovered and fixed, the customer could be lost permanently.

Improving Data Accuracy

A primary method of ensuring data accuracy is to institute consistent collection and data entry polices:

- Sharing POS and other transaction-specific data across the supply chain
- Collecting and transferring data in real time where feasible
- Completing data entry at the time and place of the event
- Use of industry-specific data accuracy standards (For example, GS1 Standards are used in the retail grocery supply chain.)

Acquiring new software without improving the quality of the data will lead to poor return on investment for the software, possibly leading to distrust and abandonment of an otherwise useful system. A way to prevent this is to combine system upgrades with data cleansing and normalization initiatives.

Data cleansing is defined in the *APICS Dictionary,* 16th edition, as

> sifting through a database to find and fix mistakes such as misspelling, missing information, and false data.

Data normalization is defined in the *Dictionary* as

> a database maintenance term used in the context of relational databases, which helps to minimize the duplication of information or safeguard the database against certain types of logical or structural data anomalies. It is often used when merging data from one or more databases.

Cleansing, normalizing, and otherwise enhancing data become especially important when two or more databases are combined. Mergers are one occasion for combining databases.

The format of the information must also be considered. IT systems should present data in like terms as well as in terms that are relevant to users' needs. For example, when an intermediate customer is creating sandpaper, a sand supplier should be able to see the customer's demand for kilograms of sand and not sheets of sandpaper.

Maintaining Data Accuracy

Once a firm's database has been deemed acceptable after cleansing or other improvements, the firm must take steps to ensure that the data quality doesn't degrade over time. Steps to ensure data integrity include

- Instituting role-based access policies, procedures, and software limits for adding, deleting, and modifying information
- Investing in data maintenance/continuous improvement process training for current and future users.

Section C: Supply Chain Metrics and Reports

This section is designed to

- Describe supply chain metrics and the process for selecting them
- Understand how dashboards can keep people focused on customized metrics that promote addressing business objectives
- Describe the balanced scorecard and how it is used to track improvements in business performance
- Describe how organization-specific scorecards help keep people focused on organizational objectives
- Describe the SCOR® model and its use for improving supply chains
- Identify how to use the SCOR metrics
- Know how to calculate the Level 1 strategic SCOR metrics
- Understand which Level 1 metrics apply to each supply chain process and how these will differ based on different operating models
- Show how using the Digital Capabilities Model for Supply Networks can help supply chains achieve higher levels of supply chain maturity
- Understand the basics of global and country-specific accounting systems and which countries use various systems
- Define key financial terms
- Explain key financial statements that are commonly used in supply chain management
- Review the types of financial metrics used to measure supply chains
- Explain the metrics used for measuring operations within the supply chain in the areas of quality, productivity, and asset management.

In this section we look at the relationship between supply chain strategy and the choice of metrics. We also review different metrics for measuring the performance of supply chains, including financial and operational metrics.

Topic 1: Supply Chain Metrics, Reports, and SCOR

Developing a useful set of supply chain metrics is key to achieving desired results. The place to start is to understand the objectives of any measurement system. Choosing the right way to present measurement results can strongly influence their effectiveness, so balanced scorecards, dashboards, and other tools are covered. Since use of a formal measurement methodology can help ensure a complete measurement system, the Supply Chain Operations Reference (SCOR®) Digital Standard and the related Digital Capabilities Model for Supply Networks are also discussed here.

Supply Chain Metrics and Reports Road Map

Here we start with the big picture of why measurement systems are useful and then introduce supply chain metrics. Supply chain metrics are useful when there are sound processes for gathering performance data, analyzing that performance, and then using the data to improve performance. Metric selection and a metric selection framework are also discussed.

Measurement System Basics

You get what you measure. When designing metrics, it is important to understand that people are motivated to improve what the organization chooses to measure and to ignore or deprioritize what the organization fails to measure. The second part of this statement references the unintended consequences lurking behind the statement “you get what you measure.” To ensure that businesses are getting the results they want while minimizing unintended consequences, organizations often turn to well-established process-oriented measurement models because they are thorough yet not overly complex or cumbersome. One of the more widely accepted and used process-oriented models is the Supply Chain Operations Reference (SCOR®) Digital Standard.

The basic objectives of any measurement system are as follows:

- **Monitoring.** Track actual system performance by observing and gathering data that is relevant to business objectives.
- **Controlling.** Compare data to appropriate standards for performance to determine when the system needs modification or attention, identifying causes, and adjusting systems to get back on course or to continuously improve the course.
- **Directing.** Develop an understanding of actual human motivation and what incentives motivate people to work toward organizational goals while minimizing unintended consequences. In other words, measurement becomes a tool to enable effective leadership and management of the workforce.

Performance measures as a whole should be objective, consistent, and quantified. They should measure at least two parameters, such as a quantity and a time (e.g., delivery by a particular day). They also require target values or standards so that the person or organization being measured and the person(s) doing the monitoring and controlling can objectively gauge relative success.

Data are turned into information by placing them in context and analyzing them. Once this occurs, the right people need to get the information that is relevant to them in the right format. The timing of when the information becomes available is also relevant to the decision. Some communication methods need to be near real-time, while others are designed for periodic appraisal.

Supply Chain Management Metrics

Measurement and feedback is essential for any supply chain, not only to continuously improve systems for greater efficiency and effectiveness but also to allow the systems to adapt to change. It is important to select measurements that will give proper incentives to the parties being measured in the areas of customer-focused, financial, and operational metrics for the supply chain.

Metrics should cut across functions and organizations in the supply chain to promote collaboration and interdependencies. For example, the finance function is concerned with the cost of various supply chain operations and determines the break-even point when an operation could become profitable. Finance is also involved in monitoring suppliers and customers for financial distress to provide early warning of trouble.

Measuring and communicating the performance of the supply chain can provide benefits such as the following:

- Control of processes and employees
- Management or influence over suppliers and customers
- Reporting to managers and external sources (e.g., financial reporting)
- Sharing demand information with suppliers and supply information with customers
- Communication of expectations and problems
- Learning and continuous improvement

Each organization will devise its own set of performance measurements for customer, operational, and financial measures. Exhibit 2-25 shows an example of a set of performance metrics one organization uses, many of which are discussed elsewhere (possibly under slightly different names).

Exhibit 2-25: One Organization's Performance Metrics

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1. % orders delivered on requested delivery date

2. % orders delivered on promised delivery date

3. Production schedule performance

4. Production schedule stability

5. Forecast accuracy
   a. Forecast bias—performance to plan
   b. Forecast bias—tracking signal
   c. Product mix
   d. MAPE—mean absolute percentage error
   e. MAD—mean absolute deviation
6. Order fulfillment lead time

7. Total supply chain cost
8. Cost of goods sold (COGS)
9. Cash-to-cash cycle time
10. Inventory days of supply
11. Days' sales outstanding
12. Days' payables outstanding

Processes for Measuring, Analyzing, and Improving Supply Chain

All along the supply chain, managers are responsible for measuring results and ensuring that they're on target to meet their functional goals as well as support the organizational and strategic plans. These plans may involve some form of continuous improvement initiative. Getting these things to move from plans or project to reality is often a challenge, so change management is often needed.

The key processes that supply chain managers need to be able to perform related to measuring, analyzing, and improving the supply chain are

- Gathering performance data
- Analyzing performance
- Improving performance.

Prerequisites to these processes involve setting measurement system objectives and planning what to measure:

- Determining organizational objectives and how to measure and incentivize their success
- Selecting metrics that are meaningful and promote desired behavior, yet are feasible and cost-effective to measure

Gathering Performance Data

The process of gathering performance data involves the following steps:

- Determining the data to be collected as inputs to chosen metrics
- Finding source(s) for the necessary data—including allowed external sources (e.g., reporting agencies, suppliers)
- Assessing data collection feasibility; for example, for customers/suppliers:
  - Assessing availability, quality, and cooperation levels
  - Planning and executing data collaboration projects when feasible
  - Finding alternative data sources (i.e., proxies) as needed
- Assessing data accuracy impact (For example, distance-based freight rates might be used unless actual freight rates would significantly improve decisions.)

- Choosing the method of gathering each type of data (e.g., manual estimate, manual measurement, automated information system)
- Determining the method of reporting the data (e.g., who, how, what, and when for manual or what events trigger automatic submission)
- Setting up these processes and systems as needed (e.g., using projects)
- Gathering and submitting data during normal operations
- Entering manual data in information systems/tools in the proper format and using controls to minimize data entry errors
- Validating data for relevance, reliability, and accuracy (e.g., compare to historical data to see if wide discrepancies exist; if so, investigate)
- Archiving the data in a role-restricted repository (database) for ease of access and reference by appropriate parties

For example, performance data could be shipping and arrival dates, percent completion of a manufacturing process, number of defects, actual costs, and so on.

In another example, financial data for suppliers might include information directly from suppliers and/or their publicly available financial statements as well as data from credit reports, bank references, or third-party ratings such as Moody's, Fitch's, S&P Global, or Dun & Bradstreet.

Analyzing Performance

The process of analyzing performance involves the following steps:

- Formulating questions that the performance information or model outputs should be able to answer
- Turning data (raw observations and measurements) into information:
  - Placing it in context (e.g., comparing to baselines, goals, benchmarks, or past results)
  - Using the data as inputs for ratio analysis, formulas, or models
  - Using the data for comparisons across supply chain organizations to see if there is a net improvement for all
- Validating information and tools for relevance, reliability, and accuracy (i.e., compare ratios to historical ratios or use historical data in models)
- Making interpretations (e.g., viable options, status, trends, or forecasts)
- Selecting formats and media appropriate to the information and audience
- Preparing reports at predetermined intervals and on request
- Presenting reports

Performance information might include shipment status, fill rate, on-time delivery variance, forecasted number of quality rejects, and so on. Reports can take the form of dashboards, regular status reports, updates, recommendations, formal presentations, and so on.

Improving Performance

The process of improving performance involves the following steps:

- Accepting feedback from decision makers and supply chain participants
- Preparing recommendations for short-term or incremental improvement
- Enacting approved short-term or incremental changes
- Periodically auditing processes (including the measurement process itself) against strategic or long-term objectives
- Preparing recommendations for changes to processes or metrics that better align with strategic or long-term objectives
- Preparing recommendations as needed for making continuous improvement become part of the organization's philosophy (e.g., lean, six sigma)
- Using change management and/or project management to enact strategic or long-term improvements to processes or performance

Selecting Metrics Related to Supply Chain Strategy

Since it's not feasible to measure and monitor every supply chain goal or activity, managers have to choose a reasonable number of metrics that are related to supply chain strategy. Some of the strategic attributes of supply chains are velocity, visibility, variability, collaboration, trust, customer focus, and flexibility. Other attributes include security (risk management), compliance with all regulations, and environmental excellence (with a well-developed, profitable reverse supply chain). Any of these attributes could be woven into strategy, expanded into specific objectives, and subjected to measurement.

For instance, if the supply chain's strategy were to increase the velocity with which information flows from the end customer back through the chain, objectives would be developed to assess the current state of the system and identify metrics to measure progress toward a specific goal. The key metric might be a measure of the actual velocity of communications. The goal could be to substitute reports from intermediate customers with the direct transfer of data from the point of sale via scanners, bar codes, and the internet. A number of enabling objectives might be put in place for buying equipment, training staff, and so on. This would be a true supply chain metric, because the process it measures crosses nodes.

What is being measured creates incentives and perhaps unintended consequences. For example, a purchasing agent whose performance is being measured on purchase price variance will work to minimize that variance but could be motivated to do so in ways that harm other objectives, like buying in bulk to get discounts and always selecting the lowest bidder. The selected metrics would introduce a side effect of increasing inventory and reducing quality. Organizations that used these as the primary purchasing metrics are moving away from cost and toward value for the final customer. While this is a

more difficult metric to measure because it requires information from supply chain participants, it produces results that better align with objectives.

Often a selection of metrics that are tailored to a specific supply chain is what is needed. For example, inventory turnover and cash-to-cash cycle time might be two of several metrics, and these would promote ordering in wise quantities. They would then be balanced with other metrics such as on-time delivery, purchase price, and total cost to produce a well-rounded incentive system. So how do you select these metrics? One can use trial and error over time, but this can be costly, so many organizations instead use a framework or methodology when designing metrics.

Metric Selection Framework

A framework for helping organizations select the best metrics to use was developed by Griffis, Cooper, Goldsby, and Closs in an article titled “Aligning Logistics Performance Measures to the Information Needs of the Firm.” In this framework oriented toward logistics metrics, there are three areas to focus on when prioritizing metrics. Each is a continuum, or range between two opposite forces:

- **Competitive basis: responsive versus efficient.** Greater responsiveness tends to lower efficiency.
- **Measurement focus: strategic versus operational.** Priority can be more toward selecting the best overall strategy, such as total cost of ownership, or on efficient daily operations.
- **Measurement frequency: diagnostic versus monitoring.** Diagnostic measurements are used to decide between alternatives, while monitoring measurements are used to assess daily performance.

The idea is to assess where the organization falls as to its competitive basis and then to determine where each metric falls on each of the second two ranges. Organizations can then select metrics that match their competitive basis. They could also use such a framework to help decide which metrics should be used when they want a strategic focus and which are more appropriate for daily operations management.

Once a company determines the metrics to use, these metrics need to be communicated throughout the extended enterprise along with the benefits of achieving them.

Scorecards, Dashboards, and Performance Metrics

Supply chain scorecards, dashboards, and performance metrics are ways of giving internal decision makers as well as other supply chain partners clear goals. When these tools are shared with suppliers, for example, both the suppliers and the organization can view performance on a daily, weekly, monthly, or other periodic basis. The tools make clear what is being measured and what results are considered unacceptable, marginal, and acceptable. This information may be presented in customizable dashboards, with role-specific display of performance information. Often when a supplier or other

supply chain partner has access to the performance information, they can self-correct issues before they become more serious. After all, to a supplier, the organization is the customer. Suppliers are naturally interested in maintaining a good relationship to promote their own success.

First we present dashboards as useful ways to display relevant performance data, and then we address the balanced scorecard. Since most organizations create their own scorecards, these are discussed as well, using an example from a real company that is involved in global sourcing. Following this, some additional performance metrics from the same company are provided.

Dashboards

The *APICS Dictionary,* 16th edition, defines a **dashboard** as "an easy-to-read management tool similar to an automobile's dashboard designed to address a wide range of business objectives by combining business intelligence and data integration infrastructure."

One type of dashboard is an executive dashboard. The *Dictionary* defines an **executive dashboard** as

> a set of cross-functional metrics for measuring company performance that indicates the health of the company. It usually includes the company's key performance indicators.

The key advantages of using dashboards are timeliness and self-management. Since dashboards provide automated near real-time information that is customized to the viewer's needs, the right information gets to that person quickly. Because the information is provided directly to the person, he or she can then plan any necessary changes without needing to be directed. Managers can then be involved in advisory and approval roles rather than needing to direct and control except in the cases when appropriate action isn't being taken.

