VERSION 4.4

MODULE 1
SUPPLY CHAIN DESIGN

Section B: Design the Supply Chain

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This section explores supply chain design by looking at the use of market research, financial modeling, and an understanding of product life cycle stages to develop a sense of customer and business requirements. Since the ideal is to design the product to meet strategic goals, various product design focus strategies are covered. Every good supply chain design also needs to address collaboration with supply chain partners as well as delivering value using supply chain information technology and the proper methods of acquiring and managing data. The section also covers primers on the fundamentals of communications and project management, which often need improvement to close the gaps between the as-is and the to-be states of a supply chain.

Once a supply chain has an approved strategy for enabling and complementing the organizational strategy, it is time to get to specifics. Network design is about specifying who, what, where, when, and why for every detail of a supply chain, not only the location and number of facilities but also how products will be designed to facilitate organizational strategy and how information systems will make the network transparent.

Processes for designing the supply chain

The key processes that supply chain managers need to be able to perform related to designing the supply chain are

- Identifying customer and business requirements
- Identifying the current and future states
- Performing a gap analysis between the current and future states
- Developing an action plan to close gaps.

The following is a general overview of these processes. The information required to plan and execute these processes is presented in this section's chapters.

Identifying customer and business requirements

The process of identifying customer and business requirements involves the following steps:

- Researching organizational and supply chain strategy for customer and business requirements
- Clarifying what degree of responsiveness and efficiency is required by stakeholders
- Performing market research
- Gathering information on customers' product or service requirements
- Developing an understanding of how customer and business requirements will change over the product's life cycle
- Understanding when customer and business requirements necessitate development of reverse or specialized supply chains
- Determining when business requirements need to be satisfied through collaboration with supply chain partners
- Determining business requirements for technology, data, and communication channels internally and between partners

Identifying the current and future states

The process of identifying the current and future states involves the following steps:

- Collecting historical data for several periods up to the present on
  - Actual inventory levels per location and in transit
  - Inventory ordering methods and communications
  - Actual transit times and costs
  - Facility costs
  - Efficiency, responsiveness, and other metrics and key performance indicators
  - Technology usage, usefulness, and administrative costs
- Mapping process flow for manufacturing and logistics for current products
- Analyzing inventory trends and ordering methods
- Modeling the supply chain in its as-is state using mathematical models, process flowcharts, and descriptive techniques
- Developing a product or service design future state that will accommodate customer and business requirements and supply chain strategy
- Using supply chain network optimization tools such as network modeling and operations research to design a supply chain that meets strategic goals including responsiveness and efficiency
- Developing a technology model for desired information flows, analytic support, and electronic business
- Communicating the product/service and supply chain designs to stakeholders and gathering feedback
- Getting approval for the finalized designs
- Documenting the finalized designs

Performing a gap analysis between the current and future states

The process of performing a gap analysis between the current and future states involves the following steps:

- Comparing the as-is to the to-be state to determine needed changes to
  - Suppliers
  - Supplier contracts and expectations
  - Collaboration agreements and processes
  - Facilities (e.g., opened, closed, modified, relocated)
  - Product or service design
  - Production process flows and production lines
  - Processes, policies, and procedures that incorporate continuous improvement and other forms of responsiveness
  - Transportation modes or providers
  - Inventory policy and ordering methods
  - Technologies (adding or retiring)
  - Communications policies or procedures
  - Metrics to provide incentives to align with strategy
- Estimating the scope of the changes and time and cost involved
- Performing a feasibility study and financial analysis to determine the return on investment
- Preparing a business plan and getting executive approval for it

Developing an action plan to close gaps

The process of developing an action plan to close gaps involves the following steps:

- Planning how to develop continuous improvement philosophies in ongoing operational processes, policies, and procedures

- Planning how to communicate and manage change initially and over the long term
- Developing project charters for all changes to be implemented as projects
- Getting approval and funding for each project charter, including the authority to plan projects and expend funds
- Planning each project to define the integration, scope, schedule, budget, quality, and how to manage human resources, communications, risks, procurements, and stakeholders
- Planning the execution, monitoring and controlling, and closing process groups for each project

Note that implementing action plans involve the following steps:

- Communicating and receiving feedback
- Executing, monitoring and controlling, and closing projects using project management
- Using change management to change the culture and ensure that project results become standard operating procedure

Change management is an important part of planning and implementing action plans but is addressed in a later section on continuous improvement.

Chapter 1: Business Considerations

This chapter is designed to

- Describe the importance of understanding the marketplace as it relates to the supply chain
- Discuss market research, demand generation, and the role of the four Ps of marketing in a customer-focused organization
- Explain the factors used to select strategic partners

This chapter on business considerations addresses some of the tools used when identifying customer and business requirements.

At the end of the previous section, we looked at market research as a tool for strategic analysis. Here, we revisit the subject from supply chain design and product design perspectives. Financial modeling involves ensuring that solutions are likely to have a positive return on investment. Product research and modeling refers to determining how to adapt the supply chain to different stages of each product's life cycle.

Topic 1: Market Research

When engineers design a product, they don't necessarily have anything in mind other than overcoming technical challenges. They assume that others will appreciate the beauty and usefulness of their creations. This, however, is not necessarily the case.

Someone must act as a liaison between the manufacturers (product specialists, technicians, engineers) and the potential consumers who either will, or will not, buy their products, and marketing is all about customers. Marketing plays a role in finding, forecasting, influencing, and sustaining demand—from the product concept to the end of the product's life cycle. Marketing and sales have different but complementary objectives. Marketing translates the external perspective for internal audiences (What does the market need?), while sales translates the internal perspective for external audiences (Why do you need what we have to offer?)

As noted in the previous section, **market research** is "the systematic gathering, recording, and analysis of data about problems relating to the marketing of goods and services." Marketing can do these tasks with in-house personnel and/or by contract with an outside company. Market research can begin when the product is merely a sketch or the inkling of an idea. It can also take place for an existing product or service, especially one that seems not to be living up to its sales potential.

Demand management

Demand management relates to business and customer requirements in that one purpose of demand management is to influence the organization to produce a product or service that satisfies actual customer requirements and expectations. Demand management will be addressed in detail in a later section but, very briefly, it includes planning, communicating, influencing, and managing and prioritizing demand. If marketing professionals succeed in influencing the organization to produce products and services that meet customer requirements, the product/service package should have certain competitive characteristics that enable demand-influencing activities to have a chance to succeed. The following marketing terms from the *APICS Dictionary,* 16th edition, relate to a product or service's ability to compete for a customer's business:

Order qualifiers: Those competitive characteristics that a firm must exhibit to be a viable competitor in the marketplace.

Order winners: Those competitive characteristics that cause a firm's customers to choose that firm's goods and services over those of its competitors.

Order losers: Areas or aspects of an organization in which poor performance can cause loss of business.

If marketing has successfully influenced the organization to produce a product or service that has the capability of being an order winner, marketing professionals can use demand management tactics to get customers to buy that product or service.

Another purpose of demand management is to convince customers to purchase an organization's products and services in a manner that supports business requirements, organizational strategy, and objectives (i.e., in a profitable manner). Marketing professionals utilize the elements of demand management to accomplish these goals.

Purposes of market research

The purposes of market research include finding potential markets, analyzing markets, and refining product design to fit the markets.

- **Finding potential markets.** The most basic question about a product is "Does anyone care?" Is there a significant and unmet need out there for the better product? In an existing company, the sales force may provide the first clue that current customers have unmet needs that seem compatible with the company's mission. Market research can begin from that point to quantify the need. The process can also begin among the engineers—the folks who look at the current products and see a way to improve them. In that case, marketing and sales can present the idea to current customers to see if there are any signs of interest. They can also begin a wider research campaign to identify the potential for new markets for the suggested product.
- **Analyzing markets.** As product design gets underway, marketing can ask more detailed questions about the potential market to divide the market into segments, as will be discussed in a later section on segmentation. As stated there, the basic questions are the best questions: Who? Where? When? Why? What? How many? The answers to such questions constitute market segmentation.

  Once you know who and where the likely customers are, you can ask how best to reach them with news about the product. Do they shop at a large retail chain store or at the local hardware store? Do they buy from catalogs or over the internet? Is telemarketing the best way to reach them?

  Marketing personnel can find out why and how prospects are interested in your product by using phone surveys, online questionnaires, focus groups, analysis of past customer complaints or feedback, or a combination of those approaches. Marketers also want to know when prospects are likely to start buying. Are they ready for the new product, or will market penetration take some time as your prospects get used to the new idea? Will the product have a long or short life cycle? How often will it need to be replaced? How soon will customers demand an upgrade?

Demand forecasting, as discussed in a later section is a marketing and sales activity. In collaborative arrangements, such as vendor-managed inventory (VMI) and collaborative planning, forecasting, and replenishment (CPFR), the forecasts need to be shared with cross-functional and intercompany teams to ensure that everyone works from the same forecasting information.

Remember: When it comes to forecasting demand, marketing has a natural bias toward optimism—a bias that may be magnified by top management policies. (Management seldom looks favorably on cautious estimates.) Demand plans based on overly optimistic forecasts can lead to problems. Most obviously, it can cost money if the company increases capacity to meet the demand plan and winds up with unnecessarily large capital expenses and/or inventory hangover. An optimistic bias in marketing can also lead supply areas to distrust the demand plan and compensate by coming up with their own plans, which may well be biased in the other direction. Cross-functional teams and supply chain collaboration can overcome such problems.

- **Refining product design.** As market researchers learn more about market segments, the information should contribute to the product's design. Market research into customer attitudes can help identify features of the product, including a strategic price that will be most attractive to the various market segments. Some prospects may strongly feel that the new product should contain certain features, while others desire the opposite features. The features that positively contribute to the profit margin should be adopted, and unprofitable variations should be avoided.

  In some cases a product's features can be varied to match differences in market requirements. For example, computers can be assembled with different components to meet the specialized needs of various segments. A basic version will appeal to customers with limited funds or limited computing needs. Add a powerful processor and sophisticated subsystems, and your basic computer appeals to "power users." Add a choice of colors and shapes, and you add value for the style-conscious buyer. Other products will not be as profitable with multiple variations, and the marketing input to design will be identification of the most profitable segments.

  At this point, researchers can also contribute to the reverse supply chain aspect of product design. What sort of support will be necessary to satisfy end users and keep them as loyal customers? Will they need product documentation? How many languages will be necessary in the pamphlets? Will phone, text, or email support options be necessary? What will be the return policy? What is the attitude of potential customers to ease of disposal and impact on the environment?

Demand generation

Demand generation is part of the influencing demand element of demand management. Demand generation involves translating latent demand identified during market research into active demand for a product or service using various forms of communications with potential customers.

Demand generation is critical for new product introductions since most new products fail. The market could either stay with the product they already know or just not notice the new product. With no historical data to guide forecasts, marketing and sales have to operate on instinct, experience, connections to past products, and market research. A great deal depends upon that research. And the rest depends upon what the marketing experts do with that research, both in the product design phase and during the introduction.

Most of all, the product really has to give the market what it wants.

If market analysis has correctly identified the needs and desires the new product can satisfy, marketing at least has a good chance to develop a campaign that triggers robust sales. Of course, all those sales have to be matched by production and delivery so your supply chain doesn't run out of stock and have to turn away eager buyers.

Marketing's major responsibilities when developing a campaign for a new product or rebranding an existing product include educating customers and supply chain partners.

- **Educating customers.** The potential buyer has to know that your product is out there. Marketing has to know where buyers are and how to reach them. This means crafting the right message, one that emphasizes the product's unique benefits and connects them to customer needs and desires that were uncovered during market research. Generating product and brand awareness are activities that often take longer and require more effort than is planned and budgeted for. Therefore, a longer planning horizon and regular feedback on marketing progress are necessary to increase the chances of a successful product introduction.

  The message also has to be conveyed through the appropriate media: print ads (Which periodicals?), television or internet commercials (Which programs and time slots or websites? Which ad agency? Which style of presentation?), email, telemarketing, in-person visits, public seminars, and so on.

  Finally, marketing has to know who the buyer is. That's not always as obvious as it sounds. For example, a new type of exterior junction box may have to be marketed to, and accepted by, developers, general contractors, carpenters, and electricians as well as regulators and inspectors. Getting the word out will probably require personal visits and demonstrations. The end user, the homeowner who may eventually plug some outdoor lights into that box, is actually of no importance in the marketing campaign.

- **Educating supply chain partners.** Part of getting a product accepted is getting it understood by those who have to design, build, transport, and sell it. Working in conjunction with engineers, suppliers, logistics managers, retailers—and whoever may be involved along the way (like those carpenters in the preceding junction box example)—marketing has to be certain that the product is produced, carried, stored, and sold by people who understand it. Training and job aids may have to be designed and delivered at multiple levels.

The four Ps of marketing and demand shaping

The *APICS Dictionary,* 16th edition, defines the **four Ps** as

> a set of marketing tools to direct the business offering to the customer. The four Ps are product, price, place, and promotion.

The four Ps are part of what is called demand shaping. The *Dictionary* defines **demand shaping** as

> the practice of using the four Ps…and other market variables to influence the demand of a product or service so that the demand better matches the available supply.

Customer-focused marketing, customer segmentation, and customer relationship management (CRM) philosophies have transformed these components of traditional marketing to respond to the changes in today's marketplace. In traditional marketing, there was a product aimed at a single targeted audience. There was one price, one channel of distribution, and one marketing message. In customer-focused marketing, a product/service package might be marketed to a particular niche segment or customized to appeal to the needs and wants of several market segments.

A customer-focused strategy may contain all of the traditional components of a marketing program or may, depending on the situation, focus on one or two components. We will therefore continue to use the terms of traditional marketing to describe the components of a customer-focused program.

Product

"Product" for our purposes includes both products and services or product/service packages. In traditional marketing, a product or service was designed to appeal to a large group of consumers. The product was essentially static—perceived in much the same way by all customers. Consumer needs were important, but they were not the starting point. For example, electricity was offered to the public before the public expressed any specific needs that it would address. The technology was what was being sold; marketing and time would create the need. Similarly, the first home computers were introduced before there was broad consumer need; it took at least 10 years and the growth of the internet to create the need.

In a customer-focused world, the starting point for a product/service package is often customer need. Food products are often designed by specialized companies to appeal to the needs of certain groups. For example, a highly engineered cooked turkey may deliver improved taste to a consumer who doesn't want to spend the time required for the traditional cooking methods that produce that taste. A new dessert might result not from a combination of flavors to create excellent taste as much as a combination of ingredients to deliver a nonfattening, good-tasting treat that can remain fresh for months.