Balanced Scorecard™

Metrics provide a way to keep score, so it was only natural that someone would create a business-related scorecard. If an organization's objective is to improve order fill rate from 93 percent to 98 percent, a scorecard can provide a means to compare actual performance against target performance. However, if the things that are being measured do not address some key objectives, this measurement imbalance can result in those objectives being ignored. To ensure that both the short- and long-term objectives are addressed, in 1992 Robert S. Kaplan and David Norton introduced the **balanced scorecard ™ (BSC),** which the *Dictionary* defines as

> a list of financial and operational measurements used to evaluate organizational or supply chain performance. The dimensions of the balanced scorecard might include customer perspective, business process perspective, financial perspective, and innovation and learning perspectives. It formally connects overall objectives, strategies, and measurements. Each dimension has goals and measurements.

The balanced scorecard (BSC) is a four-part system developed to evaluate organizational performance on more perspectives than just financial results. The BSC was initially designed to give managers a comprehensive view of overall business performance; however, it has since been adapted to many purposes, including the design and measurement of supply chain performance, both internally and to measure suppliers.

Why is the scorecard “balanced”? Because unlike traditional measures, which focus only on financial results, it includes four different types of measurements that aim to provide a broader, more balanced perspective on business performance:

- Customer perspective
- Business process perspective
- Innovation and learning perspective
- Financial perspective

Exhibit 2-26 shows a balanced scorecard for a particular supplier for a period of time (such as a month), including some sample goals and metrics. Note that the second innovation and learning goal is a subgoal of the goal above it. Subgoals should contribute to meeting the overall goal. (In this case, it is a Level 2 SCOR metric that contributes to the Level 1 metric above it.)

Exhibit 2-26: Balanced Scorecard (BSC) for Supplier XYZ

Customer Perspective				**Innovation and Learning Perspective**			
Goal	**Measure**	**Target**	**Actual**	**Goal**	**Measure**	**Target**	**Actual**
Meet customer delivery promises.	Supplier XYZ delivery performance	99%	98%	Supplier XYZ can withstand economic downturns.	Downside supply chain adaptability	20% fewer orders	15% fewer orders
Meet customer quality expectations.	Number of floor failure events related to XYZ materials	0	1	Reduce production with no layoffs.	Downside adaptability (make)	20% fewer orders	18% fewer orders

Business Process Perspective				**Financial Perspective**			
Goal	**Measure**	**Target**	**Actual**	**Goal**	**Measure**	**Target**	**Actual**
Improve supplier sustainability conformance.	XYZ’s sustainability conformance rate	100%	100%	Promote supplier cost reductions.	% cost relative to incentive cost target	–10%	+5%
Reduce WIP material refinishing time.	Number of conditionally accepted XYZ materials	0	2	Work with financially stable suppliers.	XYZ’s debt-to-total assets ratio	0.35	0.40

Note the four categories of information for each metric: goal, measure, target, and actual. All four items are necessary. The goal shows the result that should be achieved. All goals included in a scorecard must be measurable. Targets are performance standards that set a value that the measurement should achieve to be considered successful. Some organizations expand this into three categories of targets

such as good, better, and best or failing, acceptable, and excelling. The “Actual” column is where actual performance is recorded for a given period. As will be seen in the custom scorecard example to follow, there may be individual columns for multiple periods.

Consider what each perspective adds to a manager’s knowledge of his or her area’s role in the supply chain:

- **Customer perspective.** The customer’s view of the business clearly has value for assessing the current performance and future prospects of the business. Measures such as on-time delivery or subjective measures such as satisfaction with customer service or impression of reliability are important to track.

- **Business process perspective.** In a functionally oriented business, this area might focus on number of prospecting calls or productivity. It can also encompass flexible response, waste reduction, or other supply chain management goals.

- **Innovation and learning perspective.** This area can include formal training for staff, or it can refer to innovations in products or processes (such as adopting a balanced scorecard approach to supply chain management).

- **Financial perspective.** The traditional way of judging business performance relied on such measures as cash-to-cash cycle time, return on investment, and debt-to-equity ratio. But financial measures are retrospective, and they don’t always provide a true indication of the current state of affairs, much less of future performance. Kaplan and Norton wanted to give managers a tool that would encourage a broader, more future-oriented view. Nevertheless, a balanced scorecard approach must always include the financial perspective; bottom-line results are still the final measure of success. Also, the measurements used in all four perspectives must ultimately be linked to their financial contribution to the bottom line.

Key Elements in Balanced Scorecard Initiative

Developing a balanced scorecard approach to managing the supply chain requires careful preparation, leadership, and follow-through. Here are some key elements that should be present in a balanced scorecard initiative:

- **Communicate the strategic purpose of the scorecard to partners.** Organizational strategy, let alone supply chain strategy, too often remains in the minds of top executives without being communicated to other levels of management. If managers are to help make change happen, they have to understand why it’s good for the business, the customer, their own area, and themselves.

- **Develop goals and measures consistent with internal and supply chain strategies.** There’s a temptation to use the balanced scorecard as a brainstorming tool without understanding that the four

areas need to be mutually reinforcing and aligned with strategy. They aren't catch-all containers for random suggestions. If the supply strategy is to penetrate a new, high-end market with innovative electronics, then the business process perspective might be to develop a more rapid product innovation cycle linked to measures of process innovation and design workshops in the innovation and learning area, reduced delivery cycles in the customer perspective area, and a profitability measure in the financial area.

- **Create schedules and assign responsibilities.** The BSC requires establishing ownership of results. When an initiative crosses functional areas in one company it is likely to encounter resistance if not coordinated and promoted from above. But in a supply chain comprising different companies, there is no unified "above"; agreement has to be established first at the executive level across the supply chain. Then a reporting structure has to be established across company boundaries. Moreover, there may be obstacles to overcome, such as incompatible systems.

Setting up a balanced scorecard initiative is not a job for novices. The first time around it can be worthwhile to bring in outside expertise. Still, even a highly sophisticated consultant cannot substitute for support at the executive level; outsiders are not always immediately accepted if employees aren't convinced that management is behind the initiative.

Custom Scorecards

Balanced scorecards are designed to be customizable because organizations can specify their own goals and the measures used to achieve each goal. If the four perspectives are not considered useful categories for an organization, organizations often design their own custom scorecards. The benefits are that both the categories used and the individual metrics can be tailored to the needs of the organization and its culture and organizational structure. The drawback is that a custom scorecard may not be as well balanced.

When an organization has key, indispensable suppliers or alliances, it may be best to develop the scorecard in consultation with these organizations rather than handing the results down from above. Suppliers who are involved are more likely to accept the measurements and may be able to provide suggestions or innovations.

Exhibit 2-27 shows a custom scorecard that reflects the unique priorities and measurements that a particular organization uses for one of its 3PL sites.

Note the following points about this scorecard:

- It includes metrics for two suppliers to the 3PL. An organization will likely have multiple scorecards, but suppliers of the same good or service could be shown on the same scorecard for direct comparison.

- Measurements are in numbers and percentages for easy reference.
- The title of the scorecard is “Monthly Quality of Service (QOS) Report.” The categories do not have any direct financial measures, which are likely the subject of a different report.
- There are seven categories: active suppliers and parts, advanced shipment notification (ASN) compliance, receipts, receipt discrepancies, inventory count, deliveries, and corrective actions. These categories are more of a blend of business process, learning and growth (discrepancies and corrective actions), and customer perspective (the customer being the organization producing the scorecard).

Exhibit 2-27: Custom Scorecard

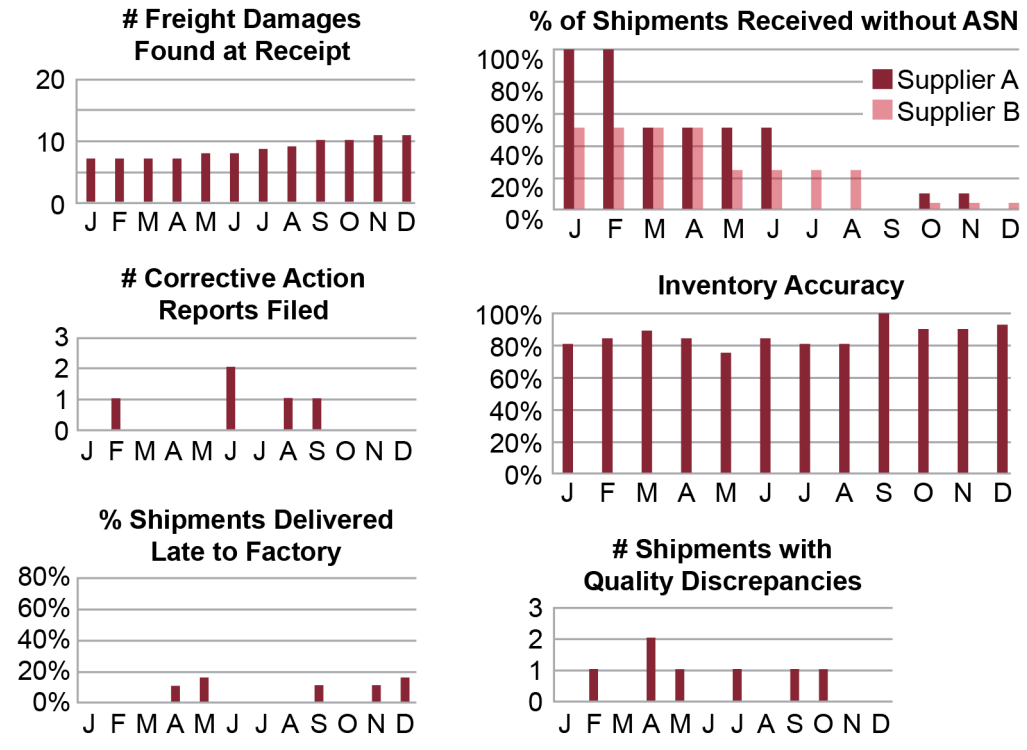
Monthly Quality of Service (QOS) Report, 3PL: Site XXX													
Category	**Target**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
ACTIVE SUPPLIERS & PARTS													
Total Active Suppliers in 3PL	—	3	3	3	3	4	4	4	4	4	5	5	5
Total Active Parts in 3PL	—	28	28	29	29	29	30	31	32	33	35	35	37
# Active Parts in 3PL: Supplier A	—	25	25	25	25	25	25	26	26	26	26	26	26
# Active Parts in 3PL: Supplier B	—	3	3	4	4	4	5	5	6	7	9	9	11
ASN COMPLIANCE													
% Shipments Received Without ASN: Supplier A	0%	100%	100%	50%	50%	50%	50%	0%	0%	0%	10%	10%	0%
% Shipments Received Without ASN: Supplier B	0%	50%	50%	50%	50%	25%	25%	25%	25%	0%	5%	5%	3%
RECEIPTS													
# Containers Received: Supplier A	—	6	6	6	6	7	7	8	9	10	10	11	11
# Containers Received: Supplier B	—	2	2	2	2	2	3	3	3	2	2	1	1
% of Shipment Received Late in System [+8 Hrs]	0%	0%	10%	10%	10%	8%	8%	7%	6%	0%	5%	5%	2%
RECEIPT DISCREPANCIES													
# of Freight Damages Found at Receipt	0	0	0	0	0	1	0	0	1	0	0	1	0
# of Shipments with Quantity Discrepancies Found at Receipt	0	0	1	0	0	2	1	0	1	0	1	1	0
INVENTORY COUNT													
# of Parts Physically Counted	—	28	28	29	29	29	30	31	32	33	35	35	37
Inventory Accuracy Based on Physical Count	100%	80%	85%	90%	85%	75%	85%	80%	80%	100%	90%	90%	95%
DELIVERIES													
% of Shipments Delivered Late to Factory [+1 Hr]	0%	0%	0%	0%	10%	15%	0%	0%	0%	8%	0%	10%	15%
CORRECTIVE ACTIONS													
# of Corrective Action Reports Filed	0	0	1	0	0	0	0	2	0	1	1	0	0

Source: Laura Gram

Visual Tools for Scorecards

The custom scorecard in also contains some visual tools to augment the seven categories of measurements in the previous scorecard. Visual tools such as those shown in can make some trends obvious.

Exhibit 2-28: Visual Tools for Scorecards

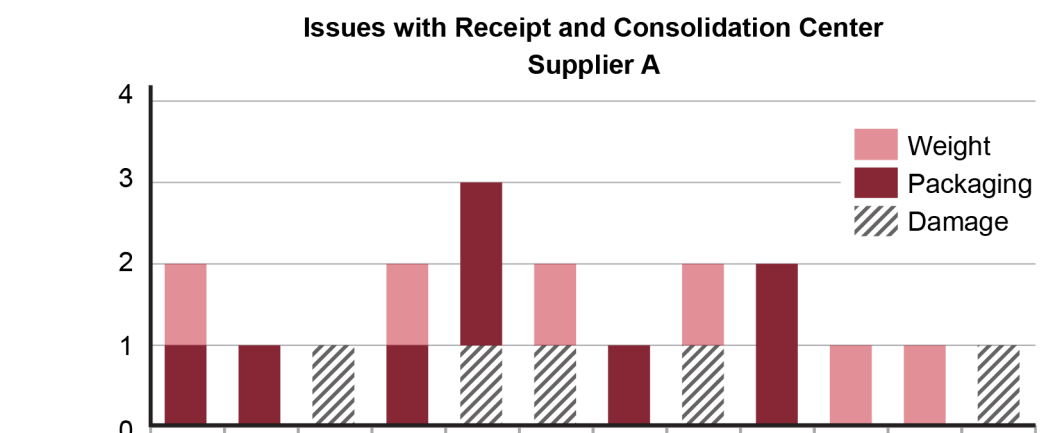


Source: Laura Gram

Performance Metrics

This discussion continues the case study for the organization that designed the previous custom scorecard. Performance metrics for its raw material suppliers and its freight forwarders are also in the form of visual graphs and charts that are easy to interpret and easy to discuss with the suppliers. These tools help the organization exercise the proper level of control over its suppliers because problem areas become obvious. Exhibit 2-29 and Exhibit 2-30 are KPIs (key performance indicators) for raw material suppliers; Exhibit 2-31 and Exhibit 2-32 are KPIs for freight forwarders.