Increasingly, product/service packages may be designed to be customizable for specific customer segments. This allows the seller (or supply chain) to add desired value and competitive differentiation to the product and ideally sustain or grow profit. For example, a manufactured building like a barn or storage facility may have elements (like windows, doors, partitions, porches, or trim) that can be combined in various ways to create structures that meet very specific needs and tastes. The same credit card may actually be multiple card programs distinguished by features that offer values to specific groups, such as low transfer rates, frequent flier mileage, waived fees for checked bags in air travel, bonus rewards, or co-marketing partners.

Value-added products have various implications for a customer-focused program:

- The product itself must be designed to fulfill customer expectations and pose few challenges for customer use. This necessitates extensive research and/or customer involvement.
- The product must be manufactured or created to meet quality levels that satisfy customer expectations and business profit margins. Performance must be continuously and scrupulously measured.
- Promotion and distribution must be customized as well to address the distinctive needs of a segmented audience. The performance of the program must be tracked so that the program can be retooled for higher performance.
- Sales methods may need to be customized and measured for effectiveness. The sales force must be

thoroughly familiar with each product for which it is responsible—with its intended audience and use as well as with the marketing goals for the product. Ideally, they should be aware of what the customer has bought before.
- Customer care personnel must also be familiar with each product variation, its use, and its potential problems. Ideally, they should be familiar with what the individual customer has bought and the status of the order without having to be told by the customer.

Price

Pricing is generally a strategic decision, based on competition, perceived value, and brand identity. While some businesses may still calculate profit by adding an acceptable and competitive price margin to the total costs of creation, sales, and overhead, many take a more nuanced approach to pricing. If the market is highly competitive and a product has become a commodity, price will be dictated by the competitive situation, but in a more differentiated marketplace, pricing becomes more subjective.

In pricing a new drug, for example, a pharmaceutical company may consider not only their research and development, marketing, and manufacturing costs but also the value of the drug to patients. How much would a person pay for a drug that enabled him or her to return to work or that caused fewer side effects? How much would a person pay if there were no other products on the market that could do this?

In the customer-focused business model, price and product are tightly connected. Price may be another way to differentiate products for specific customer segments. For example, a credit card company may waive annual fees for highly desirable customers who use their cards often and carry a balance from month to month. A computer company may create product/service packages for different customers. Customers who buy more frequently or who buy more expensive systems may receive free upgrades to higher-performance features or may receive free in-home repair service.

Obviously, strategic pricing must be carefully and frequently analyzed to ensure that the pricing structure is attractive to customers but still profitable to the business. Specific sales data for customer segments are invaluable, as they can help automate delivery of messages intended to move customers into different pricing groups.

What pricing is too high to penetrate the market? What pricing is too low to cover salaries and bonuses and still return a profit? Demand is not an absolute; it increases and decreases depending on many factors, and price is often the major variable. Demand may rise as the price falls, but even that correlation has its limits. Some products sell better at a price slightly more than that of the competition, because a higher price adds to their status appeal. A light bulb may be perceived as a better value due to a higher price and a recognized brand name, even if its generic equivalent is produced on the same production line and is identical but for the name. But for some products, and in some markets, the “everyday low price” draws customers in. Synchronizing the selling price with the costs of design, manufacturing, and logistics is an area in which marketing can effectively collaborate across functions and companies.

Placement

Placement, or distribution, is another task that falls to the marketing department. Where is the right place—or right combination of places—to sell the product to the target market in sufficient quantity to meet the demand

forecast?

Placement has traditionally referred to the way in which a product is sold—how the product or service gets into the hands of the customer. A company might decide, for example, to distribute its product through warehouses and retail outlets, through a direct sales force calling on customers, or through a catalog. It's worth noting that placement has traditionally been seen as a one-way form of communication: Product is placed by shipping to outlets or being sold through a sales force, or customers call in orders.

In the most traditional location—retail store shelves—placement can include the design of the display. While this might seem to fall naturally within the competence of the retailer, in VMI partnerships the supplier may design and construct the display as well as manage the replenishment.

In the customer-focused model, placement is often referred to as the contact channel strategy. It is a means to increase profitability, first, by ensuring that the most cost-effective and customer-preferred channel is used to distribute products and services and, second, by securing lifetime customers through highly effective customer care and customer research activities.

Customer-focused placement may be determined by customer segment. Essentially identical product may be distributed through different channels that have been chosen because they match the communication and contact preferences of different customer groups. Airline tickets may be sold on the internet, at automated kiosks, at counters, over the phone, via mobile device app, or through intermediaries (agencies). Different means of placement may affect pricing, however. High touch customer service methods may command a premium price.

Improved transportation has made placement itself a key element in a product/service package. For example, placement may be customized according to the customer's need for fast delivery (regular speed, faster, overnight). Other transportation may specialize in consistent delivery that is neither early nor late.

Customer-focused placement requires a more interactive form of communication than traditional placement does. Since customers must be satisfied and since information about the customers' actions and attitudes is critical to the business, information must flow back and forth between the business and the customer. Thus, in the customer-focused model, placement includes the way in which the customer gains information about the product and post-purchase support. Interactive contact channels include call centers, online repositories that allow customers to find desired information, websites that incorporate live dialogue or email communication, and chat rooms for users.

One-way channels may also be used in customer-focused placement; these include direct marketing (direct mail, mass mailings by fax or email, telemarketing) and media-based marketing (television, radio, newsprint, periodicals, trade publications, banner ads, billboards, etc.).

Throughout the communication process, information is continually being gathered. This information may point out commonalities and trends that suggest future product crafting, promotion, and support.

Technology has greatly changed customer care. It's hard to imagine a new product introduction campaign that doesn't use e-commerce as part of the mix. A website is necessary even if only for informational

purposes. Many products can be both advertised and sold online through one's own site or through third-party sites. Customers can download software and hardware documentation and manuals, refer problems to automated expert systems, consult information databases, and communicate with technical support or even other customers about problems or questions. Digital products can be advertised, ordered, and shipped via the web: software applications, music, movies, and written materials are examples.

The channel strategy must be continuously evaluated to ensure that it is fulfilling the needs of both the customer and the business. From the customer's perspective, an effective channel has the following characteristics:

- **Accessible.** Are help lines toll-free numbers? Do the hours of operation allow access at different times of the day to meet different schedules? Are websites kept current, and do they reflect real-time changes? Can the customer contact the organization by chat or text?
- **Reliable.** Are materials or services available within the expected time frame without exception? Is the social website always operational?
- **Complete.** Can the customer get accurate, current, and complete answers?
- **Secure and error-free.** Is e-commerce adequately encrypted? Are orders taken accurately?
- **Direct.** Can the customer reach someone who can assume ownership for the issue, has decision-making authority, and can resolve a problem? Are questions easily answered by phone or automation?
- **Convenient.** How many telephone handoffs does the customer have to pass through before reaching someone who can actually solve a problem or answer a question? How much hunting on the website is necessary? How long is the customer on hold when calling?
- **Fast.** Does the customer have to repeat account and problem information or can all the customer care personnel access this information automatically? Does the customer receive a quick response to emails or phone messages?
- **Flexible.** Can the business be reached easily by those with and without computers? Are there accommodations for non-native speakers?

From the business's perspective, the channel must allow the following:

- **Control and consistency.** Does the channel promote the intended values, ideas, or content? Is every customer's experience the same?
- **Profitability.** Does the channel minimize the use of expensive human resources, for example, by using automation whenever possible?

Promotion

The last of the four Ps, promotion, includes such marketing activities as consumer research and market analysis; segmentation of customers or audience; setting of strategy for targeted segments; planning, creation, and placement of advertising; and creation of brand image. It also involves determining and communicating the timing of marketing and promotional activities and collecting feedback on their impact.

All of the traditional promotional activities are still valid in a customer-focused business model. What is different is the level of research, segmentation, and customization of the promotional message or offer that is possible. With customer relationship management technology, businesses can capture information about every interaction with customers. This enables unparalleled opportunities to study buyer motivation and behaviors and to segment customers into groups with distinctive CRM programs. Printing technologies allow for cost-effective customization of advertising materials. The explosion of communication channels—including not only the web but also satellite radio, podcasts, and email—allows businesses to select alternative channels that offer clear advantages for specific audiences.

Let's look more closely at two factors related to promotion: branding and packaging.

- **Branding.** Customer-focused promotion helps to create the brand. As defined in the *APICS Dictionary,* 16th edition, **branding** is "the use of a name, term, symbol, or design, or a combination of these, to identify a product."

  An organization's or product's brand can be worth a considerable sum to market analysts. Google's and Facebook's brands were worth billions at the time of this printing. The worth of such brands is based partly on current market share and total number of customers and partly on image, which is an intangible quality that sums up a brand's awareness, popularity, and reputation. As is said about reputation, brand image is something that takes years to build up but that could be destroyed in an instant. Therefore organizations take great pains to protect their brand image.

  Part of educating customers about a new product is choosing a name and logo that emphasizes product characteristics that will attract targeted segments. If the initial research accurately measures customer needs and attitudes, and if the product's design successfully incorporates those selling points, then the name should follow suit. The Apple Computer name and logo supports the company's strategy of putting computers into classrooms by suggesting the familiar association of apples and learning ("an apple for the teacher"). Automobile names often highlight concepts that appeal to a target market. Dodge Ram emphasizes toughness and power; Jaguar suggests grace, speed, and elegance; Honda Civic incorporates, in its name, the strategy of building a sensible, economical city car.

  A new product's name and the logo that represents it visually can either link the product to an existing product family or set it apart. The name Macintosh kept the familiar association with Apple but also signaled the advent of a new line of products. Sometimes a new model can be created from an existing model simply by acquiring a different name, as when Chrysler rechristened the Mitsubishi Eclipse as the Plymouth Laser and the Eagle Talon.

  Perhaps because of the rate of change in product availability, customers are increasingly transferring their loyalty from specific products (e.g., a line of jeans) to the provider of those products (i.e., the retailer who keeps those jeans available in the right size). They grant their business to these organizations because they trust that they will find the products they are looking for and that they will be taken care of if any problems occur. This means that businesses must keep in close touch with what customers want and are buying so that they can continually upgrade, alter, or customize product and supply chain options to meet customer expectations. They must also ensure customer satisfaction. If customer care is ignored, the implications can be catastrophic. Because customers are more aware of

service, products, and the personal experience they should receive, a single failure may undo the brand image and drive customers to a competitor. Dissatisfied customers also have the means to make their disloyalty well known. Complaints posted on websites, blogs, tweets, chat rooms, or other media can have a significant impact on today's internet-savvy customer and can destroy a once-strong business relationship.

- **Packaging.** The package that contains a product also serves a marketing purpose. The more obvious marketing elements of packaging—colors, images, words, even the textures of the wrapping—are marketing devices.

  The package should command attention and reinforce the features and benefits that sell the product (market research again). Some packages are educational—like the boxes containing microwave meals on the inside and cooking instructions on the outside. Quaker Oatmeal comes in a round container. A marketer's inspiration—or focus groups—no doubt lay behind that decision.

  Packages can be functional as well as visually appealing. Some microwave pizzas come in boxes with one reflective interior surface for cooking the pizza. Hewlett Packard's laser cartridges are packaged in a box that can be used to return the spent cartridge, thus solving the end user's reverse logistics problem and protecting the environment. Market research likely determined that such a box would increase the number of cartridges that were returned, which would reduce net costs even after the free shipping expenses were included.

  Services, too, are "packaged" for sale. Presentation of meals, design of hospital waiting rooms, and the uniforms worn by many service personnel—all these matters of style and appearance serve a marketing purpose.

This completes our look at market research. While this research is useful for figuring out what the market needs, the next subject, financial modeling, is useful for figuring out what the organization can provide to the market at a profit.

Topic 2: Financial Modeling

Financial modeling involves determining the financial feasibility and return on investment (ROI) of a product/service strategy or supply chain strategy.

Optimized network models supply cost estimates for financial modeling. Since it is just the increase in costs and the increase in benefits that are important to a decision to create, change, or improve a product and/or supply chain, financial experts use marginal analysis to study the marginal costs and benefits of the option being considered. Marginal costs include constructing, leasing, or contracting out all of the parts of the supply chain that need to be improved, reworked, or developed. They will compare these to the marginal benefits received from new or increased demand and the resulting increases in sales revenues. For the benefit side of a benefit-cost analysis, market research provides information on projected demand for the products and services that will be produced as well as target pricing. This information can then be used to estimate revenues for future periods.

Financial modeling has more nuance than just taking the benefits and dividing them by the costs, though this is the basic formula for ROI. Since money that is borrowed requires interest payments and money that is earned can be invested to earn interest, financial analysts factor in the time value of money. Briefly stated, money to be received in the future is discounted to the value that it would be worth if received today at current interest rates, called the present value. If you will get US$100 a year from now and interest rates are 10 percent per year, and if someone gives you US$90.91 now, the principal plus interest is calculated as US$90.91 x 1.1 = US$100, so getting US$90.91 now is the same thing to a financial analyst as getting US$100 a year from now at that interest rate.

This concept is used in a number of financial metrics, including net present value (NPV) and discounted payback period.

With net present value, each year's future cash inflows are discounted back to their present values, and the present values of all cash outflows are also calculated. The difference between these amounts is a measure of profit in today's money. Any NPV equal to or greater than zero is a positive sign, but, obviously, the higher it is, the better.

Discounted payback period determines how long it will take the recoup the initial investment or break even. It also discounts the future cash flows to the present value before applying them. A supply chain investment that will take three years to break even is better than one that will take six years. This was a key reason that Target decided to close its operations in Canada in 2015. An analysis determined that the Canadian operations would not become profitable until 2021, and apparently this six-year payback period was not acceptable. What constitutes an acceptable payback period may have to do with alternative investment opportunities and the product being offered. For example, if a product will be obsolete quickly, it will need a fast payback period or the capital investments will need alternate uses such as a follow-on model that can be produced with minimal further investment.

There are a large number of other metrics that financial analysts can compile and help interpret. One of these is economic value added. The *APICS Dictionary,* 16th edition, defines **economic value added (EVA)** as follows: "In managerial accounting, the net operating profit earned above the cost of capital for a profit

center.” EVA is useful because it specifically accounts for the capital investment cost before it calculates profit.

The results of financial modeling will indicate what level of capital investment will be possible. Knowing this information up front can help supply chain managers propose product, service, or supply chain designs that are likely to meet business requirements for profitability.

Chapter 2: Supply Chain Design

This chapter 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.

When it comes to designing a supply chain, there are standard factors to take into consideration, including:

- Translating strategy into design
- Supply chain network design
- Network configuration
- Metrics design
- Balancing efficiency with responsiveness
- Network optimization

Collectively, the decisions made regarding each of these factors should always support the organizational strategy and the supply chain strategy.

Topic 1: Supply Chain Design and Configuration

Translating strategy into design

Moving forward from the various business considerations, the next step 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 consistent, 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 can almost certainly help. But it has to be selected by specialists who know what is current and can guide process stakeholders in choosing the right hardware and software at the right 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 hardware and software 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.

A little later 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 analyzed and used
- Determining the impact of 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 they 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 *APICS Dictionary,* 16th edition, 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 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 with immediate internet file transfers, a day-shift accountant can perform services during the customer’s nighttime hours. Documents can be emailed across oceans faster than they can be printed out and carried to an office down the hall.

You will learn more about contracting (including outsourcing) in a later section.

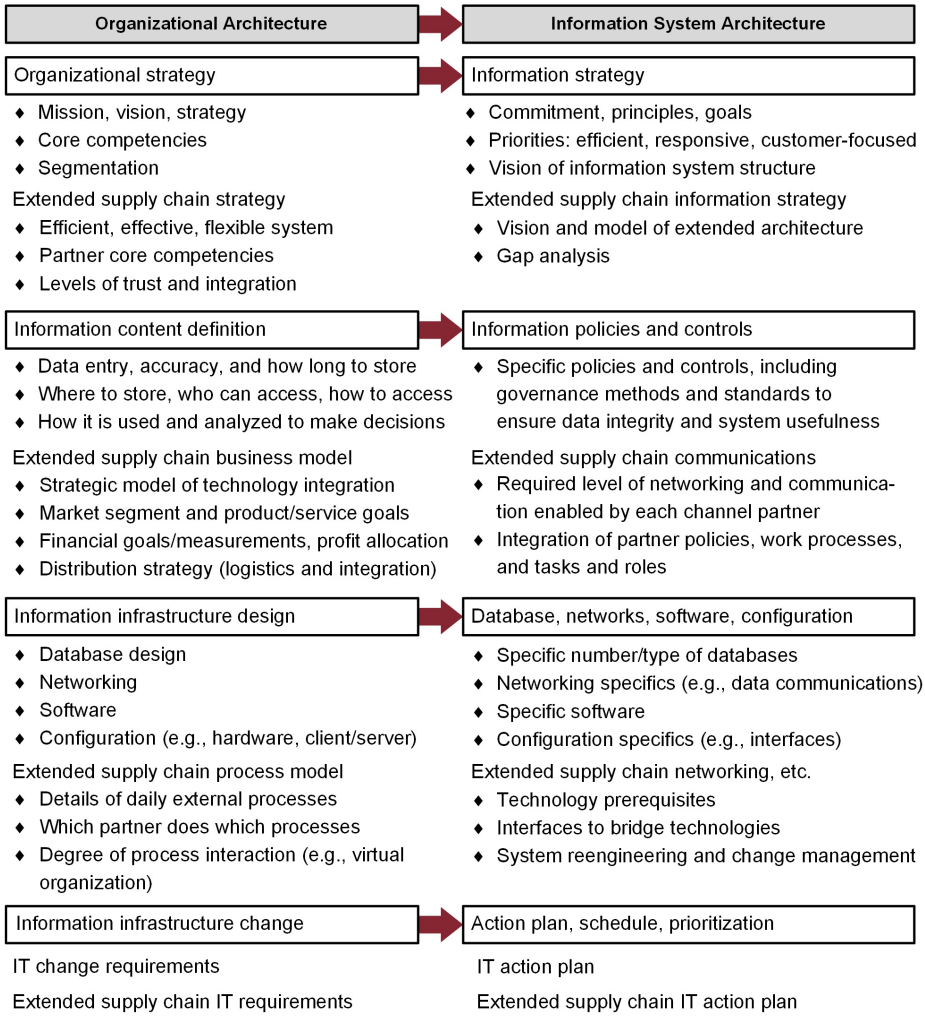
Supply chain network design

Supply chain network design and configuration include information flow design and major sourcing decisions. The goal of network design and configuration is to promote efficiency. This is done by positioning and managing inventory effectively and utilizing resources appropriately. Since the information system architecture enables various departments and external partners to become a unified whole, supply chain information system design is addressed here first. However, since information strategy is closely tied to overall network design and configuration, this section 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 1-26 provides an overview 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 1-26: Organizational and Information System Architectures



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.

Let's look at each of the categories in Exhibit 1-26 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 needs to be collected, how it will be collected, how its accuracy will be maintained, and how it will be stored, accessed, controlled, and analyzed. 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.

These decisions will be addressed in greater detail later in these materials.

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 and 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, 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 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 can cause users to distrust and discredit otherwise useful software systems.

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

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.

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 as well as 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.

Among the many considerations to be factored into the optimal network configuration are

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

For example, supply chain managers in manufacturing enterprises must consider the stocking of

warehouses with an optimal level of the right kinds of inventory and must establish transportation links that ensure timely arrival at, and departure from, warehouses. 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 gauging future demand as accurately as possible and keeping inventory as low as possible without disruptions in delivery to customers. In a later section 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 square feet 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 but a few possibilities.

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 1-27.

Exhibit 1-27: 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.

Metrics design

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®) model. This model and other information on metrics is covered in Module 3.

Topic 2: Fulfillment Strategies Considering Market Requirements

Balancing efficiency with responsiveness

Organizations often need to balance efficiency (least-cost manufacturing and supply chain) with responsiveness. Responsiveness implies being responsive to changing customer requirements. This can take the form of investing in high customer service and/or agility. Supply chain agility is measured in SCOR using metrics for flexibility and adaptability (these are defined more formally in a later section), 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 these factors 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 will likely recognize and associate certain attributes that are integral to the production of different types of products.

An efficiency-focused supply chain generally strives to have a combination of these attributes:

- Customer demand is stable and does not fluctuate significantly. (There is low demand uncertainty.)
- The number of forecasting errors is low.
- 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.
- There is limited product variety.

In an efficiency-focused supply chain, the supply chain manager is typically focused on proactively managing customer demand and may use time series forecasting methods to predict future demand. Customer orders are filled with inventory, and any unpredicted interruptions are usually managed by proactive demand management.

A responsive supply chain has the following attributes:

- Customer demand is not stable and can fluctuate significantly. (There is high demand uncertainty.)
- The number of forecasting errors can be high.
- 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.

Supply chain fit with organizations' market requirements

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? Is it based on low price, convenience, or customizable features? The answers to such questions 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

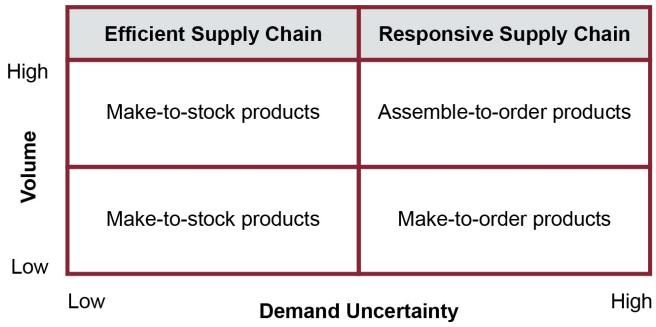
chain is located in fashionable Italy, where there's a plethora of finely made fabrics and fashions.

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, it also uses different supply networks. These networks can provide backup for each other if any experiences a disruption to its supply chain.

Gap Inc. isn't the only company in which the supply chains are tailored to meet market requirements. Callioni's *Harvard Business Review* article "Inventory-Driven Costs" describes how in the 1990s Hewlett Packard realized that its struggling PC business was barely profitable, suffering from short product cycles and decreasing prices for its products. They concluded that a mismatch between demand and supply was resulting in excess inventory and driving PC costs, and they decided to redesign the supply chain to remedy this and other inventory-related issues. They developed five supply chain options for consideration and used their inventory-driven cost metrics to pinpoint the solution, a centralized one-step manufacturing configuration that would best support the product line.

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 1-28 shows how supply chain types can be fitted to products based on volume and demand uncertainty.

Exhibit 1-28: Fit Supply Chain Type to Product



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).

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 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.

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 for the manufacturer.

Topic 3: Supply Chain Network Optimization

Once data are collected, tabulated, and verified, the next step is to optimize the configuration of the logistics network. Optimization often involves developing the capabilities to find and enact the least-cost solution for the entire network (efficient or lean) or developing the ability to manage demand and respond to actual demand (responsive) through some combination of customer focus and/or agility.

This can be accomplished by implementing network modeling and operations research planning tools that employ two techniques:

- Mathematical algorithms to determine least-cost or best solutions
- Simulation models to evaluate design alternatives

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.

Stages of supply chain network technology optimization

Supply chain network technology optimization can be mapped to the stages of supply chain evolution that exist on a continuum that ranges from traditional disconnected companies with adversarial external relationships (Stage 1) to highly efficient virtual networks of companies (Stage 4).

Supply chain optimization 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 ERP, internal integration, supply chain planning, production scheduling, external integration, and so on. A company's stage of supply chain optimization is important for benchmarking the firm against its competition.

Exhibit 1-29 lists the levels of supply chain optimization at each of the stages of supply chain evolution.

Exhibit 1-29: Stages of Supply Chain Network Technology Optimization

Capability	Stage			
	1: Multiple Dysfunction	**2: Semifunctional Enterprise**	**3: Integrated Enterprise**	**4: Extended Enterprise**
Internet	Static websites	Online catalogs	Intranets across all functions	E-commerce
Integration	None; no teamwork	Batch	Internal process integration; design teams	Supply chain networks; process integration across entity boundaries
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.	Integrated global planning; supply chain vs. supply chain competition
Production	Basic MRP (time-	MRP II	MRP—ERP	Externally integrated

scheduling	phased order point)	(manufacturing resource planning)		ERP
Integration with suppliers	Fax/phone	EDI/fax/phone; low-price purchasing strategies	Electronic data interchange (EDI) with all large suppliers	VMI, online requests for quotation (RFQs)
Customer delivery	Research	Local inventory	Available-to-promise (ATP)	Capable-to-promise (CTP)

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 get 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 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 and staying at 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.

Moving between optimization stages

Many companies become bogged down in their evolution through the stages of optimization, especially between Stages 2 and 3 and Stages 3 and 4. 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 only move more of the company or network 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 an ERP 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 with 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. 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.

Supply chain network optimization strategy

Evolving from a Stage 3 to a Stage 4 company 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.

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 from a Stage 2 company to a Stage 3 company, or from a Stage 3 company to a Stage 4 company, is often facilitated 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.
- **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 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. Thereafter, the teams work toward continuous improvement. At Stage 4, teams see the results of their labor, as real-time network communications are actively used by all cross-functional teams.

Chapter 3: Product Design for New Products or Requirements

This chapter is designed to

- Describe the design process and identify the contribution of design to product and delivery costs
- Describe the levels of supplier involvement in product design and explain the trend toward supplier integration
- Contrast traditional over-the-wall design with collaborative design for the supply chain
- Explain the features, benefits, and tradeoffs of various approaches to design, including design for logistics and design approaches that focus on standardization, simplification, customization, quality, and sustainability
- Explain how product life cycle stage affects requirements and supply chain design.

Product **design** is a "process [that] consists of translating a set of functional requirements into an operational product, process, or service" (*APICS Dictionary,* 16th edition).

Design spans all the work between marketing and production. Depending on the industry, the business, and the product, design may involve models and prototypes as well as sketches and plans. Automobiles are sketched, rendered as models, and constructed in prototype for test driving and are subject to design revision at each step in the process. Each component of the finished vehicle must be designed with more than looks and function in mind but also raw materials, sourcing, manufacturing, labor costs, and regulations regarding safety and environmental impact.

Services, too, go through a design phase. Investment portfolios, for example, were once custom-designed for wealthy clients. Today, prepackaged mutual fund portfolios tailored to specific customer desires and sourced from "raw materials" such as stocks, corporate and government bonds, and traded commodities are marketed to a much wider customer base. Bank accounts, guided tours, and personal services such as manicures are all similarly subject to careful design and packaging to make the best use of resources and provide benefits customers desire.

Is good design important? Expenses related to design account for about 5 to 15 percent of product cost. But about 70 percent of delivery cost results from choices made during design. A poor design process can kill a product by forcing its price to unacceptable levels for the quality delivered or by slowing its design cycle and time to market until the competition has the market share.

What aspect of product design needs to be considered when designing a supply chain? The answer is every aspect—because the traits and features of every product will impact the supply chain process in some manner. Design has implications for all the stakeholders in the supply chain, and it should be approached with the supply chain's key indicators in mind.

Topic 1: Traditional Over-the-Wall Design Versus Collaborative Design

Ideally the design process should be collaborative, involving all the functions and partners that are impacted

by the product's design. However, in reality, sometimes the design of a product or service is carried out in isolation by one or two departments and without involving supply chain partners. Traditional design takes this over-the-wall approach.

Traditional design process

The traditional sequential design process, once almost universal and still used in some companies, incorporates the corporate organization of separate functional areas separated by imaginary walls. This process often goes like this:

- Marketing sends customer needs and attitude information to engineering.
- Engineering incorporates the information into design drawings and schematics and "tosses those over the wall" to production and purchasing, perhaps having created a design incorporating the finest materials and extra engineering features.
- Purchasing sources the materials necessary for production, discovering that some specified parts are not available and others are not affordable.
- Production looks at the design and realizes that it would require expensive process modifications and costly additions to staff and equipment.
- Production and purchasing send the designs back to engineering for revisions.
- After several rounds of sending the designs back and forth to various areas, engineering delivers a workable design and production creates a product that logistics is expected to deliver.
- Logistics discovers that packaging and shipping costs exceed the original budget and that the system lacks capacity to get the product to market on time.
- And so it goes until the finished, packaged product arrives at the distributor.

This traditional process can result in problems being unknowingly built into the product design. For instance, certain product designs may increase inventory holding or transportation costs relative to other design options, while other designs may require a shorter manufacturing lead time.

Collaborative design process

Collaborative design breaks down walls between departments and supply chain partners. Here's how the design team project commonly unfolds:

- A design team forms, including members from engineering plus other departments and, perhaps, other supply chain partners.
- The design team considers issues that will arise along the supply chain from raw material to the final stage of the product's life cycle, making rough approximations of cost differences between alternatives.
- Once all functions and partners have agreed upon a design, purchasing and production go to work to bring the design to fruition.

How much collaboration?

Because organizations can choose the level of involvement they desire from any given supplier or customer, collaborative efforts in product design extend along a continuum. Exhibit 1-30 expresses the range of supplier or customer integration as going from over-the-wall design, to informal collaboration, to formal collaboration.

Exhibit 1-30: A Spectrum of Approaches to Design

Over-the-wall approach: The supplier/customer plays no role in design.

Informal collaboration: Design includes information from conversations or informal consultation with the suppliers/customers but no formal collaboration.

Formal collaboration: The design team involves representatives of the supplier/customer in a formal collaboration. This may involve anything from using the voice of the customer (VOC), to getting regular formal input on a design, to asking a supplier to design a subcomponent due to specialized expertise.