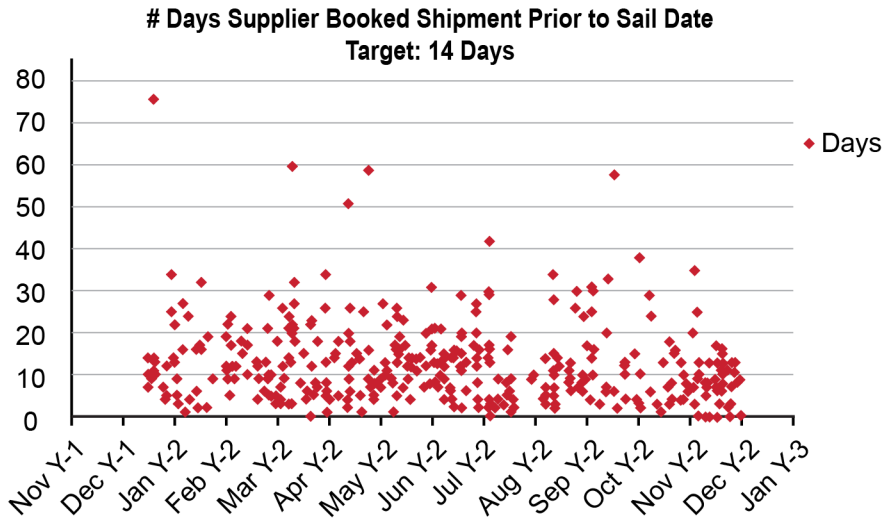
Exhibit 2-29: KPIs for Raw Material Suppliers



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Weight	1	0	0	1	0	1	0	1	0	1	1	0
Packaging	1	1	0	1	2	0	1	0	2	0	0	0
Damage	0	0	1	0	1	1	0	1	0	0	0	1

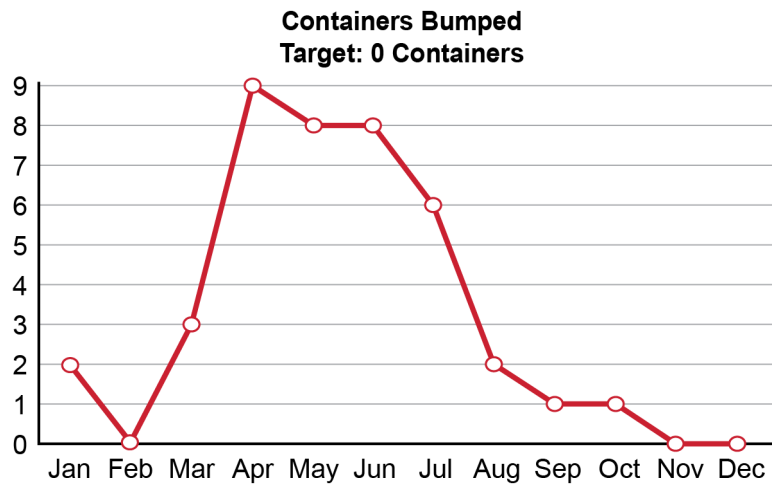
Source: Laura Gram

Exhibit 2-30: KPIs for Raw Material Suppliers



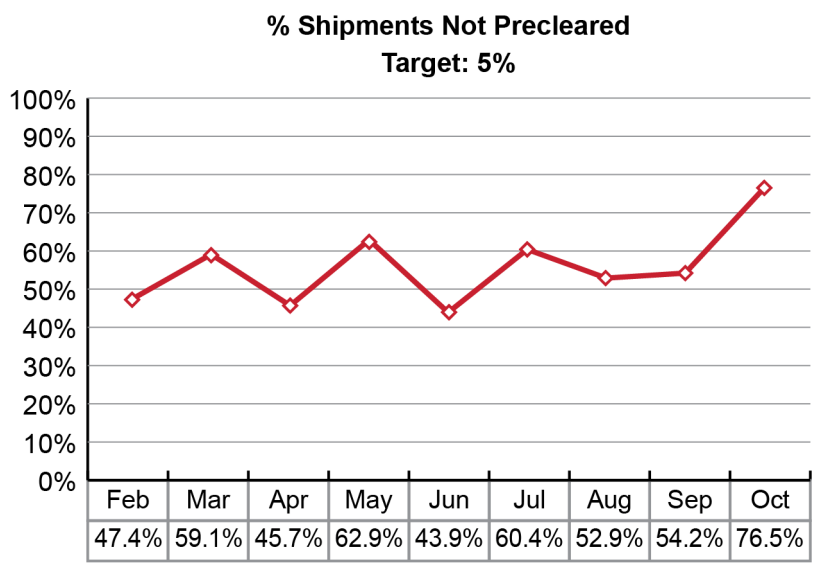
Source: Laura Gram

Exhibit 2-31: KPIs for Freight Forwarders



Source: Laura Gram

Exhibit 2-32: KPIs for Freight Forwarders



Source: Laura Gram

Exhibit 2-29 shows months in which there were occurrences of incorrect weight, packaging problems, or damage to raw materials. The categories stack to highlight months when multiple problems occurred. This chart cannot show the magnitude of the problems, only that they exist. Exhibit 2-30 shows that relative to the target shipment booking of 14 days prior to sail date, many suppliers booked shipment

with little or no notice. Exhibit 2-31 shows that only in February, November, and December did the freight forwarder meet the target goal of no containers bumped and that April through July may require more serious monitoring in the next year. Exhibit 2-32 shows that the average number of shipments that were not precleared was around 50 percent even though the target was five percent. This may be an area where the measurement and target must be reviewed to see if they are accurate and feasible, which could result in either mandating a supplier process correction or setting a more realistic target.

The key points about supplier scorecards and performance metrics that can be gained from these examples is that rather than just having a few universal ways to measure performance, organizations have many ways. However, organizations should select only measurements that can be objectively gathered, that provide useful information for decision making, and that can be enforced. The standard or target selected should be challenging but realistic. Finally, there is no point in measuring something unless you intend to do something about it if it is significantly or consistently off target (and celebrating it if it exceeds expectations).

Sustainability Scorecards

Many organizations are now presenting their sustainability reports in the form of a sustainability scorecard. Using a scorecard format allows a quick view to compare year-over-year results on key performance metrics.

These scorecards enable organizations to target and track the best opportunities for improvements in energy, water, pollution, and waste reduction targets across their supply chain. They also demonstrate continuous progress toward implementing sustainability plans.

While formats vary across organizations, some examples exist in open format for review and usage. Proctor & Gamble (P&G) has a sustainability scorecard and rating process to measure the environmental performance of its key suppliers. Their scorecard is “open code” for use by any organization to help determine common supply chain evaluation processes across all industries. P&G relied on input from a supplier sustainability board and used protocols set by the World Resources Institute, the World Business Council for Sustainable Development, and the Carbon Disclosure Project. It focuses on year-on-year improvement regardless of the current stage of a supplier’s sustainability program.

The P&G scorecard was developed by referencing another example, Walmart’s The Sustainability Insight System (THESIS) Index, in which the retailer asks questions about the sustainable practices of its suppliers. This allows them to understand the sustainability hotspots within product categories and rank the suppliers based on information they provide around those hotspots. In 2017, Walmart reached its goal of buying 70 percent of its U.S. goods from suppliers that participate in the index (and can use the index), or 1,300 suppliers. By 2020, this had increased to 1,600 suppliers.

SCOR Performance Measures

One of the more widely accepted and used process-oriented models is the **Supply Chain Operations Reference (SCOR®)** Digital Standard. It is “a process reference model developed and endorsed by the [APICS] Supply Chain Council (APICS SCC) as the cross-industry, standard diagnostic tool for supply chain management” (*APICS Dictionary,* 16th edition). It reflects the collective wisdom of years of field-based practices and provides a unique framework that links business processes, metrics, best practices, skills, and technology features in a unified structure.

The SCOR Digital Standard provides methodology and tools to diagnose and benchmark organizations. Individuals can enhance their understanding of supply chains and associated processes using this model, and they can improve their own supply chain management systems and practices by using these tools. The model has been developed and refined by dozens of major companies and applied in initiatives available as case studies.

The SCOR Digital Standard has several major categories:

- A **Processes** category, which is organized around the SCOR process model explored below.
- A **Performance** category, which is the specific metrics in the model. Each part of the process model references selected performance indicators.
- A **People** category, which is standards for managing supply chain talent in terms of baseline skills, critical skills, related performance measures, and skill credentialing.
- A **Practices** category, which is related emerging practices and technologies, best practices, and standard practices.

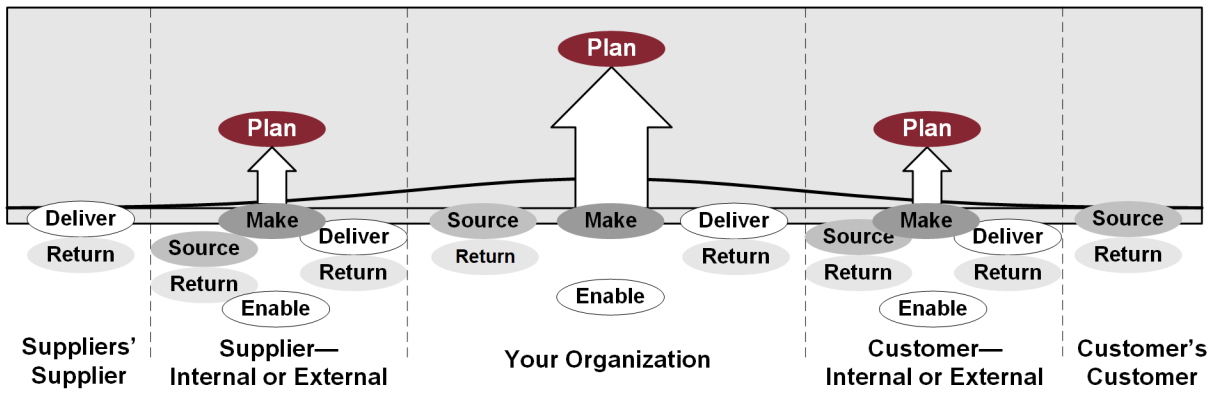
Note that the SCOR Digital Standard (this version supersedes SCOR 12.0) is designed to enable the supply chain digital transformation. The SCOR Digital Standard has added a number of new emerging practices, including augmented reality, robotic process automation, artificial intelligence, big data analytics, should-cost modeling, predictive analytics, digital twin, smart contracts, advanced data visualization and visibility, real-time location systems, autonomous delivery, stock taking via drones, dynamic inventory management, quick-response codes, mobile distribution centers, machine learning, dynamic routing, virtual reality, and multi-enterprise business networks. This has augmented the prior version’s emerging technology practices, which included things like blockchain and the Internet of Things. These emerging practices, plus the best practices and standard practices, are linked to specific supply chain processes. For example, for planning the deliver process, there are standard practices such as cross-docking, best practices such as vendor-managed inventory, and emerging practices such as machine learning. These practices help show where to leverage each technology.

Another way that the SCOR Digital Standard helps create an intelligent supply chain is by linking to a new model called the Digital Capabilities Model for Supply Networks. This model is discussed in its own area.

The SCOR process model and its metrics are the primary subject of the rest of this discussion of SCOR. The boundaries within which the SCOR process model applies are carefully defined. Specifically, it does not apply to all business processes, only to those involved in the supply chain as the chain extends two tiers in both directions from the company at the core. This is shown in Exhibit 2-33.

- At the center is “Your Organization.”
- To the immediate right is the first tier of customers, which can be either internal or external.
- To the left is the first tier of suppliers, which, again, can be either internal or external.
- The model goes out two tiers in both directions; the second-tier suppliers and customers are assumed to be external.

Exhibit 2-33: Supply Chain Operations Reference (SCOR) Model



Source: Adapted from APICS Supply Chain Council

The model focuses on six areas:

- Plan—creating strategies to meet goals and developing best practices to guide decisions
- Source—obtaining goods and services in a way that meets market demand and quality expectations
- Make—assembling finished products to meet customer demand
- Deliver—managing ordering, transportation, and distribution processes
- Return—accommodating returned goods from suppliers, distributors, or customers
- Enable—supporting performance in the other areas through, for example, effective hiring and performance management, information sharing, and business expertise (e.g., compliance, quality, risk management, information technology)

These processes—which are not traditional functional areas or departments—exist within the entities of the supply chain. All the processes are carried out by the central triad of chain members.

The entities at each end of the supply chain (a raw material supplier and a retail outlet, for example) perform only two processes (the supplier’s supplier handles only delivery and returns, while the customer’s customer manages only sourcing and returns). This model can also be applied to supply chains containing many more linked organizations.

SCOR does apply to the following activities:

- All customer interactions from order entry through paid invoice
- All product transactions (defined as physical materials and services), including equipment, spare parts, bulk product, and software, among others
- All market interactions from understanding aggregate demand through order fulfillment

SCOR does not apply to the following processes:

- Sales and marketing (defined as demand generation)
- Research and technology development
- Product development
- Some elements of post-delivery customer support (But it does include returns as a fundamental process.)

The SCOR model assumes that the product has already been designed and tested for production. However, the design of a product may significantly influence the functioning of the chain, so supply chain representatives should play a role in the design process.

The SCOR model was developed specifically to measure cross-functional, cross-company supply chain processes at four levels. It includes metrics that allow it to be used to compare performance against industry-best or best-in-class performance as well as against a company's own previous performance and future goals. Once the supply chain has a percentage score for a particular metric, it can then conduct research to determine its ranking among relevant organizations and decide whether to undertake an improvement initiative.

SCOR Levels

The levels of SCOR metrics are as follows:

- Level 1 SCOR: These are the strategic-level metrics. This level defines the scope and content of a given supply chain. Here is where the competitive basis of the organization is translated into high-level performance targets.
- Level 2 SCOR: These are the operational strategy metrics. Examples of operational strategies include make-to-stock and make-to-order.
- Level 3 SCOR: This level is used to configure the individual processes and enable execution of the strategy. It involves defining processes, inputs and outputs, process performance (including more detailed performance metrics), practices, technology capabilities, and staff skills.
- Level 4 (not in scope for SCOR): These are the industry-, company-, or location-specific processes and practices needed to achieve required performance. Metrics at this level will be defined by the organization.

The selection of metrics depends upon the supply chain strategy; there is no requirement, for example, that all the metrics for a particular SCOR level have to be applied simultaneously. In fact, the opposite is more likely to be true. Achieving greater overall velocity might require that one link in the chain

actually underperform in the interest of boosting performance elsewhere. Shipping might have to rely on more expensive transportation, for example. These tradeoffs have to be carefully negotiated with those involved, and rewards may have to be shared in such a way that the interest of each stakeholder is brought into alignment with that of the overall enterprise. Strong leadership from above is paramount. A pilot project is helpful if it starts at the most manageable level and has a good chance of quick success. Applying one metric across two or three supply chain partners is not too modest a project.

Level 1 SCOR

SCOR Digital Standard Level 1 includes six management processes. As seen in , each process is made up of subprocesses, specific tasks, and activities.

Exhibit 2-34: Level 1 SCOR Management Processes

Process	Activities
Plan	The plan processes describe the planning activities associated with operating a supply chain. They include gathering customer requirements, collecting information on available resources, and balancing requirements and resources to determine planned capabilities and resource gaps. This is followed by identifying the actions required to correct any gaps.
Source	The source processes describe the ordering (or scheduling) and receipt of incoming goods and services. They include issuing purchase orders, scheduling incoming deliveries, receiving, shipment validation and storage, and accepting supplier invoices.
Make	The make processes describe the activities associated with the conversion of materials or creation of the content for services. They focus on conversion of materials rather than production or manufacturing because they represent all types of material conversions: assembly, chemical processing, maintenance, repair, overhaul, recycling, refurbishment, remanufacturing, etc. As a general guideline, these processes are recognized by the fact that one or more item numbers go in and one or more different item numbers come out.
Deliver	The deliver processes describe the activities associated with the creation, maintenance, and fulfillment of customer orders. They include the receipt, validation, and creation of customer orders; scheduling order delivery; pick, pack, and shipment; and invoicing the customer.
Return	The return processes describe the activities associated with the reverse flow of goods back from the customer. They include the identification of the need for a return, the disposition decision making, the scheduling of the return, and the shipment and return of the returned goods. (Repair, recycling, refurbishment, and remanufacturing processes are not described using the Return process elements. See “Make” above in this exhibit.)
Enable	The enable processes describe the activities associated with establishing, maintaining and monitoring information, relationships, resources, assets, business rules, compliance and contracts required to operate the supply chain. Enable processes support the realization and governance of the planning and execution processes of supply chains.