Once the decision is made to forego the over-the-wall approach and instead develop a collaborative approach to design, the question becomes “How much collaboration?” Contributions can be as casual as tips provided in conversation or as formal as fully integrated inter-organizational teamwork with assigned roles and responsibilities.

In a study of supplier integration funded by the National Science Foundation and the Global Procurement and Supply Chain Benchmarking Initiative at Michigan State University, researchers identified several general levels of supplier integration and assessed the value of each. The results of a survey conducted during the project showed that greater levels of supplier involvement produced, on average, greater improvements in cost and quality.

While one study doesn’t constitute a definitive analysis, it’s fair to say that the trend in designing for the supply chain is toward formal supplier collaboration and away from the over-the-wall and informal approaches. This is true for the involvement of customers in design as well. Involving representatives of key customers in design or collecting the broad input of many smaller customers using the voice of the customer and other methods will benefit from a formal process to ensure that customer requirements and expectations are represented in the design. It makes sense that the more functions and partners contribute to a design, either casually or in formally organized teams, the better chance you have of getting a product or service that is actually desired by the market into production at a reasonable cost and on time.

Note that while suppliers or customers may be asked to be part of a design team, the organization whose brand is at stake should retain responsibility for the overall design rather than allowing anyone else to take the lead.

Implementing design collaboration

Busy managers have tight deadlines, and designers and marketing managers often have performance scorecards that fail to reward supply chain cost reductions. Therefore, a process is needed to gain both internal and extended partner acceptance for design process improvements.

Cargill and Fry describe such a process used at Hewlett Packard, which is paraphrased here:

- **Proof of concept.** Small projects are performed, harnessing experts and internal staff to test the concept. Successes are celebrated and internally advertised. Simple graphics are used to make the goals easy to understand and accept.
- **Formalize concepts.** Terms are standardized, concerns are addressed, case studies are shared, and formal training and online at-will training are created to educate staff and partners.
- **Formalize processes.** Cross-functional teams are created, and individuals are assigned to work a percentage of their time on the teams. Performance metrics, scorecards, and rewards such as formal praise are implemented. Experts are made available.
- **Prioritize opportunities based on best value to encourage adoption.** Concepts that have proven the most effective are pushed to other teams.

In this way, internal teams and external partners can be led a step at a time toward appreciating the financial and other benefits of collaborating on design, finding real ways to make these concepts work for them, and finally incorporating collaboration into normal processes so that efforts can turn to sustaining and continuously improving the effort.

Benefits of design collaboration

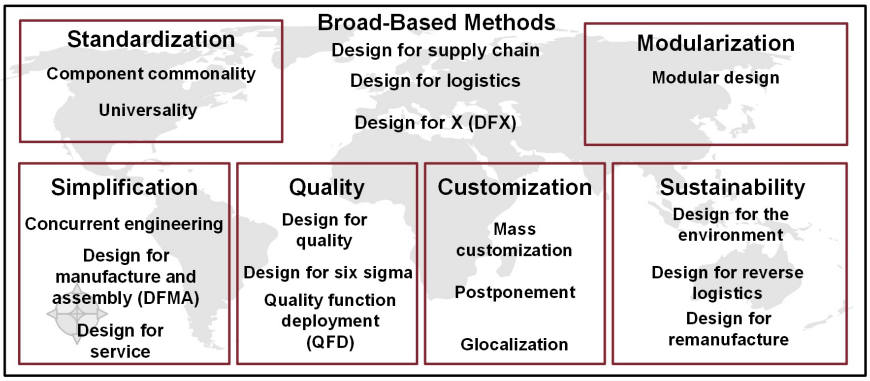
Integrating suppliers and customers into the design process provides many potential benefits, including those that follow:

- **Fewer cost overruns.** Collaboration with the supplier brings greater clarity about manufacturing processes and materials, reducing the likelihood that designs will be impractical to manufacture. Collaboration with customers can help prioritize which design elements to include or exclude.
- **New and improved approaches to design.** The supplier brings special expertise in processes, materials, and technologies that can give the designers new ideas and avoid problems caused by reliance on expensive or hard-to-find parts. Customers can indicate if a new process would be perceived as value-added.
- **Improved customer satisfaction.** Collaborating with the supplier in the testing of prototypes, models, and preproduction samples reduces the number of product failures. Involvement of customers aligns products with actual customer needs.
- **Improved efficiency (faster to market).** The supplier’s experience in manufacturing and logistics can lead to products that are more easily manufactured, assembled, shipped, and stored. Customer involvement can keep the focus on actual requirements.
- **Higher product quality for the price.** Sharing quality requirements with the supplier before final selection of parts and processes results in higher quality and more affordable pricing. Customers can indicate the price/quality level they are willing to pay for.

By including perspectives such as those of marketing, production, and supply chain management, designers can develop products that are better matched to customer needs, cheaper to build, easier to transport and store, and easier on the environment.

Now we'll look at some approaches to design collaboration. These include both broad-based and more specific methods, as shown in Exhibit 1-31.

Exhibit 1-31: Summary of Design Methods



Topic 2: Broad-based Design Methods

There are a number of broad-based approaches to product design, all of which are focused on improving different aspects of the supply chain design. We'll take a closer look at three broad-based design approaches: design for the supply chain, design for logistics, and design for excellence (or everything).

Design for the supply chain

Design for the supply chain refers to "enhancement of a firm's product design in consideration of the issues that will arise in the supply chain, from raw materials to the final stage of the product's life cycle" (*APICS Dictionary,* 16th edition).

The need to meet supply chain goals of faster inventory turnover, lower inventory costs, reduced inventory transit time, and quicker time to market has inspired modifications to the design process in recent decades. Design for the supply chain incorporates concepts of design related to supply chain standardization, simplification, customization, quality, and sustainability, each of which is discussed later.

Design for logistics

A term closely related to design for the supply chain is design for logistics (DFL). Adding logistics to the design agenda assumes that the supply chain and the product are designed simultaneously to optimize efficiency, affordability, and quality.

Design for logistics is concerned with minimizing supply chain costs by

- Designing to minimize transportation and storage costs: efficient packaging for fast loading/unloading and higher density of items per pallet
- Designing to minimize manufacture and assembly time
- Designing to maximize standardization.

The first of these principles is discussed next, while design for manufacture and assembly and standardization are discussed later in this topic.

Design to minimize transportation and storage costs may involve designing products to fit into standard box sizes (full size, half size, quarter size, etc.) so that different boxes can fit in a master carton or on a pallet efficiently. This process is called unitization or containerization. For example, four six-packs of beer can be designed to fit into a master carton that holds 24 cans and stacked along with 24-packs. This process allows different assortments to be shipped together. Master carton design should also facilitate loading and unloading by hand without mechanical assistance when feasible.

Changing product designs and how items are packed can also reduce overall box sizes. For example, designers could reinforce a product's internal frame so it requires less cushioning material or store a cable within a printer output tray rather than requiring the packaging to be designed with an additional tray. Such size reductions can have huge cost savings, for example, being able to fit an additional row of goods on each pallet.

Examples of design for logistics abound in retail stores. Plastic garbage pails that can be stacked one inside

the other are a result of DFL. Since they are made of plastic rather than metal, they are lightweight for ease of transport. When nested, they occupy much less storage space and are more economical to ship. Many other products now come in kit form for similar reasons. Ikea's scalable bookshelves, for example, are shipped as unassembled boards and connectors in flat cartons for efficient handling and storage. One unit in each size can be set up in the store for viewing, and customers have easier transportation, too, because they can take away the flat cartons to assemble at home. In a sense, the customer becomes the final work site in the manufacturing process.

Benefits

Benefits of the transportation and storage component of design for logistics include the following:

- Lowering transportation and warehousing costs increases profit margins.
- Warehouses can store more goods, relieving capacity pressures.
- Recognizable master carton design helps retailers when looking for a particular item to restock from storerooms.
- Packaging design can allow some retailers to sell directly from a pallet.

Tradeoffs

Tradeoffs of the transportation and storage component of design for logistics include the following:

- Maximizing items on a pallet needs to be balanced against the needs of retailers; slow-moving goods may not be desired in larger quantities.
- Product requirements may make standard box sizes problematic.
- The density of items may need to be altered to balance between maximum vehicle volume ("cube out") and vehicle weight restrictions ("weigh out").

Design for X (DFX)

The *APICS Dictionary,* 16th edition, defines **design for X (DFX)** as follows:

> Also referred to as design for excellence, a design process that ensures the outcome is manufacturable, maintainable, cost effective, and high quality.

Design for X is sometimes called design for everything to describe a need to design a product or service with all of the design considerations that an organization determines are of strategic importance. For example, a particular organization could decide that its critical design goals include universality, design for manufacture and assembly, quality function deployment, postponement, and design for reverse logistics. Each organization will set its own priorities.

Topic 3: Standardization

Standardization is “the process of designing and altering products, parts, processes, and procedures to establish and use standard specifications for them and their components” (*APICS Dictionary,* 16th edition).

A related term is **standardized product,** which is “a product that can be made in large quantities, or continuously, because of very few product designs” (*APICS Dictionary,* 16th edition). When the standardized product is production equipment, it is called procurement standardization, meaning that equipment is designed to allow for design variance and adaptation to new customer demands.

An important step for design teams to take when pursuing standardization is to look at existing product families. Creating a common component that will work for an entire line (or using one that was already created for those lines) will multiply the savings from standardization. For example, when Hewlett Packard merged with Compaq, it found that its server racks had incompatible shapes, needing 12 varieties of rail kits. Customers didn’t place any value on the difference. They reduced this number to five types of kits, for an estimated product lifetime savings of US$32 million.

Types of standardization include component commonality and universality.

Component commonality

Component commonality is a form of design standardization where a single part is used to replace a variety of similar parts. For example, instead of using a variety of bolt sizes in an assembly, the assembly can be designed in such a way that the same size bolt will work for all purposes.

Benefits

Common components can increase efficiency and lower costs in several ways:

- Lower purchasing costs because less variety allows economies of scale
- More streamlined production because of fewer shifts between different processes and tools
- Simpler, cheaper storage

Tradeoffs

Tradeoffs include the following:

- Cost of product modifications required to accept the new part
- Less flexibility for designers, who may prefer a variety of similar parts
- Reductions in quality if the greater variety of parts would, for example, allow closer tolerances or more attractive design

Modularization

The *APICS Dictionary,* 16th edition, defines **modularization** as

> In product development, the use of standardized parts for flexibility and variety. Permits product development cost reductions by using the same item(s) to build a variety of finished goods.

A module is a part that can be used in multiple products. According to the *Dictionary,* a **modular design**

strategy is

> planning and designing products so that components or subassemblies can be used in current and future products or assembled to produce multiple configurations of a product.

Modular design is a type of component commonality, and the terms are sometimes used interchangeably.

In addition to design for component reuse, modular design can start by considering existing products on the open market to avoid design and manufacture costs for those parts.

Computers provide a perfect example of modularity. RAM, hard drives, and graphic and audio subsystems are interchangeable among many different computers. Some computer parts—hard drives and RAM, for example—can be added to a machine as upgrades, or they can be replaced with new, improved components. Modular bookshelves that can be stacked vertically or integrated horizontally to fit different spaces provide another example.

The opposite of modularity is integral design, in which all components are designed to work together in one specific product. Apple computers focus on integral design, while PCs are modular. Clothing can also illustrate the two types. Trousers, shirts, ties, and sport coats can be mixed and matched because they are modular. A uniform, on the other hand, is an example of integral design.

Services can be modular, too. An *à la carte* menu exemplifies modular design; the special of the day, with all courses determined by the chef and the price set by the house, is an integral design. Breaking down a process can allow various components to be outsourced. For example, some McDonald's restaurants rely on (possibly offshored) call centers to take drive-through orders to decrease the time involved in filling orders. The call center relays the order to the kitchen with a customer photo to assist in accurate delivery at the drive-up window.

Benefits

Benefits of modular design include the following:

- Reduced cost of design and manufacturing when using modules to create a family of products, possibly leveraging postponement strategies (described later in Topic 7)
- Increased efficiency and decreased cost of production, since multiple products can be created simultaneously from the standard components
- Expanded customer base, because products can be customized closer to the end user (and sometimes by the end user)
- Easier, more cost-effective shipping, warehousing, and display of the product if it is designed with packaging in mind (e.g., boxed furniture kits)

Tradeoffs

There are potential tradeoffs involved in taking a modular approach to design:

- While modular design may reduce logistics costs, the cost of each product in a family may go up.
- Errors in module assembly can create a poor end user experience.
- Integral design generally allows more emphasis on style, beauty, quality, "fit and finish," user experience, and customization. Costs can be higher.

Universality

Universality is “the strategy of designing a product initially intended for one market in such a way that it can also be sold in other markets” (*APICS Dictionary,* 16th edition). Being a form of standardization, “one-size-fits-all” items exemplify universal, or standardized, design, as do unisex clothes. Sometimes astute marketing can convert a specialized product into a universal one. For example, restaurant-quality kitchen appliances have become popular in homes. Universality can be used for product components, too. For example, power supplies can be made to accept either 110 or 220 power for use in different countries with only a different end cable.

Benefits

Benefits of universal design include

- Increased sales volume
- Reduced design and manufacturing cost compared to market-specific items.

Tradeoffs

On the debit side, universal designs may be less suited to any given market than a specialized product would be. And this can translate to a shorter product life cycle and less customer loyalty.

Topic 4: Simplification

Simplification is “improving quality and cutting costs by removing complexity from a product or service” (*APICS Dictionary,* 16th edition). Less complex products and services have shorter lead times, fewer quality issues, and higher profit margins. Simplification provides synergy with other design approaches such as standardization or customization as well as with manufacturing approaches such as build-to-order.

Types of simplification include concurrent engineering, design for manufacture and assembly, and design for service.

Concurrent engineering (CE)

One of the first steps along the path toward supply-chain-oriented design is sometimes called concurrent engineering (CE). Originating in the 1980s, CE has also been called simultaneous engineering or participative design. Whatever the name or particular tactics, concurrent engineering starts from the premise that the product design processes can be shortened and simplified when stakeholders other than the engineers contribute. Variations on that theme are known as early manufacturing involvement and early supplier involvement (ESI); of course, manufacturing and supplier representatives can both be assigned to a design team to work with customers and representatives from other functions and other partners, including marketing and sales, service, and purchasing.

Benefits

Benefits of concurrent engineering include the following:

- Emphasizes design collaboration
- Shortens the design cycle when events are parallel rather than sequential
- Can make use of newer collaborative design tools for interactive design participation in virtual meetings

Tradeoffs

Concurrent engineering has been replaced by more complete methodologies such as design for manufacture and assembly.

Design for manufacture and assembly

According to the *APICS Dictionary,* 16th edition, **design for manufacture and assembly (DFMA)** is

> a product development approach that involves the manufacturing function in the initial stages of product design to ensure ease of manufacturing and assembly.

DFMA is essentially a further development of concurrent engineering. A related term in the *Dictionary* is **design for manufacturability,** which is the “simplification of parts, products, and processes to improve quality and reduce manufacturing costs.”

In the traditional sequential approach to design and production, manufacturing engineers get design drawings from the design engineers and determine an efficient way to build the product as designed. DFMA acknowledges the benefits of including suppliers, manufacturing engineers, and warehouse managers responsible for assembly in the design process. When these other stakeholders review the design as it is

being created, they can draw upon their experience and firsthand knowledge of existing manufacturing/assembly processes to catch unrealistic assumptions about production while amending the design is relatively easy. (Correcting flawed design assumptions becomes much more costly and time-consuming after the design has been completed.) The result is a high-quality product that remains affordable and is ready for market in a reasonable length of time.

The goals of DFMA are as follows:

- To select materials for ease of production as well as product function
- To design components so that they do not require extremely tight tolerances
- To reduce the number of parts
- To reduce the number of instances parts need to be handled
- To use concurrent and parallel processing to reduce work-in-process time
- To make assembly obvious and easy
- To simplify the process steps for assembly
- To design in easy product testing

For example, a U.S.-based pinball machine manufacturing company followed DFMA principles by creating a completed internal assembly harness that could be rotated 360 degrees, giving troubleshooters access to all of the internal wiring for fast repair when performing product testing. Such innovations help them stay competitive with lower-cost labor markets.

Benefits

The benefits of DFMA include the following:

- Confusion, complexity, and variability are reduced, in turn reducing production delays, long setup times, and extensive training requirements.
- Standards and policies, such as requiring evaluation of existing equipment before resorting to a new production line, can enforce DFMA.
- DFMA makes use of standardization, such as common parts for product families or off-the-shelf parts, whenever possible.
- It assists lean philosophies, modular design, and mass customization.
- Software automates many features of DFMA.

Tradeoffs

The main tradeoff of DFMA is that it could be at odds with customer demand and marketing desires if simplifications result in some demanded features being omitted. (Usually these are features that fail to increase marginal profits.)

Design for service (design for maintainability)

Design for service is the “simplification of parts and processes to improve the after-sale service of a product” (*APICS Dictionary,* 16th edition). It is also called design for maintainability.

Once a purchase has been made, customers’ opinions of a product often hinge on their most recent experiences with it, so serviceability or maintainability strongly impact customer satisfaction and retention of lifetime customers. For products that require regular maintenance, this may involve changing cartridges,

filters, or other replacement parts. Parts that need to be replaced frequently should be easily accessible and replaceable by someone with no training. Even when the parts are designed to be replaced by professionals or service teams, faster service reduces maintenance charges.

Benefits

- Design for service lowers the total cost of ownership. For example, if a facility manager can replace all air filters in a building in a day rather than two days, it saves the organization a great deal of money over the life of the building.
- Design for service also extends to logistics, since a ready supply of replacement parts must be available. Replacement parts can be a significant source of profit. If the ordering experience is easy, it can be a source of customer satisfaction.

Tradeoffs

Design for service may compete with other design goals such as aesthetics or minimizing development cost.

Topic 5: Quality

Quality is defined by the *APICS Dictionary,* 16th edition, as follows:

> Conformance to requirements or fitness for use. Quality can be defined through five principal approaches: (1) Transcendent quality is an ideal, a condition of excellence. (2) Product-based quality is based on a product attribute. (3) User-based quality is fitness for use. (4) Manufacturing-based quality is conformance to requirements. (5) Value-based quality is the degree of excellence at an acceptable price. Also, quality has two major components: (1) quality of conformance—quality is defined by the absence of defects, and (2) quality of design—quality is measured by the degree of customer satisfaction with a product's characteristics and features.

In other words, quality is a critical issue in product design and manufacture that can be measured and controlled in multiple ways. Methods of incorporating quality into design include design for quality, design for six sigma, and quality function deployment.

Design for quality

The *APICS Dictionary,* 16th edition, defines **design for quality** as

> a product design approach that uses quality measures to capture the extent to which the design meets the needs of the target market (customer attributes), as well as its actual performance, aesthetics, and cost.

Design for quality uses a number of measurements to control quality, such as those addressed in Module 3. Each organization will determine the measurements they wish to use and then set requirements for acceptable quality and goals for exceptional quality. Some of these measurements will be subjective, such as for aesthetics.

Benefits

Benefits of design for quality include the following:

- Fewer defects reduces waste and increases customer satisfaction.
- High quality can move the product from an order qualifier to an order winner if the organization's strategy is to compete on quality.

Tradeoffs

Tradeoffs of design for quality include the following:

- Quality may involve significant initial expense.
- Over time it usually lowers total costs, but these savings may be hard to trace back to the quality program.

Design for six sigma

Design for six sigma is defined by the *APICS Dictionary,* 16th edition, as

> an approach to designing products and processes that attempts to ensure the firm can provide products or services that meet six sigma quality levels. These quality levels correspond to approximately 3.4 defects per million opportunities.

Six sigma is addressed in Module 3, Section C, Chapter 3, “Continuous Improvement and Change Management.”

Quality function deployment (QFD)

Quality function deployment (QFD) is defined by the *APICS Dictionary,* 16th edition, as

> a methodology designed to ensure that all the major requirements of the customer are identified and subsequently met or exceeded through the resulting product design process and the design and operation of the supporting production management system.

QFD is more than just a design for quality philosophy; it extends to operations and support functions. However, QFD must start with design by translating customer segment demand data and the voice of the customer into design requirements. QFD uses precise steps and a methodology such as the “house of quality,” which is essentially a comparative spreadsheet that ranks how a product or service stands up to customer wants as well as to what the competition is offering. All of this is translated into a set of technical specifications to meet customer priorities. The philosophy uses group decision making to make sure that conflicts are resolved with the customer in mind.

Benefits

Benefits of QFD include the following:

- Provides all of the benefits of design for quality
- Improves customer service
- Shows relative levels of interactions between desired product characteristics so they can be prioritized when in conflict with one another (e.g., light and sturdy or fast acceleration and low gas mileage)

Tradeoffs

One issue with QFD is that, like any complex methodology, it requires the organization to wholeheartedly champion, adopt, and maintain it.

Topic 6: Customization

Customization is a design goal that allows products or product families to be adapted to changing customer demand over time. Customization that requires engineering-to-order has a very high product cost and long lead times. While this is appropriate for some markets, it cannot be profitable for many products and services. Therefore, methods of customization have been developed to harness mass production as much as possible.

Customization methods include mass customization, postponement, and glocalization.

Mass customization

Mass customization is the practice of moving final product configuration closer to the customer. The *APICS Dictionary,* 16th edition, defines it as

> The use of mass production techniques to create large volume of products in a wide variety keeping production costs low while enabling customized output primarily utilizing postponement or delayed differentiation.

It's also known as delayed differentiation, which is a description of the process that leads to mass customization. That is, a basic product or set of components remains in undifferentiated form as long as possible before being converted or assembled into a customized, or differentiated, configuration. Sometimes differentiation doesn't occur until the end customer selects the specific components to be assembled-to-order.

A classic example of mass customization is Hewlett Packard's decision to stop sending completely assembled, regionally differentiated printers from one plant to all geographic markets and instead to ship modular parts to each regional distributor for assembly closer to the customer.

Mass customization benefits from modular design, as shown in this HP printer example. The fewer the modules to be shipped, stored, and assembled, the more efficient the supply chain—and the more easily the final differentiation can be accomplished. University education, investment portfolios, and restaurant meals are all customized for the individual end customer. In fact, the customer may do the customizing.

Making mass customization work efficiently depends upon establishing instantaneous communication among the units that build or supply each module. It may also require the availability of considerable expertise at the point of differentiation. In the HP example, the regional distributors had to acquire the equipment and expertise necessary to assemble printers; before this they only had to warehouse and distribute the printers.

Mass customization may also require more expertise by employees at the point-of-sale, since customers may have to be guided in their selection of custom products. Moreover, the retail salesperson may be the final assembler. It takes greater training, and perhaps aptitude, to build items to order in a retail setting than to sell them supplied as a finished product.

Benefits

Benefits of mass customization include the following:

- Savings due to economies of scale
- Increased efficiency and expertise of workers who create assembled-to-order modules
- Increased sales volume because of the appeal of differentiated products to different market segments
- Reduced inventory costs, because aggregation of demand increases the accuracy of forecasts and allows each region to reduce its inventory
- Creation of semiskilled jobs to benefit local communities

Tradeoffs

Tradeoffs of mass customization include the following:

- Costs of investing in equipment and training to enable distributors to assemble the product
- Potential friction with distributors who don't want the added tasks
- Potential for quality issues if assemblers are poorly trained or designs fail to make assembly foolproof

Postponement

Postponement is very similar to mass customization. As defined in the *APICS Dictionary,* 16th edition, it is

> a product design or supply chain strategy that deliberately delays final differentiation (i.e., assembly, production, packaging, tagging, etc.) until the latest possible time in the process. This shifts product differentiation closer to the consumer to reduce the anticipatory risk, eliminating excess inventory in the form of finished goods in the supply chain.

The *Dictionary* defines **product differentiation** as

> a strategy of making a product distinct from the competition on a nonprice basis such as availability, durability, quality, or reliability.

Postponement is an excellent example of a push-pull strategy, where the organization designs the product and manufacturing process so that differentiation can be delayed as long as possible. A generic product is produced at the start of the manufacturing process and, when demand is determined, only then is it differentiated to a specific product. With this strategy, production starts can be based on aggregate forecasts or actual orders. Thus postponement addresses the uncertainty relative to final demand even if forecasts can't be improved.

Benefits

Benefits of postponement include the following:

- Postponement is useful as a countermeasure against the bullwhip effect because it reduces the need for safety stock in multiple varieties.
- The amount of in-transit (pipeline or transportation) inventory is reduced, lowering insurance and handling costs and increasing cash flow.
- Materials needed only locally can be locally sourced and produced to assist with corporate social responsibility initiatives.

Tradeoffs

Tradeoffs of postponement include the following:

- Requires process, equipment, product, and packaging redesign capital expenditures
- Can actually increase costs if there are few varieties of the end product

Glocalization

As international companies strive to educate their employees on cultural protocols around the globe, they are also indirectly contributing to their knowledge about the types of products that would be embraced by these various groups. How can they work toward meeting the particular needs and wants of different markets around the globe—by designing new products or services, or by redesigning existing ones? **Glocalization** is a hybrid term based on the words globalization and localization, coined by Japanese economists in the 1980s and popularized by sociologist Roland Robertson. According to the *APICS Dictionary,* 16th edition,

> When used in a supply chain context, glocalization is a form of postponement where a product or service is developed for distribution globally but is modified to meet the needs of a local market. The modifications are made to conform with local laws, customs, cultures or preferences.

Here are some examples of glocalized products from international companies:

- Some fast-food restaurant chains are "glocalizing" their menus. For instance, McDonald's offers different menus to correspond to the tastes of the community or region. In India, they offer more vegetarian options; in Israel, they serve kosher food. Pizza Hut in Macao, China, offers squid rather than pepperoni to match their customers' palates.
- General Electric's handheld electrocardiogram device and a portable PC-based ultrasound machine were developed for rural India and China to provide improved quality, increased access, and less cost. Rural patients no longer have to choose between going to urban medical providers and going without medical care.
- Yahoo!, an international internet company that is headquartered in California, successfully markets its web portal in 25 countries by offering localized versions of its website and related services. A Yahoo! website visitor can view customized content and the latest local news, entertainment, and sports from their area 24/7.
- MTV, an international cable and satellite television channel, customizes its broadcasts of popular music and promotional music videos to appeal to audiences of all ages and tastes in about 150 countries and nearly 20 languages.
- Unilever has created more than 400 brands of food and health products that it markets around the globe. One product in particular, mayonnaise, is formulated differently for the variations of tastes preferred by people in the Netherlands, Belgium, and France. Unilever's food scientists and marketing teams have been able to pinpoint the preferences of the mayonnaise connoisseurs of these countries.

Glocalization is similar to a **multicountry strategy,** which has, as we learned in Section A, self-contained country markets in which "customers have unique product expectations that are addressed by local production capabilities" (*APICS Dictionary,* 16th edition).

Need for reverse innovation

According to a *Harvard Business Review* article, "How GE Is Disrupting Itself," glocalization was successful when wealthy nations comprised the majority of the market and less-developed countries didn't have much to offer. The authors state that this 30-year time period of glocalization is over and multinational corporations

now need to put effort and funds into global reverse innovation, because success in developing countries is contingent on ongoing sales in these countries. Reverse innovation involves developing innovative new products that meet specific needs and budgets of customers in particular markets using a decentralized, local-market focus.

According to the article, the following are two glocalization “assumptions” that General Electric learned are in fact not true and that need to be updated:

- GE had assumed that emerging economies would evolve the same way as wealthy economies. In fact, developing countries don’t evolve the same way, because they are more willing to adopt breakthrough innovations and they have less money to spend. So, for instance, innovations in low-cost medical devices, alternative wind and solar power, and water desalination are becoming more abundant in emerging markets.
- GE had believed that products that address developing countries’ unique needs would not be sellable in developed countries. Instead what has been demonstrated is the ability of these products to create brand-new markets in developed nations. They are able to do this successfully due to their significantly lower price points and novel new applications.

GE has embraced reverse innovation and has experienced positive results: It created and placed numerous local growth teams. These teams have helped GE better customize product objectives, customer training, and key metrics. For example, using reverse innovation, it doubled the number of low-cost ultrasound machines made in China from 2006 to 2010.

Topic 7: Sustainability

Sustainable supply chain management was mentioned a couple of times in Section A of this module (and is covered in detail in Module 3, Section A). This topic looks at some sustainable design processes, including design for the environment, design for reverse logistics, and design for remanufacture.

Design for the environment

Design for the environment (DFE) requires "considering health, safety, and environmental aspects of a product during the design and development phase of product development" (*APICS Dictionary,* 16th edition). It has become a feature of product design due to customer demand for sustainability, increased government regulations, and a greater organizational focus on corporate social responsibility. DFE aims to create a product that lives and ends its life cycle economically, with the least damage to the customer, the company, and the environment.

Design for the environment includes the following considerations:

- **Provision for reuse or recycling.** Rapidly increasing garbage is one unfortunate feature of the consumer society. Good end-of-life-cycle design takes into account the potential for reuse (at best) or recycling (at least). Service stations and other businesses that sell motor oil in the United States must agree to receive used oil and recycle it—for a fee. Germany requires domestic beer brewers to use refillable bottles. Reuse is generally easier on the environment than recycling, since it involves less (or no) processing, but using recyclable materials is friendlier to the environment than design for the landfill.