In Level 1, there are also five core supply chain attributes: reliability, responsiveness, agility, cost, and asset management. These are addressed elsewhere.

Level 2 SCOR

Level 2 can be broken down into two processes, planning and execution, as illustrated in .

Exhibit 2-35: Level 2 Process Types

Process Type	Description
Planning	A process that aligns expected resources to meet expected demand requirements Planning processes: • Balance aggregated demand and supply • Generally occur at regular, periodic intervals • Consider consistent planning horizon • Can contribute to supply chain response time
Execution	A process triggered by planned or actual demand that changes the state of material goods Execution processes: • Generally involve: 1. Scheduling/sequencing 2. Transforming product, and/or 3. Moving product to next process • Can contribute to order fulfillment cycle time

The execution process, for example, has three different possible capabilities of representing and responding to customer orders, as seen in :

- Make-to-stock (production in anticipation of a customer demand)
- Make-to-order (production due to an incoming customer order)
- Engineer-to-order (customer order requiring specific engineering involvement)

Exhibit 2-36: Possible Capabilities in Execution Process

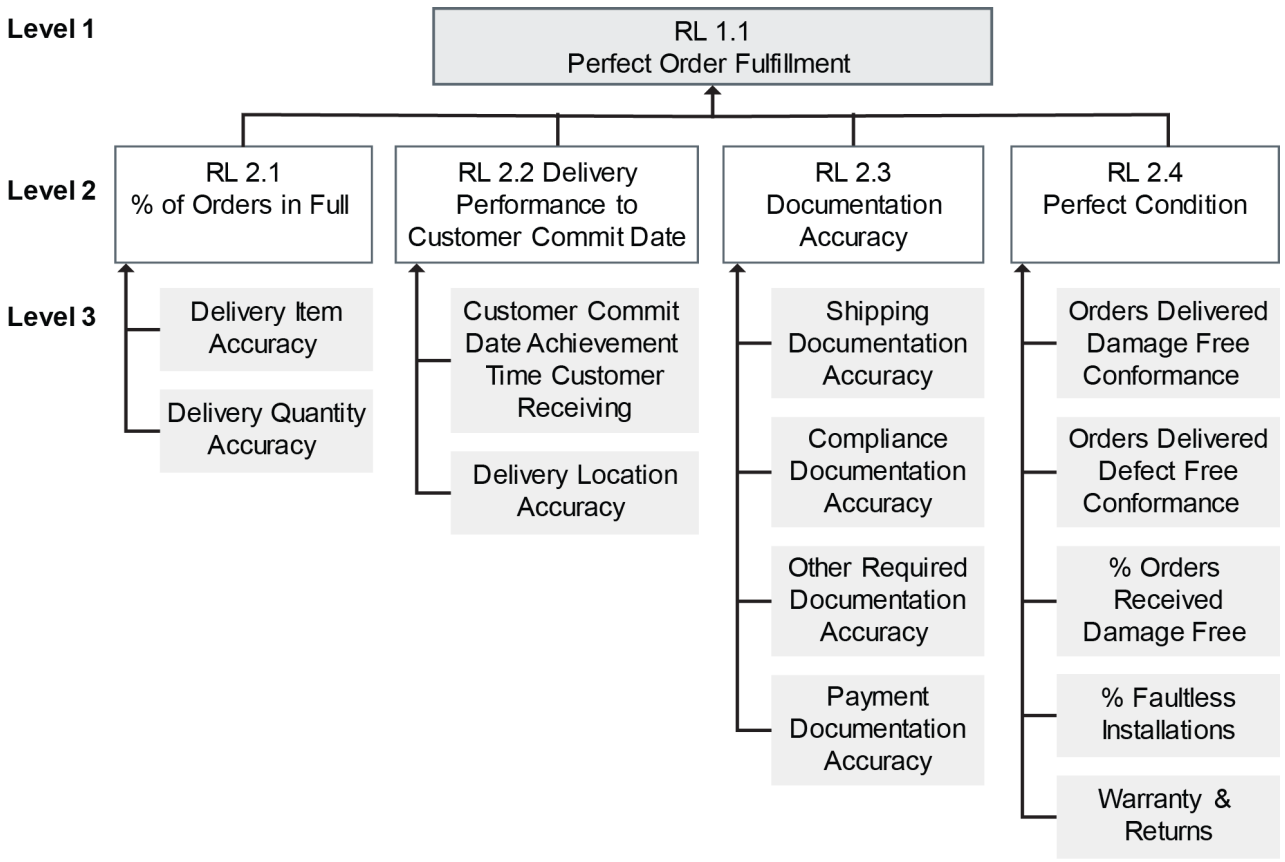
Make-to-Stock	Make-to-Order	Engineer-to-Order
• Driven by inventory (plan) • Standard material orders • High fill rate, short turnaround	• Driven by customer orders • Configurable materials • Longer turnaround times	• Driven by customer requirements • Sourcing new materials • Longest long lead times, low fill rates

Different supply chain strategies support corresponding product or service types. These categories also affect the plan and return processes.

Level 3 SCOR

In Level 3, the processes describe the steps performed to implement the Level 2 processes. illustrates how the SCOR metrics for perfect order fulfillment cascade from one level to the next.

Exhibit 2-37: SCOR Level Metrics for Perfect Order Fulfillment



Industry Level 4 Processes

The SCOR model does not detail Level 4, so organizations and industries create their own Level 4 processes. The processes detail the industry- or company-specific activities that are needed to perform Level 3 processes.

Level 1, 2, 3 Metrics

Understanding the three levels of SCOR process details will help you understand how each level cascades down to the next, which contains more details and more specific measures.

Exhibit 2-38 shows the SCOR levels, the application for each, and some examples.

Exhibit 2-38: Levels of Process Detail in SCOR

Level	Application	Examples
1	**Level 1 processes** describe the scope and high-level configuration of a supply chain. SCOR has six Level 1 processes.	Plan, source, make, deliver, return, enable
2	**Level 2 processes** differentiate strategies of the Level 1 processes. Both the Level 2 processes themselves as well as their positioning in the supply chain determine the supply chain strategy.	"Make" Level 2 processes: • Make-to-stock • Make-to-order • Engineer-to-order

Level	Application	Examples
3	**Level 3 processes** describe the steps performed to execute the Level 2 processes. The sequence in which these processes are executed influences the performance of the Level 2 processes and the overall supply chain.	“Make-to-order” Level 3 processes: • Schedule production activities • Issue sourced/in-process product • Produce and test • Package • Stage finished product • Dispose waste • Release finished product
4	**SCOR does not detail Level 4 processes because they are industry-specific.** Organizations and industries develop their own Level 4 processes (standard process descriptions of activities within Level 3 processes).	“Issue product” Level 4 processes for the electronics industry might include: • Print pick list • Pick items (bin) • Deliver bin to production cell • Return empty bins to pick area • Close pick order.

Source: Adapted from Supply Chain Operations Reference (SCOR®) Model, Overview

If you would like more information on the SCOR Digital Standard or its levels, links to a quick reference pamphlet and to an inexpensive SCOR application are available online in the Resource Center.

Level 1 SCOR Metrics

Level 1 strategic metrics help an organization measure its success in achieving its market positioning goals relative to the competition. Here are the Level 1 metrics grouped by performance attribute:

- Supply chain reliability
  - Perfect order fulfillment
- Supply chain responsiveness
  - Order fulfillment cycle time
- Supply chain agility
  - Upside supply chain adaptability
  - Downside supply chain adaptability
  - Overall value at risk
- Supply chain cost (financial metric)

    - Total supply chain management cost
    - Cost of goods sold (COGS)

- Supply chain asset management
    - Cash-to-cash cycle time
    - Return on fixed assets
    - Return on working capital

All supply chain processes (plan, source, make, deliver, return, and enable) are directly or indirectly tied to Level 1 metrics. However, the Level 1 metrics that are needed may differ depending on the operating environment. For example, for the source metrics, under reliability, perfect order fulfillment is a metric for make-to-order and engineer-to-order but not for make-to-stock.

We will go through the metrics for each performance attribute next.

Supply Chain Reliability

The only Level 1 measure of supply chain reliability is perfect order fulfillment. The *APICS Dictionary,* 16th edition, defines **perfect order fulfillment** as “a measure of an organization's ability to deliver a perfect order.” The *Dictionary* defines a **perfect order** as follows:

> 1) An order in which the “seven R’s” are satisfied: the right product, the right quantity, the right condition, the right place, the right time, the right customer, the right cost. 2) A fulfillment metric used measure order proficiency, which meets the following criteria: on time, complete, accurate and undamaged.

In short, it is the percentage of orders meeting delivery performance with complete and accurate documentation and no delivery damage or defects.

Components of a perfect order include all items and quantities, so any late items or any items delivered in the wrong amount would violate the requirements of a perfect order. The definition of “on time” has to come from the customer. Documentation includes all packing slips, bills of lading, invoices, etc.

A perfect order must satisfy all of the following conditions:

- A product is considered perfect if the product ordered is the product provided.
- A quantity is considered perfect if the product ordered is provided in the ordered quantity.
- A delivery is considered perfect if the location and delivery time ordered are met upon receipt.
- A customer order is considered perfect if the product is delivered to the specified entity.
- Documentation supporting the order is considered perfect if it is all accurate, complete, and on time.
- The product condition is considered perfect if the product is delivered and faultlessly installed (as applicable) according to specifications with no damage, is customer-ready, and is accepted by the customer.

The calculation for perfect order fulfillment is as follows:

$$\text{Perfect Order Fulfillment} = \frac{\text{Total Perfect Orders}}{\text{Total Number of Orders}}$$

Supply Chain Responsiveness

The order fulfillment cycle time metric is the only Level 1 measure of supply chain responsiveness. The *Dictionary* defines **order fulfillment cycle time** (order fulfillment lead time or customer order cycle time) as follows:

> The average amount of time between the customer's order until the customer receives delivery; this includes every manufacturing or processing step in between.

Since it is an average, cycle time for individual orders may vary. For each individual order, this cycle time starts with the order receipt and ends with customer acceptance of the order.

The order fulfillment cycle time is calculated as follows:

$$\text{Order Fulfillment Cycle Time} = \text{Order Fulfillment Process Time} + \text{Order Fulfillment Dwell Time}$$

Order fulfillment process time approximates order fulfillment lead time (the minimum amount of time to fulfill a customer order in the absence of inventory). Dwell time is the amount of time an order spends waiting to move from one stage of processing to another stage.

The formula for calculating average actual cycle time for a group of orders is the following:

$$\text{Average Actual Cycle Time} = \frac{\text{Sum of Actual Cycle Times for All Orders Delivered}}{\text{Total Number of Orders Delivered}}$$

Supply Chain Agility

Agility in the supply chain is its ability to respond to market changes and remain competitive. Agility is measured using three Level 1 metrics: upside supply chain adaptability, downside supply chain adaptability, and overall value at risk.

Upside Supply Chain Adaptability

The *Dictionary* defines **upside supply chain adaptability** as "a discrete measurement of the quantity of increased production a supply chain can achieve and sustain in 30 days-time." In other words, if unexpected orders come in with the requirement that they be filled within 30 days, what total amount of new product can the organization produce in that time?

The calculation of upside supply chain adaptability determines the largest sustainable quantity increase that can be achieved when considering source, make, and deliver components.

Downside Supply Chain Adaptability

The *Dictionary* defines **downside supply chain adaptability** as “a discrete measurement of the reduction in quantities ordered sustainable at 30 days prior to delivery with no inventory or cost penalties.” In other words, how much of a reduction in quantities can the company sustain given 30 days?

The calculation for downside supply chain adaptability determines the least reduction sustainable when considering source, make, deliver, and return components.

Overall Value at Risk (VaR)

Another Level 1 metric that measures supply chain agility is based on value at risk (VaR), which can be used in the supply chain to evaluate the different aspects of risk. Suppliers can be evaluated based upon the VaR of performance measures. Customers can be measured based upon performance measures (profitability, volume growth, returns, and complaints) as well as products (warranty claims, etc.). VaR can also be applied to internal supply chain entities such as manufacturing, distribution, or sales locations.

Each VaR calculation uses historical data for a specific event, such as on-time delivery, to calculate the number of times the event performed below target expectations times the amount below the target.

The *Dictionary* defines **overall value at risk (VaR)** as “the sum of the probability of risk events times the monetary impact of the events which can impact any core supply chain functions (e.g. Plan, Source, Make, Deliver and Return) or key dependencies.” The overall value at risk calculation is simply the sum of the supply chain’s VaRs (Plan + Source + Make + Deliver + Return).

Supply Chain Cost (Financial Metrics)

The financial metrics for a supply chain can be complex. The financial measures that the CFO of a large company focuses on may be different than those that are pivotal to supply chain managers. There are two metrics at Level 1 for measuring the costs of operating the supply chain: total supply chain management cost (TSCMC) and cost of goods sold (COGS).

Total Supply Chain Management Cost

The total supply chain management cost is calculated as the sum of the costs associated with the SCOR Level 2 processes to plan, source, deliver, and return. The official calculation for total supply chain management cost is to combine the Level 2 costs including mitigation.

TSCMC = Cost to Plan + Cost to Source + Cost to Make +
Cost to Deliver + Cost to Return + Mitigation Costs

As you can see in this formula, the SCOR framework also includes cost calculations for the cost to plan, the cost to source, the cost to make, the cost to deliver and/or install, the cost to return, and

mitigation cost. However, since these calculations are Level 2 calculations, a summary calculation that can be used for Level 1 TSCMC is:

TSCMC = Sales – Profits – Cost to Serve (e.g., marketing,selling,administrative)

Note that the cost to serve is the more difficult part of this second calculation, as a number of different expenses can be included. Though collecting these data is commonplace, assigning these expenses to the core processes of the organization and transforming them into calculated costs is a challenging task.

Cost of raw material and make costs are generally accounted for in cost of goods sold. It is recognized that there is likely to be overlap or redundancy between supply chain management costs and COGS. A similar concept, **total cost to serve**, includes the costs of the SCOR make process and is defined in the *Dictionary* as

> the sum of the supply chain cost to deliver products and services to customers. Includes the cost to plan the supply chain; source materials, products, goods, merchandize and services; produce, manufacture, remanufacture, refurbish, repair and maintain goods and services; manage orders, customer inquiries and returns; and deliver products and services at the agreed location (point of revenue). Comprises both direct cost and indirect cost.

Other costs to consider are direct material cost, direct labor cost, and indirect cost related to production.