- **Reduced energy consumption.** Collaborative teams can design products that use less energy—such as the hybrid gas/electric automobile or an energy-efficient appliance. Manufacturing engineers and logistics specialists can also contribute to designs that take less energy to build and transport.

- **Avoidance or mitigated danger of hazardous materials.** Design can make some products less hazardous—taking lead out of paint and gasoline, for example. For products that remain inherently dangerous, designers can consider all possible ways to mitigate the hazard. Cars, for instance, can be designed to lessen the likelihood that gasoline in their tanks will explode in a collision—and all along the supply chain, right up to the pump that dispenses gasoline in the service station, careful design of facilities and instruction of handlers can reduce product hazards.

- **Use of lighter components and less material.** When it comes to environmentally friendly products, less is definitely more. A lighter-weight car gets better mileage. Lighter products have fewer materials in total and lower transportation costs.

Benefits

Potential benefits of design for the environment include the following:

- Consistent with supply chain management's attention to all phases of the product life cycle
- Enhanced corporate reputation and resulting goodwill
- Limits on corporate liability and legal costs that can result from harm to the environment or violation of regulations

- Increased marketability among ecology-minded consumer segments (ads can emphasize a product's benefits for health, clean air, etc.)

Tradeoffs

Tradeoffs of design for the environment include the following:

- Increased manufacturing expenses and higher price to the consumer
- Reduced safety and convenience when some products are small and light
- Reduced longevity of natural, less-processed products

Design for reverse logistics

Supply chain managers have for some time been paying an increased amount of attention to reverse logistics, or the reverse supply chain, which begins with the customer and moves toward the manufacturer or suppliers. The reverse chain handles products that need to be returned, repaired, replaced, or recycled.

This implies several imperatives for the design team. Product packaging can be designed to account for common consumer frustrations such as not knowing to install a memory chip before a cell phone will start working. Clear instructions or a help line can reduce the number of returns based on user error.

If the product has to be returned for repairs or replacement, the process of doing so should be simple for the user. This might include ease of disassembly for repairs, an affordable warranty program, a box that can be used for shipping and return, well-trained and accessible customer service personnel, and comprehensible instructions—as well as a product designed to endure.

Benefits

Potential benefits of design for reverse logistics include the following:

- Enhanced customer loyalty resulting from ease of repair, replacement, return, and recycling
- Lower cost of returns
- Improved product designs through attention to reasons for returns

Tradeoffs

An issue in design for reverse logistics is that this is a complex system that can often be underestimated. It may not be able to use the forward supply chain logistics infrastructure and has added costs such as warranty expenses and restocking fees.

Design for remanufacture

Design for remanufacture is defined in the *APICS Dictionary,* 16th edition, as

> products developed in a manner that allows components to be used in other products. This process is associated with green manufacturing.

Design for remanufacture involves a strategic decision during the design phase of a new product to remanufacture the product for resale. In general, 70 percent of the cost to build something new is in the materials and 30 percent is in the labor. By implementing remanufacturing, companies can effectively address the larger cost component of reclaiming products after they have been used for one or more life

cycles.

With material and resource costs expected to increase, the cost advantage of remanufacturing lies in the fact that items normally discarded can become raw material for the next product life cycle, eliminating waste and closing the loop on the system. In addition, environmental laws that are being instituted in the European Union and are expected to follow in the U.S. may force companies to embrace remanufacturing as a sustainable practice.

Remanufacturing is a service business as well as a product business. For the process to work, companies have to form a replacement relationship with customers. For example, Caterpillar, the heavy equipment company, has created a separate division for remanufacturing. When a customer replaces a product, they are offered a remanufactured one for about half the price. However, the customer will be charged full price until he or she turns in an old product—one that is inspected and certified as remanufacturable. Thus, customers benefit by becoming Caterpillar's partner. Customers are actually creating assets, in the form of returned products, for their supplier. In return, they receive less expensive replacement parts, so they can keep their fleets running with minimal downtime.

Benefits

Proven characteristics of design for remanufacturing include lower cost to the customer, lower impact on the environment, and lower product development costs. Also, the increasing costs associated with materials and resources and impending environmental laws make remanufacturing an attractive option for various companies.

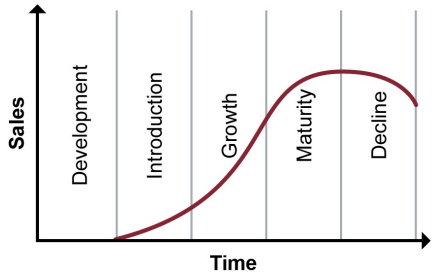
Tradeoffs

The primary tradeoff of remanufacturing is that rather than receiving full cash, the manufacturer receives parts as partial payment, so cash can be tied up in inventory longer. Note also that in the U.S. and possibly elsewhere a remanufactured product cannot be sold or marketed as a new product.

Topic 8: Product Life-Cycle Stages

Product design is only the first step in a product's life cycle. In supply chain, it is important to remember that after a product has been designed, produced, and sent off into the market, the product life cycle undergoes different stages which impact how a supply chain for a product might be handled. The **product life cycle** can be defined as "the stages a new product goes through from beginning to end." (Refer to the *APICS Dictionary,* 16th edition, for more information.) As illustrated in Exhibit 1-32, the traditional product life cycle from a classic marketing view includes development, introduction, growth, maturity, and decline.

Exhibit 1-32: Product Life Cycle



- **Development.** Product (or service) development is the incubation state of the product life cycle. There are no sales at this point, as the organization prepares to introduce the product. Traditionally, this is the period when market research, product design or service definition, testing, and finalization are accomplished.

- **Introduction.** During the introduction stage, sales of the product or service will be low until customers become increasingly aware of it and its benefits. The organization is likely to have additional costs associated with establishing distribution of the product or service. The higher costs added to the low sales volume typically make this stage a time of negative profits.

- **Growth.** The growth stage is a time of rapid revenue growth. Sales increase as more customers become aware of the product and its benefits. Once the product has proven success and customers begin seeking it, sales will continue to increase as retailers become interested in offering the product. Distribution may be expanded at this point. During this stage, competitors may enter the market. The organization's promotional costs may increase in order to sustain market share.

  As the base of customers and distributors grows, businesses must commit increased resources to both satisfying the market's needs and gathering and analyzing data in an ongoing manner. Production and inventory levels must be managed to avoid stockouts or delays that could lead to customers switching brands. A make-to-stock strategy may work well for many products in the growth stage.

- **Maturity.** The maturity stage is the most profitable. While sales continue to increase, they do so at a slower rate. Competition will result in decreased market share and/or prices. The competing products may be very similar at this point, making it difficult to differentiate them from that of the organization.

- **Decline.** Eventually sales begin to decline as the market becomes saturated, the product becomes technologically outdated, or customers' tastes change. If the product has developed brand loyalty, profitability may be maintained longer, but with the declining production volumes and increased unit costs, eventually no more profit will be made. Organizations that used a make-to-stock strategy may need to transition to a make-to-order strategy to prolong profitability as long as possible. Ideally, new products have been developed and the cycle will continue.

The purpose of learning the differences between these phases is to enable product life cycle analysis and management. The *APICS Dictionary,* 16th edition, defines **life cycle analysis** as

> A quantitative forecasting technique based on applying past patterns of demand data covering introduction, growth, maturity, saturation, and decline of similar products to a new product family.

The *Dictionary* defines **product life cycle management** as

> the process of facilitating the development, use, and support of products that customers want and need. PLM helps professionals envision the creation and preservation of product information, both to the customer and along the reverse-logistics portion of the supply chain.

Chapter 4: Technology Design

This chapter is designed to

- Show how information technology can reduce friction in the supply chain by enabling new strategies and operational methods
- Classify information system infrastructure: databases, networks, software, and configuration
- Show how the return on investment for an IT initiative is computed
- Show how IT fits in a comprehensive supply chain management system
- Examine the impact of automatic identification systems and automatic identification and data capture devices, including bar codes, warehouse automation, and radio frequency identification

Without technology, the current concept of supply chain management would not exist. Technology has allowed businesses to move from department-centric spheres of control to a focus on business processes that spans departments and extended supply chains. As technology has evolved, it has enabled increasingly complex business strategies, metrics, and analysis, which in turn have sped up the pace of business and given business a global reach. Technology is quickly becoming a world-class performance enabler because it helps interconnect the key elements of a value-driven network.

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: Role of IT in Supply Chain Management

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 *APICS Dictionary,* 16th edition, 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" (*APICS Dictionary,* 16th edition), people 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 sets a new 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 2: Information System Architecture

The degree of efficiency and effectiveness of a supply chain's functions is limited by the velocity of information (ease and speed involved in creating, compiling, transferring, understanding, analyzing, and using information). The information system architecture is the key to increasing the velocity of information.

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 need to understand an organization's information system architecture at a high level even if this architecture already exists so that they can determine if it needs to be changed or upgraded to facilitate a specific supply chain strategy.

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 *APICS Dictionary,* 16th edition, 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 *APICS Dictionary,* 16th edition, 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.

Details of database types are provided in another section.

Networks

The *APICS Dictionary,* 16th edition, 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 (LAN). 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.

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 (WANs) to share information between geographically dispersed facilities. The *Dictionary* states that a **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 *APICS Dictionary,* 16th edition, 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 *APICS Dictionary,* 16th edition, 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), 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 fee. The user owns the software, and the vendor or developer provides support and updates according to the terms of the licensing agreement. An alternative to this is **software as a service (SaaS),** defined by the *APICS Dictionary,* 16th edition, 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 applications do not have licenses. Software payments are for subscriptions (usually monthly). User access and use ends when the user stops paying for the subscription.

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 1-33 summarizes some basic advantages of SaaS for users and vendors.

Exhibit 1-33: Key Advantages of SaaS

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 software licensing fee • Only one active version to support • 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, and 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 are either mainframe systems or servers. The O/S 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.

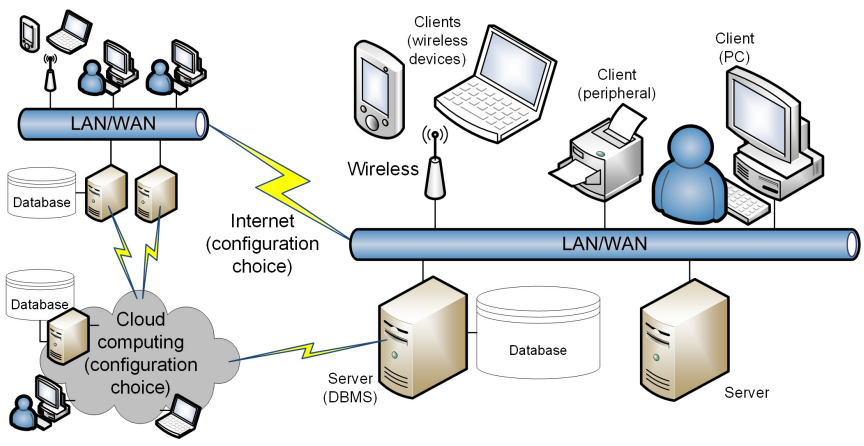
Another option for configuration with supply chain partners or other internal offices is cloud computing. **Cloud computing** allows authorized members to have virtual access to a network of remote servers and databases no matter their actual location.

Cloud computing deploys powerful computing applications, platforms, and services over the internet. The "cloud" is a network of data centers enabling computing resources to be accessed and shared as virtual resources in a secure and scalable manner. While cloud computing is often advertised as a way to connect with external service providers, it can also be used for internal purposes. For example, large companies can virtualize their own servers and create internal clouds that can save money and provide better results than having dedicated servers for each application.

At this time, standards for connecting the computer systems and the software needed to make cloud computing work are not fully defined, and vendor technologies differ. However, many SaaS cloud-based systems do have ways to interface with an organization's enterprise resources planning systems, for example. As cloud computing continues to gain mass appeal in corporate data centers, supply chain applications will undoubtedly grow. According to 2014 Infosys and Verizon Enterprise Solutions surveys, cloud computing has entered the mainstream and businesses want to use it both to reduce costs and to increase business agility. Many ERP systems have enhanced their delivery methods using cloud- and web-based access, and cloud-only ERP systems such as NetSuite also exist.

Exhibit 1-34 shows the technology components of information system architecture, including the connection to external system(s) over the internet or via cloud computing.

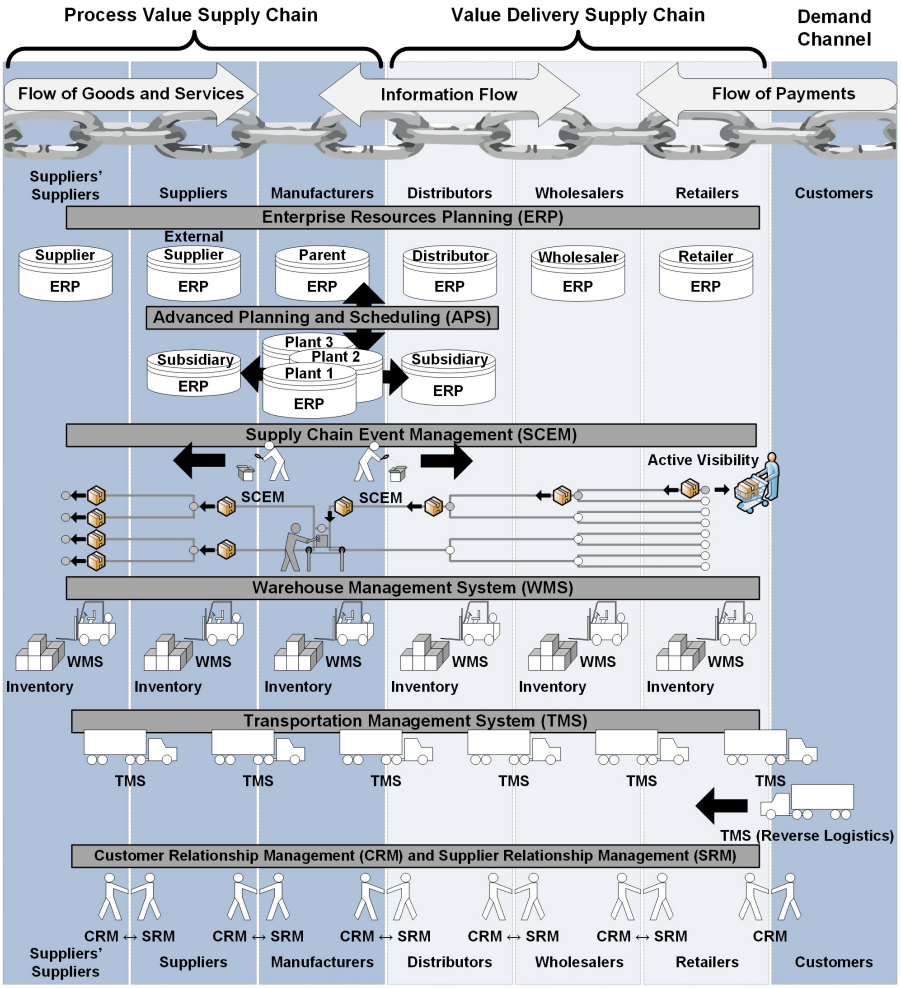
Exhibit 1-34: Information System Architecture Components



Comprehensive Supply Chain Management System

Exhibit 1-35 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.

Exhibit 1-35: 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.

Topic 3: Benefit-cost Rationale for New Technologies

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 a computer project. New technology should be matched to the company'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 proved successful before 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 1-36 displays some tangible and intangible benefits of successful IT investments.

Exhibit 1-36: 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 1-36 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.

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 include annual license fees and maintenance fees for vendor support, 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 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 1-37 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 ERP system has estimated total benefits at US$345,000 in tangible and intangible savings and performance increases over five years. The company also tallied US$259,000 in tangible and intangible costs for five years.

Exhibit 1-37: 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.

Topic 4: Implementation Considerations

Even after a cost-benefit analysis has been conducted and a positive ROI has been calculated, it is important that before an IT project is initiated that the proper analysis is conducted. Administering an organization-wide audit to analyze the firm's current capabilities and mitigating typical IT risks can help to ensure a successful launch.

Technology Audits and Implementation Reviews

A thorough analysis of the organization is required before making IT investments. What are the firm's current networking capabilities? What is needed to get to the next stage of supply chain development? A technology audit can answer such questions. It can also help in mitigating risks (see below) and allocating technology spending.

IT audits test for system availability, security, confidentiality, and integrity. They play a critical role in compliance with the U.S. Sarbanes-Oxley Act of 2002 (SOX), which requires U.S. public companies to establish adequate internal financial reporting and IT controls. (Canada has a similar Bill 198, known as "Csox.") For example, an IT audit should reveal that persons who approve purchase orders cannot also receive goods.

The audience for a technology audit is upper management, not IT or a specific department. The audit may investigate multiple companies in the supply chain and report to a cross-enterprise executive committee or boards of directors.

Technology audits include pre- and post-implementation IT reviews, system development life cycle (SDLC) reviews, and database reviews.

A post-implementation review addresses whether or not the company got the expected return on investment. Reviewing lessons learned can help the next project be more successful. If the review is included as part of the initial project plan, each manager will have a strong feeling of accountability. A post-implementation review should focus on items that can be measured and therefore managed. Incentives for project team members are key to success in achieving overall supply chain goals. These incentives should include financial success as well as other measures such as customer satisfaction and quality (i.e., a balanced scorecard system). Stock price is not a fair measure for IT investment because it fluctuates in response to many factors.

Audits can reveal

- Software vendor promises that were false
- Failure to provide the promised level of system integration
- That full features of the software are not being exploited because of resistance to change or inadequate training.

The results of audits are rarely entirely positive, but negative results should be used to create positive organizational change.

The external auditor's recommendations on IT should include an explanation of the cost of continuing to use

the existing technology versus replacement cost. A benefit-cost study from historical past estimates and true costs can show where costs were poorly estimated or overlooked. If current or prior investments had a negative ROI, the auditor should indicate how future IT can produce a positive return, such as by using add-ons to current technology.

Mitigating Typical IT Risk

To be successful, IT projects can mitigate typical risks by adopting the following approaches.

- **Make incremental improvements.** Management may be tempted to try to solve all problems in one mega project. These large projects are hard to manage and prone to failure. Organizations that take incremental steps can add innovation between steps.
- **Clearly define business requirements.** Because evaluations take weeks and thousands of vendors can be available, management must be convinced from the start to clearly define business goals to ensure that evaluators have met management's principal criteria.
- **Perform due diligence on proposals.** Rather than rely only a marketing presentation from the provider, IT purchasers can limit the risk of a new system by interviewing previous purchasers and using third-party evaluators. Many project failures are traced to processes or proposed software that were not properly understood.
- **Control scope creep.** The activities required to carry out a project should be fully and carefully defined in written documents. There should also be written procedures for defining and estimating the costs of additional work.
- **Control excessive customization.** When packaged software cannot fit the organization's business processes perfectly, a dilemma organizations may face is deciding whether to adapt their processes to fit the standard delivered functionality or to customize the software to allow current practices to remain in place. A good rule of thumb is to look for packages that meet at least 80 percent of needs "out of the box." The remaining 20 percent can be met through customization. While there will be short-term pains in pursuing organizational change over customization, in the long run it will lead to a much lower total cost of ownership, easier software upgrades, and less expensive training of users. Many companies have faced expensive technology issues because they customized software when they should have updated and changed their business processes. Note that some customizations are riskier than others. At the low risk end, many software packages have built in extra "blank" data fields for custom use; far riskier customizations involve altering raw source code.

Supply chain risk management is covered in detail in a later section.

Chapter 5: Key Technology Applications

This chapter is designed to

- 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

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

Topic 1: ERP Systems

The *APICS Dictionary,* 16th edition, defines **enterprise resources planning** 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.

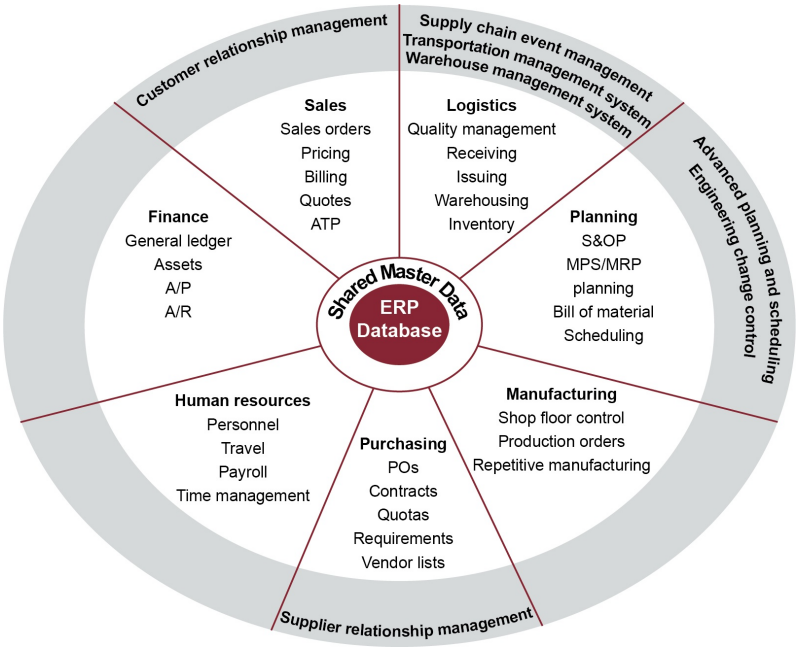
ERP software is a modularized suite of business applications that are seamlessly integrated to provide automated interactions and a common source of data. ERP systems are built around a large database with shared access to data and include a number of transactional modules (for example, planning, manufacturing, 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 1-38 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 1-38: ERP System Functionality



ERP components

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 set corporate 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 make use of 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 in a later section.) 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 1-38 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 1-38 shows that ERP systems are continually evolving and adding new functionality such as CRM, SRM, SCEM, TMS, WMS, engineering change control (ECC), or APS. Engineering change control, 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, 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 utilize 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.

Use of 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 ROI 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, translation 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. As mentioned previously, 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.

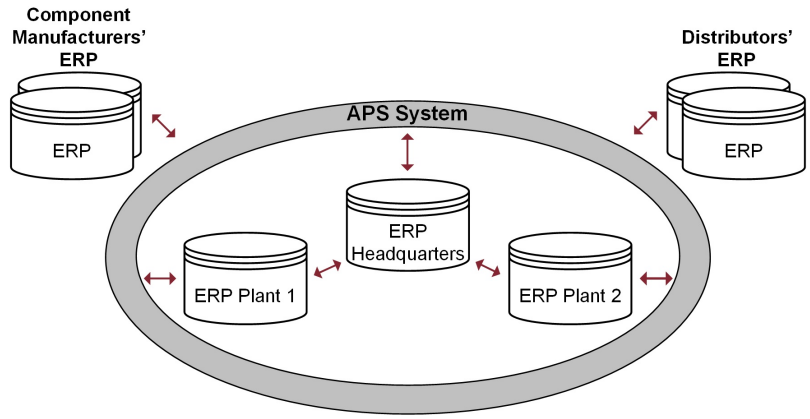
Topic 2: Advanced Planning and Scheduling Systems

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 1-39 illustrates, APS is an intermediary to ERP systems that feed it.

Exhibit 1-39: Advanced Planning and Scheduling Systems



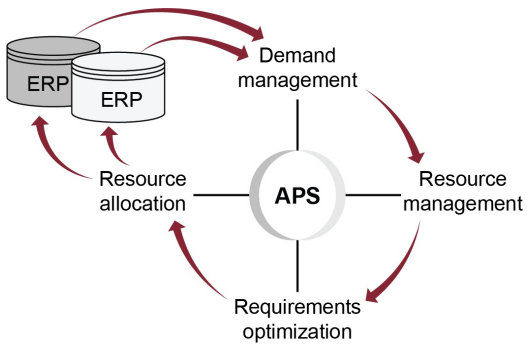
APS applications use analytical tools such as modeling, optimizing techniques, and simulations. APS usually includes user-friendly planning tools such as interactive scorecards and drag-and-drop functionality in its interfaces. These advanced tools help plan at the strategic, tactical, and operational 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 1-40 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 1-40: 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 *APICS Dictionary,* 16th edition, 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.

Benefits of APS

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 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.

Topic 3: 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.

Such alerts are 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 TMS or WMS, for example, when optimizing or making ATP 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 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.

Topic 4: 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 ERP 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 (uses 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. These automatic identification technologies are discussed in another section.

Web-based WMS

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 SaaS.

Web-based WMS has functions such as 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 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

Topic 5: 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 container ships.

- **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 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.

Web-based TMS

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 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.

Chapter 6: Data Acquisition and Management

This chapter is designed to

- Discuss the need for timely and accurate data
- Compare data acquisition and communication tools, including interface devices, data communications methods, and database types

Sometimes supply chains are all about computers talking to one another without human intervention. Many companies process millions of transactions per day. A vast amount of data that can be used for numerous purposes is produced. For 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.

"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 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. The *APICS Dictionary,* 16th edition, defines **big data** as "collecting, storing, and processing massive amounts of data for the purpose of converting it into useful information."

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.

For 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 vendor 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.

These materials cover a number of factors related to data acquisition and management which includes types of data, data capture and several methods to accomplish it (including automatic identification technologies and point-of sale systems), various types of databases, interface devices (devices used to get otherwise incompatible systems to work together), data communication methods, data accuracy, and data analysis.

Topic 1: Data Capture and Storage

Data can be either static or dynamic. Static data include plant locations, warehouses, stock keeping units (SKUs), or part numbers; dynamic data include forecasts, current deliveries, and direct materials and direct labor costs. Some dynamic data are entered as standard costs/time (a "should cost" amount or time period) for planning purposes, and the actual cost/time data are recorded when available and compared to the standard. The expected use of the data should be a primary driver of the data to be collected.

The types of data used will vary between department, company, supply chain, and industry. The most

important data for analysis include

- Purchase orders for raw material cost and spend analysis
- Orders for demand analysis, customer profitability, and customer service
- Inventory data for working capital, customer service costs, and obsolete or excess inventories
- Shipment data for network optimization, transportation spend analysis, carrier performance analysis, and transportation rate negotiations
- Customer and supplier master files.

Data exist for every department and area of a company. For example, customer data include customer order history, point-of-sale (POS) data, and the customer master file, among other things. 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.

Data Capture

While the goals of greater collaboration are easy to see at a high level, the first hurdle can be difficult. 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. Without accurate and timely data, no other aspect of supply chain management can be fulfilled.

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, organizations can become overwhelmed by too much data—the "big data" we looked at earlier. More data than is 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 money. 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. (These data capture methods are discussed below.) 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 in the process measurement is required 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 technologies and point-of-sale systems.

Automatic identification technologies

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

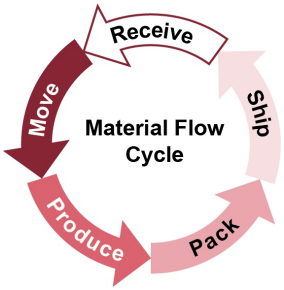
are faster information visibility and increased transaction accuracy and processing speed.

Unlike just having a serial number on an object, an AIDC device can communicate the object's presence. AIDC devices have two key features: automatic classification and automatic identification. Proper classification is a prerequisite to creating a unique identifier for an item. The 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.

Because the internet allows access to information from anywhere, AIDC devices can classify and identify themselves on a network. Instead of trying to keep all product data on a tag, or even in a static database, only a unique identifier is required and the product data for the AIS can be stored on the internet.

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 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 1-41.

Exhibit 1-41: Automatic Identification System (AIS) Interface Points



The benefits of automated identification devices include reduced errors and lead times, productivity increases, optimized storage density, better response times, and more accurate shipping and inventory leading to less shrinkage. The cost of purchasing, implementing, and maintaining such technologies should be offset by the benefits, especially if paperwork can be eliminated.

The following content looks at types of AIS and related AIDC devices, 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 a 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 that likely includes 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.

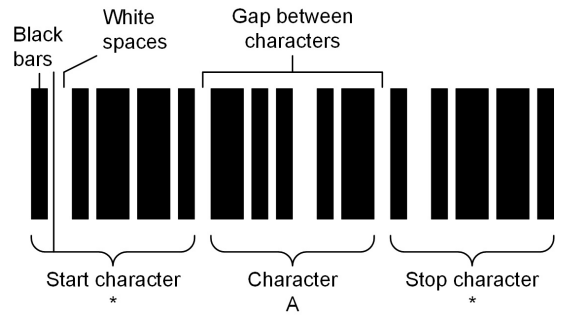
The bar-code system is heavily integrated in all areas of the supply chain. It will continue to coexist with other methods of data scanning such as RFID because bar-code labels are very inexpensive compared to RFID tags. Most RFID labels have a bar code on the outside of the tag for use with either system. RFID and bar codes can be complementary; when an RFID tag experiences 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 (ERP, TMS, WMS, or POS capture)
- Applications to process the data collected.

Exhibit 1-42 shows a typical bar-code label.

Exhibit 1-42: 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 a hundred 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. Exhibit 1-42 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 Exhibit 1-43, 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 in retail sales for checkout at cash registers.