Cost of Goods Sold (COGS)

The *Dictionary* defines **cost of goods sold (COGS)** as “an accounting classification useful for determining the amount of direct materials, direct labor, and allocated overhead associated with the products sold during a given period of time.” COGS is a financial accounting measurement of the cost associated with buying raw materials and producing finished goods. The cost of raw materials and the cost to make in the SCOR model are generally included in this calculation. The formula includes direct costs (labor, materials) and indirect costs (overhead). The calculation for COGS is

Cost of Goods Sold = Direct Material + Direct Labor + Overhead

SCOR states that direct material costs include the purchased materials cost at their purchase price net of any discounts. (Purchased materials cost may equal the landed cost if the price includes the cost to deliver, such as if a freight-and-duties-paid method of billing is used.) SCOR includes the following costs in direct labor: wages, income taxes at all levels, and employer contributions to health insurance, social security, and retirement plans. Overhead is not well defined globally, but SCOR's definition includes product automation costs (software and hardware acquisition, depreciation, and disposition, licensing fees, cost of maintenance contracts, and cost of internal maintenance and support); property, plant, and equipment cost (leases, rents, acquisition, depreciation, maintenance labor and parts, and

disposal); and governance, risk management, compliance, inventory, and other overhead costs (e.g., human resources, legal, quality, office supplies, and process improvements).

Supply Chain Asset Management

Metrics related to the supply chain's effective use of resources, including fixed and working capital, are the cash-to-cash cycle time, return on fixed assets, and return on working capital.

Cash-to-Cash Cycle Time

Cash-to-cash cycle time is defined as the time it takes for an investment to flow back into a company after it has been spent for raw materials. It is a continuous measure of how many days the organization's working capital is invested in managing the supply chain. The data needed to calculate cash-to-cash cycle time (average inventory, accounts receivable, and accounts payable) can be found on the balance sheet (statement of financial position). Cash-to-cash cycle time is calculated as follows:

$$\begin{aligned}\text{Cash-to-Cash Cycle Time} &= \text{Days' Sales Outstanding} \\ &+ \text{Inventory Days of Supply} \\ &- \text{Days' Payables Outstanding}\end{aligned}$$

Each of the items used in this calculation can be determined as follows:

$$\text{Days' Sales Outstanding} = \frac{\text{Receivables}}{\left(\frac{\text{Annualized Revenue}}{365}\right)} \text{ or } \frac{\text{Receivables}}{\text{Annualized Revenue}} \times 365$$

$$\text{Inventory Days of Supply} = \frac{\text{Inventory}}{\left(\frac{\text{Annualized Cost of Goods Sold}}{365}\right)} \text{ or } \frac{\text{Inventory}}{\text{Annualized Cost of Goods Sold}} \times 365$$

$$\text{Days' Payables Outstanding} = \frac{\text{Payables}}{\left(\frac{\text{Costs of Sales}}{365}\right)} \text{ or } \frac{\text{Payables}}{\text{Cost of Sales}} \times 365$$

The *Dictionary* has some relevant definitions:

> **Days' outstanding .** A term used to imply the amount of an asset or liability measured in days of sales. For example, accounts payable days are the typical number of days that a firm delays payments of invoices to its suppliers.
>
> **Days' sales outstanding .**A measure of the average number of days that a company takes to collect revenue after a sale has been made calculated by the total accounts receivable/average daily sales rate. [Also called accounts receivable days.]
>
> **Days of supply .** 1) Inventory-on-hand metric converted from units to how long the units will last. For example, if there are 2,000 units on hand and the company is using 200 per day, then there are 10 days of supply. 2) A financial measure of the value of all inventory in the supply chain/the average daily cost of goods sold rate.

Cash is tied up in the system by the difference between amounts owed to the organization and amounts still owed to others plus inventory. Reducing inventory will directly reduce the cash-to-cash cycle time, thus increasing cash flow.

For example, if a supply chain has 60 inventory days of supply, 40 days of sales outstanding, and 45 days of payables, its cash-to-cash cycle time is 55 days.

Cash-to-Cash Cycle Time	= Days' Sales Outstanding
	+ Inventory Days of Supply
	− Days' Payables Outstanding
55 Days	= 40 + 60 − 45

The three elements of the cash-to-cash cycle reflect the impact of supply chain management on the company's cash position. Negative indicators include high levels of inventory, high days of sales (receivables) outstanding (it's taking a long time to get paid), or low levels of payables (the company is not benefiting from keeping money invested as long as possible before making payments). If unnecessarily high inventory levels are the problem, the company can reduce the cycle time by improved forecasting and Just-in-Time (JIT) initiatives to reduce inventory (consistent with avoiding stockouts).

Cash-to-cash cycle time is considered to be an important indicator of a company's health. The faster the cycle, the healthier the company. A fast cycle indicates effective management of cash flow to maximize the use of the cash and to reduce working capital requirements.

However, what is considered a normal duration for the cash-to-cash cycle time will differ by supply chain, industry, and organizational strategy. Even within a given industry, one organization may have owned less of its inventory than another due to heavier use of strategies such as vendor-managed inventory (VMI) or consignment. VMI helps to lower the inventory in the pipeline by sharing information between the links in the supply chain. Consignment stock postpones the handoff of ownership. Similarly, an organization that is vertically integrated will own its inventory for much longer than one in a horizontal supply chain. Therefore, it is not necessarily possible to compare cycle times without understanding the relevant strategies for each business. An organization's cycle time can always be a benchmark for its own continuous improvement.

One advantage of using this metric is that it can be easily benchmarked to information found in public financial statements such as those of a competitor. Note that while cash-to-cash cycle time can be calculated using historical data, a preferred method for supply chain management is to base the inventory portion of the calculation on more current data such as dividing the current inventory level by average daily demand.

Return on Supply Chain Fixed Assets

The *APICS Dictionary,* 16th edition, defines **return on supply chain fixed assets** as "the return an organization receives on its invested capital in supply chain fixed assets. This includes the fixed assets used to Plan, Source, Make, Deliver and Return." Fixed assets include property, plant, and equipment. Return on supply chain fixed assets is calculated as follows:

$$\text{Return on Supply Chain Fixed Assets} = \frac{(\text{Supply Chain Revenue} - \text{COGS} - \text{Supply Chain Management Costs})}{\text{Supply Chain Fixed Assets}}$$

For example, if supply chain revenue is US$1,000,000, cost of goods sold is US$700,000, supply chain management costs are US$150,000, and supply chain fixed assets cost US$600,000, then the return on fixed assets is 25 percent.

$$25\% = \frac{(\text{US\$1,000,000} - \text{US\$700,000} - \text{US\$150,000})}{\text{US\$600,000}}$$

Return on Working Capital

Another metric used to measure supply chain asset management is return on working capital. The *Dictionary* defines **return on working capital** as “a measure of profit on the amount of cash consumed calculated as after-tax operating income/net working capital.”

Return on working capital assesses the magnitude of an investment relative to a company’s working capital position versus the revenue generated from a supply chain. Components include accounts receivable (A/R), accounts payable (A/P), inventory, supply chain revenue, cost of goods sold, and supply chain management costs.

The calculation for return on working capital is as follows:

$$\text{Return on Working Capital} = \frac{(\text{Supply Chain Revenue} - \text{COGS} - \text{Supply Chain Management Costs})}{(\text{Inventory} + \text{A/R} - \text{A/P})}$$

Digital Capabilities Model for Supply Networks

The Digital Capabilities Model for Supply Networks is a joint development of ASCM and Deloitte. It is designed to work with the SCOR Digital Standard to help organizations increase their supply chain maturity level to that of an orchestrated supply chain. This includes breaking down organizational silos more, reducing buffer inventories and safety stocks by providing end-to-end visibility, and better management of the bullwhip effect. The model defines capabilities as “the synergistic combination of people, processes, and technologies that creates sustained business value.” Here is a brief overview of each of the capabilities:

- **Connected customer.** This is about creating a seamless customer experience throughout the customer life cycle, which ranges from inspiration at the beginning of the model to service at the end of the model.
- **Product development.** This is about optimizing product life cycle management using proactive planning and emerging technologies.

- **Synchronized planning.** This is about making planning significantly more efficient by leveraging human and process capabilities like information sharing.
- **Intelligent supply.** This is about leveraging emerging technologies to reduce costs.
- **Smart operations.** This is about bringing operations into the digital transformation by increasing connectivity, agility, and proactivity.
- **Dynamic fulfillment.** This is about providing speed and agility to order fulfillment to increase customer service.

This model integrates well with the SCOR Digital Standard. SCOR's enable process links to all of these capabilities (and it is the only SCOR process that maps to connected customer and product development). Plan maps to synchronized planning, source maps to intelligent supply, make maps to smart operations, and both deliver and return map to dynamic fulfillment.

Rather than focusing on the linear relationships of a traditional supply chain, the capabilities in this model are presented as a network. This shows how the capabilities are interrelated and how a digitized supply chain no longer needs to be linear in every case but could use various enabling processes (including emerging technologies) to skip some processes or do them in a different order. For example, 3D printing can skip the source process or sensor-driven replenishment can directly feed data into the plan process.

Organizations should prioritize various capabilities as needed to fit their strategy or to address gaps. Like the SCOR Digital Standard, the Digital Capabilities Model contains more than one level. At the top level are the capabilities. At the second level, there are subsets of these capabilities that help clarify the top level capability and how to use the capability to differentiate the organization from less mature traditional supply chains. For example, connected customer has seven supporting capabilities: product as a service (PAAS), connected field services, self-service, customized experience, customer issue management, intelligent product tracking, and monitoring and insights.

Topic 2: Financial and Operational Metrics and Reports

Financial and operational metrics and reports are prepared by specialists in these areas, but supply chain managers need to have an understanding of them. Here we address cost accounting and financial statements as well as financial and operational metrics. Cost accounting addresses core production costs; financial statement analysis covers these and other organizational costs. Being able to interpret organizational accounting and financial reporting information can help supply chain managers develop an understanding of the current state of the organization's finances. It is also vital to sell the financial impact of improvements. Operational metrics address quality, productivity, and asset management.

Cost Accounting

According to the *APICS Dictionary,* 16th edition, **cost accounting** is

> the branch of accounting that is concerned with recording and reporting business operating costs. It includes the reporting of costs by departments, activities, and products.

A term related to cost accounting is management accounting. Cost accounting is used to calculate the costs that will be reported on the organization's external financial statements and to tax authorities; management accounting is used for internal management decision making and doesn't need to conform to external reporting or tax accounting rules. While cost accounting is backward- or historical-looking, management accounting is forward-looking (budgets and forecasts).

A basic understanding of how costs are managed internally by the organization can help supply chain managers determine a complementary cost structure for the supply chain. One common method of cost accounting is standard costing.

Standard Costing

According to the *Dictionary,* **standard costs** are

> the target costs of an operation, process, or product including direct material, direct labor, and overhead charges.

The *Dictionary* defines a **standard cost accounting system ,** or standard costing, as

> a cost accounting system that uses cost units determined before production for estimating the cost of an order or product. For management control purposes, the standards are compared to actual costs, and variances are computed.

Standards are targets that the organization sets to show the expected or desired outcome of an activity. These are periodically reviewed and changed as needed.

To understand standard costing, some additional terms from the *Dictionary* should also be reviewed or introduced.

> **Cost of goods sold (COGS) :** An accounting classification useful for determining the amount of direct materials, direct labor, and allocated overhead associated with the products sold during a given period of time.
>
> **Current price :** The price currently being paid as opposed to standard cost. (A related term is market price, which is the going price for an item on the open market.)
>
> **Usage variance :** Deviation of the actual consumption of materials as compared to the standard.

Cost variance : In cost accounting, the difference between what has been budgeted for an activity and what it actually costs.

Standards are set for each of the elements of the cost of goods sold. Each cost has two components that are set as standards: volume and rate.

Cost =	Volume	x Rate
Direct Materials Cost =	Quantity Purchased	x Unit Cost
Direct Materials Used =	Quantity Used	x Unit Cost
Direct Labor Cost =	Standard Hours	x Hourly Rate
Overhead Cost =	Cost Driver	$x \frac{\text{Total Overhead}}{\text{Total Cost Driver}}$

Volume is how many units of a resource are purchased or used, and rate is the cost per unit of that resource. When volume has variances from the standard, it is a usage variance; when the rate has variances, it is a cost variance. Both variances are tracked separately, and their sum should equal the total variance. Variances can be positive or negative. Negative variances occur when costs are greater than expected; positive variances occur when costs are less than expected.

Note that the quantity of materials for an operation has standards both for what should be purchased and what should be used, since these quantities may differ due to factors such as scrap in an operation or quantities for bulk discounts.

Note also that overhead costs are allocated based on a cost driver. A cost driver is simply a measurable aspect of an operation that is used to approximate how much of the overhead should be associated with the units produced. The rate is the total expected overhead for the period divided by the total of the expected cost driver for all operations at that site for the period. A frequently used cost driver is direct labor hours. For example, during a given period

- An operation to make 30,000 units is expected to use 1,500 direct labor hours.
- All operations in the plant are expected to use 15,000 direct labor hours.
- Total overhead costs for the plant are expected to be US$300,000.
- The overhead rate is US$300,000/15,000 hours = US$20/direct labor hour.
- The standard overhead cost for the 30,000-unit operation is 1,500 hours x US$20/hour = US$30,000 (one-tenth of the total overhead cost).

The following shows the variance calculation for actual results:

- Actual overhead cost for 30,000-unit order: 1,300 hours x US$21/hour (a rate determined only at the end of the period) = US$27,300.
- Variance: US$30,000 − US$27,300 = US$2,700 positive overall variance (less cost than expected), made up of a large positive variance from lower labor hours than expected and a smaller negative variance (higher cost than expected) from the higher actual overhead rate.

Standard costs and variances for direct materials and direct labor would be similarly calculated and accounted for, except that the actual costs may be known during or before production.

Standard costing is used to estimate the cost of goods sold before all costs are known with certainty. It also provides benchmark targets for use during production. Thus it is a method of controlling a process during production rather than only being applied by accounting after production is complete. When variances are detected as they occur, process controls can sometimes keep negative variances from continuing to expand or can prevent the problems from recurring in a later operation. Management and accounting should exercise a high level of control over variances, because this is the key to avoiding period-end surprises that impact financial results.

Note, however, that variances can occur simply because standard costs need to be revised. Depending on how quickly material, labor, and overhead prices are changing, organizations may need to revise their standard costs annually, quarterly, or even monthly.

Many of the concepts discussed in these modules make use of standard costing. Inventory can be valued using standard costing. (Although other methods also exist.)

If standard costing is used at an organization, efficiency can be calculated using a formula:

$$\text{Efficiency} = \frac{\text{Standard Hours of Work}}{\text{Hours Actually Worked}} \times 100\,\%$$

For example, a work center that produces 110 standard hours of work while operating for only 100 hours has an efficiency rate of 110 percent. This is where supply chain management comes into play. It is used to bring a synergy for all the entities in the supply chain and to enable them to operate and produce more efficiently, whether this means optimizing production, storage, or movement capacity.

The effectiveness and efficiency of supply chain management are partly measured by its contribution to the bottom line, and financial statement analysis can provide this information.

Analysis of Financial Statements

Financial statements help managers and investors track the financial results of an organization’s activities.

Whenever you are discussing supply chain financials, remember that each department in an organization has its own particular priorities based on its activities, and those priorities may compete with each other. For instance, the primary objective of marketing is to maintain and boost revenue, and it strives toward that by providing great customer service. Although the finance function is also interested in increasing revenues, its primary focus is on keeping costs and investment expenses low. Production wants the lowest operating costs it can achieve. Those conflicting viewpoints may spill over into how each function views financial documents and metrics.

Accounting Standards

Accounting standards are an important factor in creating financial statements. While supply chain managers do not need to know the details of these standards, a brief overview will help in understanding how doing business in multiple areas with conflicting accounting standards will increase costs due to multiple reporting requirements.

The majority of the world uses one set of financial accounting standards, the International Financial Reporting Standards (IFRS) developed by the International Accounting Standards Board (IASB). A few countries permit rather than require use of these standards, and a few others, including the U.S., use country-specific standards.

International Financial Reporting Standards

The *Dictionary* defines the **International Financial Reporting Standards (IFRS)** as follows:

> A common global language for business affairs so that company accounts are understandable and comparable across international boundaries. As a result of growing international shareholding and trade, they are rules to be followed by accountants to maintain books of accounts which [are] comparable, understandable, reliable, and relevant as per the users internal or external.

As of 2018, 144 of the 166 jurisdictions in the world (i.e., these are countries for the most part) had fully adopted IFRS for all or most of their domestic publicly accountable organizations, and others were in the process of doing so. Some countries require IFRS for financial institutions but not listed companies, and others (12 jurisdictions) permit rather than require it.

IFRS is a principles-based accounting system, meaning that it presents simple accounting and disclosure requirements and expects organizations to live up to the principle being set down rather than presenting more detailed rules. The argument in favor of principles-based accounting is that promulgating rules provides an incentive to find loopholes and exceptions and workarounds, while principles do not provide this incentive. The organization and regulators can assess whether the entity is operating within the spirit of the principle or not. However, ethics violations have occurred under IFRS.

IFRS and the U.S. system—U.S. GAAP—both allow businesses to organize as proprietorships, partnerships, and corporations, but the most advantageous business form may differ by country, not only due to differences in the country's required accounting rules but also to other country-specific legal and tax differences.

The IFRS financial statements include the following. Since IFRS financial statements are very similar to U.S. GAAP financial statements, naming differences are called out in parentheses.

- A statement of financial position at the end of the period. (This is similar to the balance sheet presented in Exhibit 2-39.)

- A statement of comprehensive income for the period. (This is similar to the income statement presented in Exhibit 2-40.)
- A statement of changes in equity for the period. (This is similar to a U.S. GAAP statement of retained earnings, which is not presented in these materials.) This statement breaks down changes in equity, including shares purchased, held, or sold.
- A statement of cash flows for the period. (This is similar to the statement of cash flows shown in Exhibit 2-41.)
- Notes and explanations of significant accounting policies and so on. (U.S. GAAP also requires notes such as these.)
- A revised statement of financial position as soon as possible if there have been significant changes in accounting policy. (U.S. GAAP has this same revision policy.)

IFRS statements report on assets and liabilities, equity, income (called revenue in U.S. GAAP), and expenses using simple principle-based definitions. (By contrast, U.S. GAAP uses rules-based definitions that are slightly more complex and legalistic.) Here are the IFRS definitions of the major financial statement components:

- **Assets.** A resource controlled by the entity as a result of past events and from which future economic benefits are expected to flow to the entity.
- **Liabilities.** A present obligation of the entity arising from past events, the settlement of which is expected to result in an outflow from the entity of resources embodying economic benefits.
- **Equity.** A residual interest in the assets of the entity after deducting all its liabilities.
- **Income.** Increases in economic benefits that result in increases in equity (other than those related to contributions from shareholders). Income includes both revenues (resulting from ordinary activities) and gains.
- **Expenses.** Decreases in economic benefits that result in decreases in equity (other than those related to distributions to shareholders). Expenses include losses that are not the result of ordinary activities.

Country-Specific Accounting Regulations

A number of countries, including the U.S., use country-specific accounting regulations.

As noted above, the U.S. generally accepted accounting principles (U.S. GAAP) use rules-based accounting, meaning that the standards for accounting are detailed and specific. The intent is to ensure that all of the details are addressed. However, a drawback to this system is that organizations can operate within the rules while still finding loopholes to exploit, which can mean that organizations might be less transparent than the rules intend. Like the IFRS system, rules-based accounting has had its share of accounting scandals.

While the broad strokes of IFRS and U.S. GAAP are very similar, there are numerous small differences in what is allowed and what is not allowed in accounting. For example, under U.S. GAAP a disaster at a

plant that is not expected to recur may be classified as an extraordinary item, which means that gains or losses from the event are not classified as part of normal operating revenue or expenses. Under IFRS all income and expense is considered ordinary; there is no such thing as an extraordinary item. The effect of significant unusual events would be handled as part of disclosures in the notes.

The U.S. GAAP financial statements (primarily the balance sheet, the income statement, and the statement of cash flows) are very similar to the IFRS financial statements. The statements have different but complementary functions.

Supply chain managers need to understand that doing business in multiple areas with conflicting global and country-specific accounting standards will increase administrative costs due to the need to use multiple reporting methods and comply with any related transparency and disclosure rules and regulations. However, these costs are decreasing. Most of the countries that do not use IFRS or only partially adopt it are working toward convergence of their standards with the international standards. In addition, the need to reconcile international standards with country-specific standards (i.e., produce two sets of statements) is lessening. For example, the U.S. no longer requires foreign companies that trade shares in the U.S. to reconcile their accounting with U.S. GAAP.

Next, we'll take a closer look at each of the U.S. GAAP financial statements, define some key terms, and discuss some key relationships among the elements of the statements.

Balance Sheet

The *APICS Dictionary,* 16th edition, defines the **balance sheet ,** or statement of financial position, as "a financial statement showing the resources owned, the debts owed, and the owners' share of a company at a given point in time." The balance sheet is often called a "snapshot" of the company's financial position, because it is a static view of financial value or net worth at a point in time, usually the last day of the fiscal or calendar year, though it could also be for the end of any reporting period, such as a month or quarter. It gets its name from the fact that it has two major sections that have to be in balance—assets on the one hand and liabilities and owners' equity on the other.

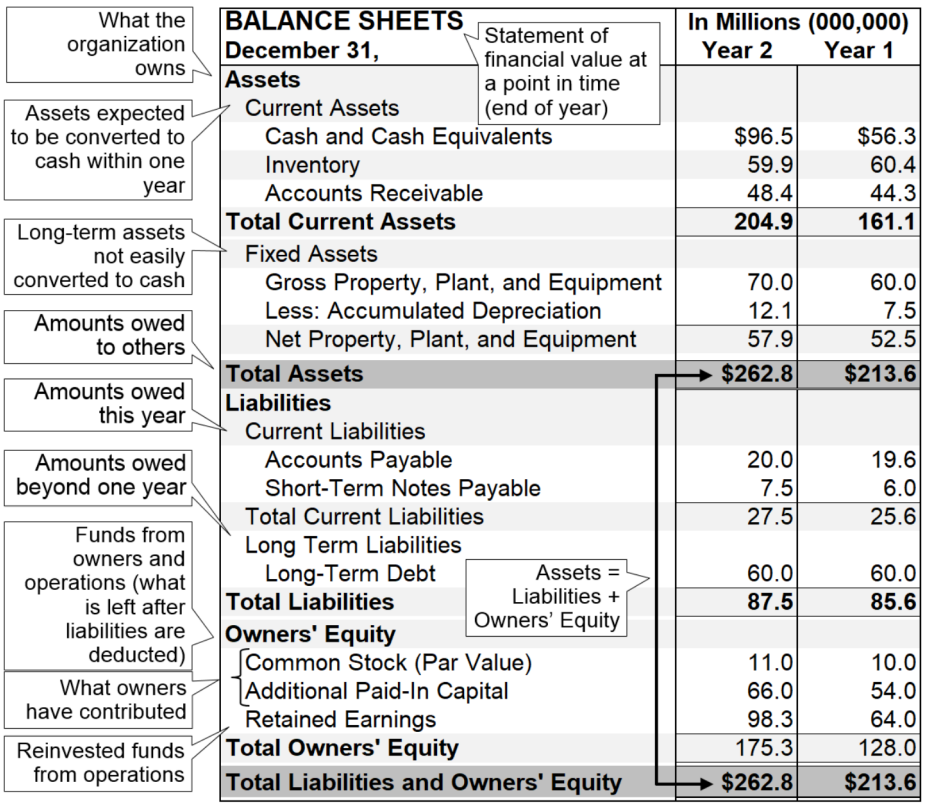
The accounting equation defines this balance; it states that

Assets = Liabilities + Owners' Equity

The balance sheet sections are always in balance because owners' equity is simply the difference between assets and liabilities. An organization uses investments from owners (e.g., shareholders) and amounts owed to others (e.g., bank debt) to acquire assets that are expected to generate a return greater than the amount invested. Owners' equity can increase or decrease if the organization generates a positive or negative return. The balance sheet shows the increases or decreases in assets, liabilities, and owners' equity from year to year.

Exhibit 2-39 shows a sample balance sheet for a publicly traded company.

Exhibit 2-39: Sample Balance Sheet Showing Two Years of Results



BALANCE SHEETS December 31,	In Millions (000,000) Year 2	 Year 1
Assets		
Current Assets		
Cash and Cash Equivalents	$96.5	$56.3
Inventory	59.9	60.4
Accounts Receivable	48.4	44.3
Total Current Assets	**204.9**	**161.1**
Fixed Assets		
Gross Property, Plant, and Equipment	70.0	60.0
Less: Accumulated Depreciation	12.1	7.5
Net Property, Plant, and Equipment	57.9	52.5
Total Assets	**$262.8**	**$213.6**
Liabilities		
Current Liabilities		
Accounts Payable	20.0	19.6
Short-Term Notes Payable	7.5	6.0
Total Current Liabilities	27.5	25.6
Long Term Liabilities		
Long-Term Debt	60.0	60.0
Total Liabilities	**87.5**	**85.6**
Owners' Equity		
Common Stock (Par Value)	11.0	10.0
Additional Paid-In Capital	66.0	54.0
Retained Earnings	98.3	64.0
Total Owners' Equity	175.3	128.0
Total Liabilities and Owners' Equity	**$262.8**	**$213.6**

One purpose of the balance sheet is to show whether the organization has increased or decreased its owners' equity during the year. This is done by comparing the current year's amounts to the amounts in prior years. Note that in Exhibit 2-39, the size of the owners' equity has increased in Year 2 from Year 1, based primarily on profits that were reinvested (retained earnings) and to a lesser degree on new owner investments (common stock and additional paid-in capital).

The value of inventory as presented on the balance sheet may not match the value of inventory used by supply chain managers for internal control purposes. This is because there are a number of ways accounting rules may allow for inventory to be presented for purposes of external financial reporting. The *Dictionary* defines **inventory valuation** as

> the value of the inventory at either its cost or its market value. Because inventory value can change with time, some recognition is taken of the age distribution of inventory. Therefore, the cost value of inventory is usually computed on a FIFO basis, LIFO basis, or a standard cost basis to establish the cost of goods sold

FIFO stands for first in, first out, while LIFO stands for last in, first out, and each refer to whether the oldest inventory purchased is considered to be sold first when a sale is made or whether the newest inventory is sold first. Another method for inventory valuation is average costing, where the costs for all items are summed and averaged.

Once an inventory valuation method is chosen, the organization should keep it the same for a number of years so that stakeholders can compare the results of different time periods. The accounting method chosen may have nothing to do with actual inventory movement policy.

Note that IFRS bans the use of LIFO.

Inventory on the balance sheet and property on the income statement can be impacted by obsolescence. According to the *Dictionary,* **obsolescence** is

> 1) The condition of being out of date. A loss of value occasioned by new developments that place the older property at a competitive disadvantage. A factor in depreciation. 2) A decrease in the value of an asset brought about by the development of new and more economical methods, processes, or machinery. 3) The loss of usefulness or worth of a product or facility as a result of the appearance of better or more economical products, methods, or facilities.

When inventory is obsolete, it must be sold at a discount or written off and removed from the financial statements. As plants and equipment become obsolete over time, they are depreciated, as will be discussed below.

The balance sheet can also be used as a source for a number of financial measurements used in part to measure the success of supply chain activities. For example, the balance sheet lists accounts receivable and accounts payable. According to the *Dictionary,* **accounts receivable** are

> the value of goods shipped or services rendered to a customer on which payment has not yet been received. Usually includes an allowance for bad debts.

Accounts payable are “the value of goods and services acquired for which payment has not yet been made.”

These two balance sheet amounts are used to calculate the cash-to-cash cycle time, which measures how many days the organization’s working capital is invested in managing the supply chain. **Net working capital** is “the current assets of a firm minus its current liabilities.” Working capital is important to the supply chain because these are the funds the organization has readily available to invest in normal operations.

Income Statement

The *APICS Dictionary,* 16th edition, defines the **income statement ,** or statement of comprehensive income under IFRS terminology, as “a financial statement showing the net income for a business over a given period of time.”

In contrast to the balance sheet, the income statement is cumulative and dynamic, meaning that the statement covers business results over a period of time, such as a quarter or a year, rather than being a static snapshot. The income statement shows managers, investors, and creditors whether the company has made or lost money during the given period of time.

The basic equation for the income statement is:

$$\text{Income} = \text{Revenues} - \text{Expenses}$$

Here are key terms to be familiar with, all of which can be impacted by the effectiveness and efficiency of a supply chain:

- Profit is money remaining from revenues after deduction of certain expenses.
- The **profit margin ,** which measures the degree of financial success for a business, is “the difference between the sales and cost of goods sold…sometimes expressed as a percentage of sales” (*Dictionary*).
- The **gross margin** measures “the difference between total revenue and the cost of goods sold” (*Dictionary*). It is also called the gross profit margin.
- Net profit is figured by deducting all expenses, not only the cost of goods sold, from revenues.

Exhibit 2-40 shows a sample income statement, with some explanations in the margin.

Exhibit 2-40: Sample Income Statement Showing Two Years of Results

Expenses from providing goods/services that generate revenue

Revenue – COGS = Gross Profit

General expenses from running business that cannot be directly linked to specific units of goods/ services sold

Lowers fixed asset value for taxes

Payments on debt

Shows effect of taxes on profits

Gross Profit – Operating Expenses – Depreciation – Interest Exp. – Income Taxes = Net Income

INCOME STATEMENTS (Profit or loss over a period of time) **For the Years Ending**	**(000,000s) except per share amts.** **Year 2**	**Year 1**
Revenue (Sales)	**$302.6**	**$276.9**
Direct Labor	38.3	37.6
Direct Materials	101.5	99.7
Factory Overhead	26.6	26.1
Less: Cost of Goods Sold (COGS)	166.4	163.4
Gross Profit	**136.2**	**113.5**
Less: Operating Expenses		
Selling Expenses	30.3	24.9
General and Administrative	27.2	22.2
Lease Expense	12.1	8.3
Less: Total Operating Expenses	69.6	55.4
Less: Depreciation	4.6	4.0
Less: Interest Expense	3.9	3.9
Net Income (Profit) Before Taxes	**58.1**	**50.3**
Less: Income Taxes	16.3	14.1
Net Income (Profit) (The “bottom line”)	**$41.8**	**$36.2**
Net Income (as a Pct. of Revenue)	14%	13%
Net Income Per Share-Basic	**$3.95**	**$3.78**

Supply chain managers can use an income statement to determine the effect of supply chain expenses on net income. For example, for a manufacturing organization, the direct materials expenses listed in the statement would consist primarily of raw material expenses, so reducing this type of inventory would reduce overall expenses, directly increase profits, and likely increase owners’ equity on the balance sheet.

Note that operating expenses such as sales bonuses or general and administrative expenses (all costs that cannot be linked to specific units sold) are called period costs because they must be expensed in the period in which they are incurred. COGS are called product costs. Product costs are accounted for in the period in which the units are sold even though many of these costs may be incurred in earlier periods.

A final concept of importance to the income statement is matching. Matching refers to reporting related revenues and expenses together in the period in which they were incurred. For example, sales

expenses incurred to make a sale should fall in the period in which the sale was made. When they do not, accountants use adjustments called accruals to account for the period differences.

Note the text “The ‘bottom line’ ” near the bottom in the exhibit. This refers to the line at the bottom of the income statement that shows a net profit or loss. Note also that the economic perspective of the triple bottom line is a reference to this financial bottom line.

Statement of Cash Flows

The *APICS Dictionary,* 16th edition, defines the **statement of cash flows** (funds flow statement) as “a financial statement showing the flow of cash and its timing into and out of an organization or project.” The statement of cash flows shows the sources of a company’s cash flows and how these cash flows are used over a given period of time. Within a cash flow statement, there are three sections of cash flows: operating, investing, and financing.

According to the *Dictionary,* **cash flow** is

> The net flow of dollars into or out of the proposed project [organization]. [It is] the algebraic sum, in any time period, of all cash receipts, expenses, and investments.

There are three factors that determine cash flows: sales, after-tax operating profit margins, and capital requirements. Some organizations consider cash flow to be a better long-term indicator of financial health than net income.

The purpose of a statement of cash flows is to show lenders, investors, and creditors whether the organization has sufficient cash to pay debts, bills, and dividends to owners, because cash, not net income, is needed to make these payments.

The after-tax net income on the income statement is not the same as cash flow, but it is the starting point for the statement of cash flows (under the most popular method for preparation, the indirect method). The statement adjusts this amount by increases or decreases in certain accounts to show whether the cash balance has increased or decreased in the period.

Being able to read and understand a cash flow statement is important:

- In order to keep the cash flow turning over, the supply chain professional must efficiently manage the company’s inventory level and cost while maintaining and improving customer satisfaction.
- The cash flow statement shows if the company is generating enough cash to fulfill its minimum obligations to lenders, investors, and governments (taxes).
- Generating extra cash can be used to repay debt, purchase additional assets for growth, or invest in new products.

This information is particularly helpful for financial managers, who use it along with a cash budget when forecasting their organization’s cash positions.

Exhibit 2-41 shows a sample statement of cash flows using the indirect method.

Exhibit 2-41: Sample Statement of Cash Flows Showing Two Years of Results

A viable firm needs positive cash flow from operations in most years.

Depreciation is deducted on the income statement but doesn't reduce cash (added back).

Increase in inventory or accounts receivable reduces cash.

Increase in accounts payable increases cash.

Increase in business investments decreases cash.

Increase in new debt or equity provides cash.

Net Income
+/– Change in (Δ) Operating
+/– Δ Investing
+/– Δ Financing
+ Beginning Cash
= Ending Cash

CASH FLOW STATEMENTS	In Millions (000,000)	
Year (Change in cash balance over a period of time)	Year 2	Year 1
Operating Section		
After-Tax Net Income	$41.8	$36.2
Depreciation Add-Back	4.6	4.0
(Increase)/Decrease in Inventory	0.5	(8.6)
(Increase)/Decrease in Accounts Receivable	(4.1)	(4.1)
Increase/(Decrease) in Accounts Payable	0.4	1.8
Cash Flow from Operations	**43.2**	**29.3**
Investing Section		
Capex Spend (Capital Expenditures)	(10.0)	(10.0)
Cash Flow from Operations and Investment	**33.2**	**19.3**
Financing Section		
Additional Equity Capital	13.0	7.0
Less Dividends Paid	(7.5)	(5.0)
Increase/(Decrease) in Long-Term Debt	-	-
Increase/(Decrease) in Short-Term Notes	1.5	(1.5)
Cash Flow from Operations, Investments, and Financing	**40.2**	**19.8**
Beginning Cash Balance	56.3	36.5
Ending Cash Balance	**$96.5**	**$56.3**

Note the depreciation amount that is added back on the statement of cash flows. Depreciation is a predetermined incremental reduction in the value of fixed assets, such as property, plant, and equipment, on the income statement to account for their deterioration over time. This provides organizations with a tax benefit to offset the investment in fixed assets. However, while depreciation is calculated and expensed on the income statement as the cost of using an asset over its life, this cost is a noncash charge (i.e., no one is paid). Since depreciation reduces net income on the income statement but doesn't reduce actual cash levels, depreciation is added back on the statement of cash flows to determine the actual cash flow.

Financial Metrics

Financial metrics are often assembled by finance professionals, but supply chain managers need to know how to interpret these metrics. Financial metrics for the supply chain include profit, cost, supply chain cost, the speed of converting orders to into cash, supplier bankruptcy risk, and customer credit.

Profit Metrics

Supply chain management cost reduction and efficiency efforts are a powerful lever that can improve organizational profitability with more impact even than increasing sales. (Sales also increase the cost of goods sold and other variable costs, while cost reductions directly increase profits.) Therefore many supply chain functions measure and report on their contributions to profitability. This can be broken down into segments for further analysis, such as customer segment profitability or direct product profitability. Furthermore, individual product families or products can be assessed for their profitability

using contribution margin analysis (sales minus variable costs) to show how well the product contributes to profit.

Cost Metrics

There are a number of ways to measure the cost of an organization's supply chain function. Cost areas include order processing, inventory, transportation, warehousing and materials handling, and facility network integration. Here are some ways of breaking down the organization's costs:

- Total landed cost (or total cost)
- Cost per major supply chain function (e.g., order processing)
- Cost per detailed supply chain function (e.g., order picking, loading)
- Cost per unit
- Cost as a percentage of net sales
- Inbound freight cost
- Warehouse order processing cost
- Inventory carrying cost
- Administrative costs
- Direct labor costs
- Outbound freight cost
- Damage cost
- Return cost
- Service failure cost
- Backorder cost

In addition to cost breakdowns, supply chain managers can analyze cost trends and variances from budget. Trends analyze changes in cost over time and can be graphed to make a trend easier to project forward. Variances require some form of baseline or budget against which operational data can be compared. Variances can be in a favorable or unfavorable direction, so the direction and magnitude of the variances are tracked. Often organizations set a threshold for variances to indicate what level of minor variances are acceptable but beyond which a variance will require exception handling.

Total costs for all of an organization's supply chain functions may be challenging to collect, as this may involve multiple subsidiaries and business units as well as multiple information systems. Nevertheless, it is important to put the work in to achieve this level of data gathering so that analysis captures the big picture.

In some cases cost metrics may be best served by also measuring number of orders, volume, or weight in addition to cost. This will help explain why certain activities consume more expense than others so that management control can be fine-tuned.

Multiple-Organization Metrics

Multi-organization metrics include supply chain total cost, which is an aggregation of the costs of all organizations that participate in a given supply chain. Supply chain total cost is illustrated in .

Exhibit 2-42: Supply Chain Total Cost

The purpose of developing methods of assessing the costs from end to end is to combat suboptimization. The *APICS Dictionary,* 16th edition, defines **suboptimization** in part as "a solution to a problem that is best from a narrow point of view but not from a higher or overall company point of view," or in this case, not from an entire supply chain point of view. When one company attempts to shift costs to another supply chain participant, it is only a good move when the total supply chain cost is lower. If the total supply chain cost is higher, it ultimately means a higher price to the final end user, which reduces demand and provides more room for competitors to offer lower prices. The idea is to share the benefits of cost reductions fairly so that everyone benefits.

Many of the metrics discussed in these materials can be used with data collected and aggregated from multiple supply chain partners. However, it is difficult enough to collect data for some of these metrics from just within one's own organization. It is considerably more difficult to gather data from multiple organizations. In many cases the data will not be made available. For example, data on costs may be considered secret. One way to improve data collection for the entire supply chain is to use a third party to collect all of the data. This third party can collect the data that are available, extrapolate other data, and then provide objective reports on the performance of the supply chain.

Some additional ways to measure the entire supply chain follow:

- Measure total supply chain cost and total supply chain quality together to get a sense of value being delivered.
- Measure inventory days of supply. This is the total amount of inventory anywhere in the supply chain. It is used to show how shifting inventory to other parts of the supply chain just becomes a hidden cost. This can be extended to include raw material supplies.
- Measure dwell time. This is a measure of all inventory idle time in all parts of the supply chain. Idle inventory is nonproductive inventory for the most part, and shifting dwell time elsewhere is still a cost to all.
- Use fill rate and order-to-receipt response time (both are defined elsewhere) to measure overall delivery effectiveness.
- Measure on-shelf-in-stock percentage in addition to fill rates. Fill rates measure replenishment at warehouses and retail locations but do not provide assurance that goods are on the shelves at retail

stores when the customer wants to buy them. Therefore, also measuring the percentage of time goods are on the shelves is important for determining overall customer satisfaction.

In addition, it is a good idea to assess how much formal collaboration and information sharing is going on in your supply chain versus how much work remains to be done.

Assessing Supplier Health Using Financial Statement Ratios

The financial statements of publicly owned suppliers will be available for review. (Privately owned organizations are not required to publish financial statements, so the following techniques cannot be used unless such organizations voluntarily make the information available.) Information from financial statements can be used to develop financial ratios, which are basically one value divided by another to provide a one-number assessment of some part of the organization's relative financial status. Your organization's financial professionals can create a set of ratios for each publicly owned supplier in your supply chain (or private supplier who voluntarily publishes this data). You may need to interpret these ratios, at least in so far as to see when these ratios are improving or getting worse.

There are four major groups of ratios that can be of use in determining an organization's financial health:

- **Liquidity ratios.** Liquidity ratios measure how quickly certain assets can be converted into cash or how easily the organization can meet its short-term financial obligations. These ratios should be increasing or remaining steady if already high enough.

  Example: Quick Ratio = (Current Assets − Inventories)/Current Liabilities

- **Activity ratios.** Activity ratios measure effective use of assets. This can be total assets, current assets (excludes long-term assets), or inventory.

  These are called turnover ratios when they use sales divided by the type of asset. Turnover ratios should in general be increasing.

  Example: Inventory Turnover = Sales/Average Inventory

If there was $100 in sales and $50 in inventory, then the ratio would be 2.0, and this would mean that inventory turned over twice in a year.

Inventory days' outstanding is another example.

Example: Inventory Days' Outstanding = 365/Inventory Turnover

This ratio counts how many days it takes to sell off all the inventory (e.g., 365/2 = 182.5 days,) and this type of ratio ideally should be decreasing.

- **Leverage ratios.** Leverage ratios measure how much debt is being used to finance the business and thus help to project whether it is likely to meet its debt payments. Various types of debt divided by equity are better when they are lower, from a supplier solvency point of view.

    Example: Current Debt to Equity = Current Liabilities/Equity

  However, the interest coverage ratio should be higher. (This is how well the organization's earnings can cover its interest payments.)

- **Profitability ratios.** Profitability ratios measure various types of return on investment. All of these ratios are better when they are higher.

    Example: Net Profit Margin = Net Profit/Net Sales

    A 10 percent margin would mean that for every dollar earned, you get ten cents of profit.

Financial analysts can also look at the supplier's financial market values or growth over time to see if they are getting more valuable or growing or the opposite.

Obtaining financial statements in many parts of the world is very easy and straightforward. (They are typically available online.) Financial statements in some parts of the world may not be sufficiently regulated to be considered completely reliable. Another complication for suppliers that are owned by large holding companies is that splitting off the financial information for just one subsidiary may require significant effort. Alternate or supplemental sources of financial information may be needed.

Bankruptcy Risk Metric: Altman Z-Score

The Altman Z-score, or Z-score for short, is a combination of four or five weighted ratios developed by Dr. Edward Altman to measure bankruptcy risk. The resulting one-number score has a 90 percent accuracy in predicting bankruptcy one year into the future and 75 percent accuracy for two years out. Tracking this score on a quarterly basis can provide relatively current information on each supplier's bankruptcy risk or financial stability.

Organizations are rated using a red/yellow/green system. Suppliers with a score below the red threshold might not be selected or could be candidates for replacement. Suppliers in the yellow zone might be watched closely or given assistance. Suppliers above the green threshold are stable.

There are different Z-score formulas for public and private organizations. Public organizations use the following five-ratio formula:

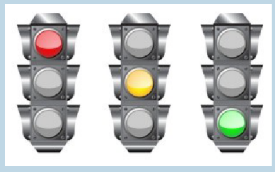
$$\text{Z-Score (Public)} = \left(1.2 \times \frac{\text{Working Capital}}{\text{Total Assets}}\right) + \left(1.4 \times \frac{\text{Retained Earnings}}{\text{Total Assets}}\right)$$
$$+\left(3.3 \times \frac{\text{Earnings Before Interest and Taxes}}{\text{Total Assets}}\right) + \left(0.6 \times \frac{\text{Net Worth}}{\text{Total Liability}}\right) + \left(1.0 \times \frac{\text{Net Sales}}{\text{Total Assets}}\right)$$

Private organizations use the following four-ratio formula:

$$\text{Z-Score (Private)} = \left(6.56 \times \frac{\text{Working Capital}}{\text{Total Assets}}\right) + \left(3.36 \times \frac{\text{Retained Earnings}}{\text{Total Assets}}\right)$$
$$+\left(6.72 \times \frac{\text{Earnings Before Interest and Taxes}}{\text{Total Assets}}\right) + \left(1.05 \times \frac{\text{Net Worth}}{\text{Total Liability}}\right)$$

While you will not likely need to calculate this ratio yourself, take a look at what makes it up and note that the first four ratios are the same for both variants. Note also how the weightings (the hard numbers to multiply against each ratio) differ depending on whether it is a public or private organization. The higher the weighting, the more importance it has as a bankruptcy predictor. shows the relevant information for the supply chain manager: the cutoff scores for the red, yellow, and green categories. Note that these cutoff scores come from Schlegel and Trent in *Supply Chain Risk Management: An Emerging Discipline* and that other resources may use slightly different cutoff scores.

Exhibit 2-43: Z-Score Cutoff Points

	**Public Organization**	**Private Organization**
Red (supplier is at bankruptcy risk)	Less than 1.8	Less than 1.1
Yellow (monitor supplier carefully)	1.8 – 3.0	1.1 – 2.6
Green (supplier is fiscally sound)	Greater than 3.0	Greater than 2.6

Customer Creditworthiness

The basic goal of monitoring customer creditworthiness is to ensure that invoices are paid on time (or at all). Customers who do not have a sufficiently high credit score might be denied trade credit (e.g., payment within 30 days or some other terms) and be asked to submit a wire transfer or other form of cash in advance. In addition to maintaining internal records, an organization's credit department might use third-party credit ratings for organizational customers. For example, Dun & Bradstreet produces ratings of organizational creditworthiness, including recommended credit limits. Another example is the Coface Group's Debtor Risk Assessment (DRA) score, which is a score from one to ten that is based on organizational history, ability to pay, and market factors.

Strategic Profit Model (Return on Assets Breakdown)

One way to measure return on investment is to measure return on assets (ROA). ROA equals net profit margin multiplied by asset turnover. This is a ratio that shows how much in profits the organization's assets generate. It is a good measure of profitability for supply chain managers, because they are responsible for managing a number of the assets that are counted in this metric as well as the expenses that make up the cost of goods sold. One way to break return on assets down into its components is the strategic profit model, which is shown in Exhibit 2-44 along with some sample data.

Exhibit 2-44: Strategic Profit Model with Sample Data

Key:		= Input cell				
		= Calculated				
Return on Assets	= Net Profit Margin		x Asset Turnover		=	0.143
Net Profit Margin	= Net Profit / Net Sales	=	0.060			
Asset Turnover	= Net Sales / Total Assets	=	2.38			
Net Profit	= Gross Profit		– Total Expenses			
USD 60	USD 200		USD 140			
Gross Profit	= Net Sales		– Cost of Goods Sold			
	USD 1,000		USD 800			
Total Expenses	= Variable Expenses		+ Fixed Expenses			
	USD 80		USD 60			
Total Assets	= Current Assets		+ Fixed Assets			
USD 420	USD 280		USD 140			
Current Assets	= Inventory		+ Accounts Receivable		+	Other Current Assets
	USD 180		USD 40			USD 60

Moving from top to bottom, the exhibit shows first how to calculate ROA (0.143 or 14.3 percent in the example), then how to calculate these two base ratios, and then how to calculate some of the inputs. (Others are simply entered into the spreadsheet as input data.) Net profit margin is net profit divided by net sales, while asset turnover is net sales divided by total assets. Of these, net profit and total assets are broken down further. Net profit is gross profit less total expenses, while total assets is current assets plus fixed assets. Gross profit, total expenses, and current assets are also calculated using the inputs shown.

The benefit of looking at ROA in this way is that it shows there are multiple ways to increase ROA. Supply chain managers can see the areas where they can have influence. They can reduce inventory but will also see how ROA could drop if lack of inventory starts to hurt net sales. They might also reduce the cost of goods sold but again only to the point where net sales don’t cause ROA to fall (e.g., due to quality issues). Supply chain managers can also use this model to work with managers in other areas, such as helping sales managers expand from a view of just increasing sales volume to a holistic view of maximizing ROA.

When the model is put into a spreadsheet, as in the exhibit, the additions and subtractions and divisions can be automated so that various scenarios can be explored. This might include reducing inventory, increasing sales, or reducing the cost of goods sold. However, these values usually affect one another. For example, reducing inventory would also reduce the inventory carrying cost, so this would reduce variable expenses by a certain amount. As stated before, it could also reduce net sales. These complexities could also be included in the model or calculated in a different way. Using the sample data in the prior exhibit, Exhibit 2-45 assumes that inventory is reduced by US$40 and that, since there is an inventory carrying cost of 25 percent, there is also a reduction in variable costs of US$10 (0.25 × US$40 = US$10). However, there is a reduction in sales of 1 percent (or US$10).

Exhibit 2-45: Strategic Profit Model with Reduction in Inventory, Carrying Cost, and Net Sales

Key:		= Input cell				
		= Calculated				
Return on Assets	= Net Profit Margin	x	Asset Turnover	=	0.158	
Net Profit Margin	= Net Profit / Net Sales	=	0.061			
Asset Turnover	= Net Sales / Total Assets	=	2.61			
Net Profit	= Gross Profit	–	Total Expenses			
USD 60	USD 190		USD 130			
Gross Profit	= Net Sales	–	Cost of Goods Sold			
	USD 990		USD 800			
Total Expenses	= Variable Expenses	+	Fixed Expenses			
	USD 70		USD 60			
Total Assets	= Current Assets	+	Fixed Assets			
USD 380	USD 240		USD 140			
Current Assets	= Inventory	+	Accounts Receivable	+	Other Current Assets	
	USD 140		USD 40		USD 60	

In this scenario, the ROA increases from 14.3 to 15.8 percent, even with the reduction in net sales. However, without that reduction, the ROA would have jumped to 18.4 percent. Conversely, a reduction in sales of about 1.59 percent or more (given this data) would result in a net reduction in ROA. In such a case, the inventory reduction would have destroyed more value than it created. Analyses such as these can play out hypothetical scenarios or be used to study the impact of actual decisions after the results have come in.

Operational Metrics and Reports

Operational metrics measure how well day-to-day operations are functioning. These metrics are important for management monitoring and control. Categories of operational metrics include quality, productivity, and asset management.

Quality Metrics

Quality is an operational metric because it relates to accuracy, manufacturing goods to quality standards, avoidance of damage to goods at various stages, and so on. Some examples of quality metrics for the supply chain follow:

- Order entry accuracy
- Information availability (e.g., manufacturing status, customer order tracking)
- Information accuracy
- Number of manufacturing defects found by quality control (in total, per million units)
- Number of manufacturing defects found by customers (in total, per million units)
- Picking and shipping accuracy
- Damage frequency in total or by functional area (e.g., warehouse, loading, transportation)
- Document and invoicing accuracy

- Number of returns and warranty issues
- Number of credit claims

Accuracy metrics are reported as the number of times the activity was done correctly in relation to the total number of times it was done. Damage frequency by functional area can be hard to tabulate since the damage is often not reported until it reaches the customer.

Supplier Quality Costs: Supplier Performance Index

When a supplier has quality issues, these costs can be added to the cost of the materials purchased from the supplier to find the true cost of doing business with them. The supplier performance index is one metric that adds these costs together so that suppliers can be compared on a basis other than price. The formula for the supplier performance index is

$$\text{Supplier Performance Index} = \frac{\text{Material Cost} + \text{Nonconformance Cost}}{\text{Material Cost}}$$

Nonconformance includes rejected materials as well as delays and failures to provide accurate or complete information. Therefore, the organization could assign their costs of tracking down missing paperwork, the costs of late deliveries, and so on. An index value of 1.05 would mean that prices were actually 5 percent higher than stated when all of the problems are factored in. The way to compare suppliers using this index is to multiply the index value times the price per unit to find an adjusted price per unit for each supplier. However, it is best to compare like amounts of the same items when comparing suppliers so as to focus just on price and quality. Note that suppliers providing very different total material costs will have different index values. (Lower total costs increase the index value.)

Productivity Metrics

The *APICS Dictionary,* 16th edition, defines **productivity** in part as

> an overall measure of the ability to produce a good or a service. It is the actual output of production compared to the actual input of resources.

When measuring productivity, the key is to see whether resource inputs are being used as efficiently and effectively as possible by looking at the outputs. When inputs and outputs are measured precisely and routinely, these metrics can be automatically generated. Some examples of productivity metrics for the supply chain are

- Labor productivity in total and by area (e.g., order entry, manufacturing, warehousing, transportation)
- Units shipped per employee
- Units shipped per labor dollar
- Orders per salesperson
- Equipment downtime.

Productivity can measure variances from schedule and budget as well as variances from goals and stretch goals. Productivity can also be compared against historical or competitor benchmarks.

Since labor expenses take up a major portion of an organization's expenses, labor productivity metrics are critical to track by total expense, expense by area, by labor hours used, and by number of employees. Analysis by multiple factors can help show where productivity issues exist and where improvements goals can be set.

Asset Management Metrics

Asset management metrics measure how well the organization is employing its substantial investment in operational assets. Inventory is an operational asset of primary concern to supply chain managers, and most asset management metrics have something to do with inventory, but equipment and facility capacity are also of concern. Here are some common asset management metrics:

- Inventory turnover
- Inventory days of supply
- Absolute inventory levels
- Obsolete inventory
- Inventory by activity-based costing (ABC) or other type of inventory classification
- Equipment capacity utilization (e.g., downtime for manufacturing equipment, materials-handling equipment, or vehicles)
- Manufacturing capacity utilization
- Warehouse capacity utilization

In addition, some financial measurements can be used in asset management, such as return on equity. Inventory turnover is discussed more next, followed by a discussion of cash-to-cash cycle time, which is a financial metric but is discussed here to compare it to inventory turnover. Supplier capacity metrics are also addressed.

Inventory Turnover

The *Dictionary* defines **inventory turnover** (also called inventory turns) as follows:

> The number of times that an inventory cycles, or "turns over," during the year. A frequently used method to compute inventory turnover is to divide the annual cost of sales by the average inventory level. For example, an annual cost of sales of $21 million divided by an average inventory of $3 million means that inventory turned over seven times.

Higher inventory turnover ratios are preferred and can result from increasing sales and/or decreasing average inventory. Increasing this ratio means that there is lower investment in inventory relative to sales volume, lower risk of obsolescence, and greater liquidity. A related term is **inventory velocity ,**

which is “the speed with which inventory passes through an organization or supply chain at a given point in time as measured by inventory turnover” (*Dictionary*).

Inventory turnover is important because of the profit margin built into each product. Sales of manufactured products convert inventory and its associated costs into revenue. The profit margins directly add to cash (an asset) and increase owners’ equity on the balance sheet. Therefore, a major objective of supply chain management is to increase the speed at which inventory can be converted to cash.

The appropriate level of this ratio depends on the organization’s industry. For example, in a French bakery, the turnover of baguettes is close to 365 times per year. Organizations in the slow-moving spare parts service industry average turnover of less than one to four times per year. Most manufacturing plants experience turnover of between six and 26 times per year. It may be a useful question to ask yourself, “What is the turnover at my organization, and why?” Benchmarking inventory turnover against competitors or even internal targets can help establish the best target values for a given organization or supply chain.

A generic inventory turnover ratio is:

$$\text{Inventory Turnover} = \frac{\text{Sales}}{\text{Average Inventory}}$$

Inventory turnover can be calculated using **average inventory ,** which the *Dictionary* defines as

> one-half the average lot size plus the safety stock, when demand and lot sizes are expected to be relatively uniform over time. The average can be calculated as an average of several inventory observations taken over several historical time periods; for example, 12-month ending inventories may be averaged. When demand and lot sizes are not uniform, the stock level versus time can be graphed to determine the average.

Average inventory can be calculated from the balance sheet if two or more years are shown, since the inventory at the beginning of the year is the same as that at the end of the prior year. Here is one way to calculate average inventory (listed in thousands):

$$\begin{aligned}\text{Average Inventory} &= \frac{\text{Inventory at Period Start} + \text{Inventory at Period End}}{2} \\ &= \frac{\$621{,}000 + \$678{,}000}{2} \\ &= \$649{,}500\end{aligned}$$

Using more than two points in a year or other time period for an average inventory calculation may be even better, because it can remove the effects of seasonality.

Different types of organizations may use variants on inventory turnover. A retail organization might use the following ratio:

$$\text{Inventory Turnover (Retail)} = \frac{\text{Sales}}{\text{Average Inventory at Selling Price}}$$

Retailers favor measuring inventory value at selling price because it is the most accurate valuation for them.

Manufacturers often use the following formula for inventory turnover:

$$\text{Inventory Turnover (Manufacturing)} = \frac{\text{Cost of Goods Sold}}{\text{Average Inventory at Cost}}$$

Manufacturers use the cost of goods sold (COGS) because they produce the inventory using the materials and labor that make up COGS. They value inventory at cost for the same reasons. Annual cost of goods sold is listed on the income statement. Note that the definition of inventory turnover calls this cost of sales, but this is a synonym for COGS. The calculation for inventory turnover follows (using information from the financial statements).

$$\begin{aligned}\text{Inventory Turnover} &= \frac{\text{Annual COGS}}{\text{Average Inventory in Dollars}} \\ &= \frac{\$1,785,000}{\$649,500} \\ &= 2.75 \text{ Times}\end{aligned}$$

This organization invests cash into inventory and gets it back 2.75 times per year.

Sellers of commodities that might shift in value quickly often use units of product in both the numerator and denominator rather than relying on volatile sales prices:

$$\text{Inventory Turnover (Commodities)} = \frac{\text{Units Sold}}{\text{Average Inventory in Units}}$$

Cash-to-Cash Cycle Time

Cash-to-cash cycle time is a financial metric that is presented here to compare it to inventory turnover. Cash-to-cash cycle time is far more useful than the most basic form of inventory turnover that uses average inventory levels on two years of balance sheets to measure how well an organization is managing its saleable assets. Average inventory levels on balance sheets can be deceiving, because they are measured at two specific points in time, when some orders might be delivered yet still awaiting payment (e.g., trade credit) and suppliers may also be awaiting payment. Since cash tied up in inventory cannot be used for other purposes, the real question is how effectively is an organization using its cash?

Cash-to-cash cycle time answers this question because it accounts not only for days of supply of inventory but also the cash benefit of accounts payable and the cash delay of accounts receivable. Since cash-to-cash cycle time is also a SCOR metric, the formula is presented where SCOR is discussed.

Supplier Capacity

A rough estimate of supplier capacity can be calculated if the total sales of the given product are known for a recent period along with their capacity utilization percentage and their price per unit. This rough

estimate calculation is as follows. (An example is also provided of sales of US$1 million for product X, a 97 percent capacity utilization, and US$5 per unit.)

$$\text{Supplier Capacity} = \frac{\left(\left(\frac{\text{Sales of Products}}{\text{Capacity Utilization}}\right) \times (1 - \text{Capacity Utilization})\right)}{\text{Price per Unit}}$$

$$= \frac{\left(\left(\frac{\text{US\$1,000,000}}{0.97}\right) \times (1 - 0.97)\right)}{\text{US\$5}}$$

$$= \frac{\text{US\$1,030,927.84} \times 0.03}{\text{US\$5}}$$

$$= \frac{\text{US\$30,927.84}}{\text{US\$5}} = 6,186 \text{ Units Available}$$

This formula can be used when selecting a supplier by comparing the units available of various suppliers. Suppliers with more units available will be less at risk of being unable to fill an order promptly. Keep in mind that other buyers could still use up this available capacity or contracts could end, freeing up capacity, so it is just a high-level assessment. Note also that too much available capacity could be a red flag of supplier distress.

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