Exhibit 1-43: 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.

One type of bar code gaining in popularity is the 2D code. A 2D bar code can be scanned by mobile devices

for automatic redirection to mobile-friendly websites (assuming the user has downloaded the appropriate application). 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. Exhibit 1-44 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 are one of the types of bar code that can be used to identify an item by its serial number.

Exhibit 1-44: 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 *APICS Dictionary,* 16th edition, 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 *APICS Dictionary,* 16th edition, 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" (*APICS Dictionary,* 16th edition). 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" (*APICS Dictionary,* 16th edition). 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" (*APICS Dictionary,* 16th edition).

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 development. Implementations at lower stages will lead to an inability to use the gathered information. (The company will experience 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 and 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 *APICS Dictionary,* 16th edition, 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.

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 with gross annual sales of more than US$100 million designs and creates high-quality running shoes and apparel and distributes goods through three outlet stores. For several years they have had a great deal of trouble managing their inventory at these outlet stores 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.

Impact of automated data capture on supply chain performance

The movement from paper-intensive activities to these 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 in 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 use an AIS, 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.

Such savings are vital to track because they will help offset the investment in hardware and software

required when installing automated data capture systems.

Now that we've looked at data capture, we'll examine ways to store and communicate data.

Databases

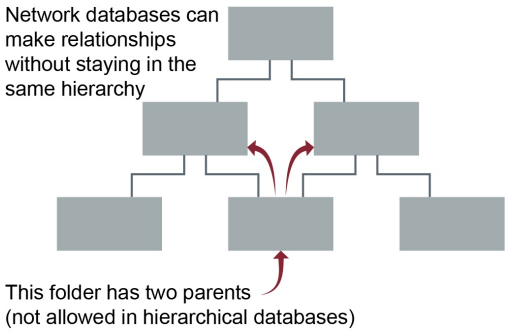
Databases are repositories for all of the electronic records and information collected from internal and external sources. Databases can be easy or hard to search, and associations between data can create or minimize redundancies.

Various database types exist to serve specialized needs:

- **Hierarchical databases.** Hierarchical databases are arranged in a hierarchy, meaning that higher level folders (parents) are created and subfolders (children) are placed under them, those folders have their own subfolders, and so on. This type of database is not used much anymore because making associations between folders not in the same branch requires duplication of data, which is very difficult to keep accurate.

- **Network databases.** Network databases assign relationships between data in any way that is needed. While hierarchical databases can arrange data only in a hierarchy (one parent to many children, but each child always has only one parent), in a network database, a child can have more than one parent, as shown in Exhibit 1-45.

Exhibit 1-45: Network Databases



Network databases have niche applications. For example, network installation tools use network databases to allocate resources (such as a printer or access to a database) and to provide visibility into those resources. However, for the most part, relational databases are used for most types of data storage.

- **Relational databases.** The most common form of database is the relational database, which groups data using common attributes. It stores each type of data in a single location with many links to it. Microsoft Access is a basic example.

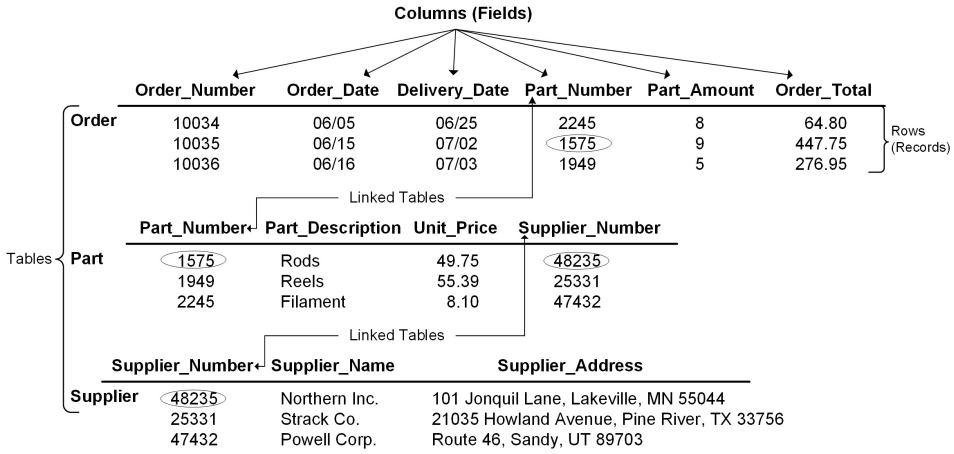
  In Exhibit 1-46, for example, there are separate tables for data about orders, parts, and suppliers. Any

two tables with a common data element can be related to one another. In the exhibit, the order and part tables both contain part numbers; the part and supplier tables both contain supplier numbers.

Although a field (such as part number) may be contained in more than one table, it will be managed within only one of those tables. The other tables containing that field do not “own” it; they merely display it. In Exhibit 1-46, for example, part number appears in two tables but is owned by the part table.

The tables can reside on a single PC or server or across multiple servers that are geographically dispersed and virtually connected through a cloud or other network to ensure data security from natural disasters.

Exhibit 1-46: Relational Database



Topic 2: Interface Devices--Middleware

Interface devices are designed to take data from one software system and format it for direct use in another system. These devices 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.

Some software systems may be inherently incompatible or reside on different hardware platforms. 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.

Software called middleware is often used to create an interface between two or more other software systems. **Middleware** is "software that interconnects incompatible applications software and databases from various trading partners into decision-support tools such as ERP" (*APICS Dictionary,* 16th edition).

Middleware is exactly what its name implies: It is software that sits in the "middle" between two applications and enables them to communicate with one another. The applications could be within the same company or at different companies. There are different types of middleware, and the term is often used broadly to refer to any technology that enables communication between two systems.

So, why should a supply chain professional care about middleware? Because middleware 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 the kind of optimized and collaborative supply chain that this course is all about. Middleware also enables secure transactions through authentication (preventing unauthorized users from gaining entry) and authorization (ensuring that users can only perform authorized transactions or access their own data).

A simple example will illustrate the use of middleware. Imagine you are having a party and want to send invitations telling people the key information, including the date, time, and address of the party. After you send out your invitation, you would like people to respond with two key pieces of information: whether they are coming or not and how many people they will be bringing. Now imagine that this is your first week at a new international school and many of the people that you are inviting speak a different language. One way to accomplish your goal is by finding out all of the different languages that your invitees speak and then translating your invitation word by word into each of their languages. Each of them will understand your invitation, and then they will translate their response into your language and send it back to you. Another possibility would be to use an online invitation service that everyone signs up for. This service has a standard template ("the party invitation template") that you can use to enter the essential information. The service can then translate this standard template into different languages for your various guests. Your friends can enter their responses into a standard response template in their own language, and that information will be transmitted to you in your language.

As you can guess, the first method will be the most time-consuming and expensive for you, but it will allow you to personalize your invitations and you will have the ability to include any information you want. This method would be called data-oriented middleware.

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 each shared data field must be mapped out. If two companies want their systems to “talk” to each other, they can map the fields one by one. When one system sends information with a “product number,” the receiving system knows that “product number” is what it calls “Finished Good ID#.” It will work to tie those two applications together, but if you decide you now want to link to a third application, you will have to start from scratch.

Implementing data-oriented middleware is a labor-intensive process that will result in effective and fast communications, but the process may need to be repeated not only to add a new software system but also after upgrades. Therefore, this middleware option is expensive and may not provide long-term benefits.

A related approach to data-oriented middleware is custom linkages, which are custom-programmed data-oriented links that are developed from scratch rather than using middleware software as a template. Custom linkages could be less expensive than purchasing and configuring a data-oriented middleware package or can be used when no package is a close enough fit for the applications, and there may be situations in which this process is still less expensive than use of the other type of middleware we’ll look at—process-oriented middleware.

Process-oriented middleware

Another approach to middleware is referred to as process-oriented middleware, or business process management software. The *APICS Dictionary,* 16th edition, 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.

This is where each application maps to a standard process. For example, what one calls “party date” and another calls “day of party” are both mapped to “event date” in the standard process. This can be much less expensive because, if dealing with multiple companies with different systems (or multiple party invitees who speak different languages), messages have be to “translated” only one time.

Process-oriented middleware is smart middleware. 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 replacing systems or attempting to make them congruous. Basically, process-oriented middleware

manages entire conversations rather than individual data. It requires businesses to focus on processes and has therefore had a side benefit of process simplification.

Process-oriented middleware

- Gives multiple systems a common communication method
- Accommodates multiple protocols and messaging standards
- Integrates commercial software and legacy systems using standard tools
- Attaches easily to existing middleware (and their integrated systems)
- Adds flexibility to the interactions between modules and systems
- Records transactions centrally in a data warehouse, providing visibility
- Does not require new code for each new system, unlike data-oriented middleware.

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.

Disadvantages of process-oriented middleware are that it may not be as simple to integrate with existing systems as advertised and different process-oriented middleware in the same supply chain may be complex to integrate.

Topic 3: Data Communications Methods

Data communications methods are the computer languages and methodologies that enable interface devices to function; they also enable communications to occur between systems without any interfaces, assuming the systems are using compatible methods.

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 ROI and customer service.

Data communications methods include electronic data transfer, EDI (electronic data interchange) standards, web services, and service-oriented architecture.

Electronic data transfer

Electronic data transfer (EDT) refers to any transfer of information using electronic means. Originally, EDT could take place only through proprietary electronic data interchange (EDI) and electronic funds transfer (EFT). **EDI** is “the paperless (electronic) exchange of trading documents, such as purchase orders, shipment authorizations, advanced shipment notices, and invoices, using standardized document formats” (*APICS Dictionary,* 16th edition). These systems were effective in sending data between two locations if each location was set up using the same standards. Distributed, open standards for EDI combined with the reach of the internet have enabled much more fluid EDI transfers. Funds transfers have their own standards and are necessarily very restricted. (EFT is important for supply chain payments but is outside the scope of this text.)

EDT is primarily performed over the internet today, but that does not limit it to transmissions between computers. Wireless and cellular devices extend the reach of the internet. Systems such as SCEM create event-based exceptions and send them to employees regardless of their location. New software selected 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 a prime consideration.

EDI data standards

EDI data standards include internationally agreed-upon protocols for transmitting data between sending and receiving companies. It is an extranet (outside of the enterprise) protocol in which the data are converted from the sending system’s native format into EDI and, once received, into the receiving system’s format. EDI is a common method of connecting systems that do not run the same applications or ERP systems.

Note that EDI is a type of middleware called content-level middleware. 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 (e.g., using data-oriented middleware) to work with this common format. While this sounds like process-oriented middleware, content-level middleware is less sophisticated. EDI is more like an electronic version of sending someone a paper invoice or other document without requiring data reentry, while process-oriented middleware is more of a method of automating multiple system interactions.

Messages can be sent through a private network for a direct computer-to-computer link between two databases. While private networks used to be the only method of sending EDI messages, web-based EDI handles such messages at a fraction of the setup cost. 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 manage the transaction. Many off-the-shelf applications, ERP systems, and internet marketplaces have entered this arena. For a fee, the processor ensures reliable transfers in a proper format.

Internet-based standards such as web services, XML (extensible markup language), and Java have challenged EDI's prominence, but EDI remains a common method of connecting supply chains for basic transactions. Giant companies have been able to dictate the use of EDI to their suppliers, and use of web-based EDI has helped sustain EDI by lowering costs. However, the common data exchanged is generally very basic and includes things such as customer orders, advanced shipment notifications, and invoices. (An example of the formatting can be viewed in our online Resource Center.) 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, web services-based offerings (discussed below) are gaining on EDI for supply chain management. Many of the more complex messaging requirements involved in supply chain management such as SCEM are too complex and too expensive to implement with EDI.

One way to get more out of EDI without the complexity is to use a value-added network. The *APICS Dictionary,* 16th edition, defines a **value-added network (VAN)** as "a network, often supporting EDI, providing services additional to those provided by common carriers."

Web services

The *APICS Dictionary,* 16th edition, 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.

Web services are portions of software applications or interface devices that are built to be interchangeable "building blocks" that can all work together so that organizations can upgrade or change one aspect of the software without needing to replace or reprogram all of the other parts of the software.

Supply chain web services might include purchase order number, purchase order status, item quantity available, and item quantity due date. Web services make use of all of the specific data elements contained in existing databases that are made available for sharing between specific supply chain partners using different systems. As used in business-to-business (B2B) processes, the term "web services" is often inaccurately applied to data or processes presumably needed by all supply chain partners. However, a web service is unique to specific partners within a specific supply chain.

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. Web services allow developers to integrate and share information among disparate systems. Because web services can be created by any company, the standard isn't monopolized by any firm and the acceptance of the standard is widespread.

B2B web services consist of XML and other XML-based standards that wrap electronic messages in a shell for universal message receipt, advertise the existence of web services, and specify how requests and responses must be formatted. XML is a language that facilitates direct communication among computers on the internet. Unlike the older hypertext markup language (HTML), which provides HTML tags giving instructions to a web browser about how to display information, XML tags give instructions to a web browser about the category of information.

XML's ability to put internet business entirely in the hands of computers and their software makes XML the basic language of internet commerce. The important thing to know about XML is that it is operating in the background of all interactive internet transactions, enabling them to occur despite differences in computer hardware and software.

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 their 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 change application from a different vendor, and their own pricing application. The components would work together as one application. Furthermore, a portion of the application could be upgraded easily.

Service-oriented architecture (SOA)

Web services are frequently enhanced using service-oriented architecture (SOA), which is a style of information technology design that guides all aspects of creating and using business services throughout their life cycles. It allows for widespread and flexible sharing of services created by one supply chain partner for use by another.

SOA is an approach to software design ("architecture") in which applications are assembled from reusable components ("services"). A service is a software building block that performs a distinct function, such as retrieving customer information from a database using a well-defined interface. (An interface is basically a way to call, or request, the service from other programs.) A service could be a credit check or matching an invoice with a purchase order.

SOA differs from other forms of computing in fundamental ways. For one thing, the software is organized into modules. This is not novel in itself; the novelty arises from SOA's two main goals: to achieve loose coupling among each of the services in its architecture 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 put together and take apart with endless configuration options. Universal functionality requires that all messages contain all data necessary to complete processing (rather than assuming that the data can be looked up). This is a major change from traditional programming, in which each application can sort out only its own data. This is what allows the best service provider in each

area to offer its service without having to offer the whole package.

An important 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 suffer from interoperability issues when platforms or systems need to be integrated. While traditional applications required custom interface devices between applications, SOA models can use generic links that are inherently more cost-effective.

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

SOA (and web services) can also handle elaborate tasks. A retailer, for example, could incorporate business rules to reroute trucks automatically based on a weather report. If flooding were forecast, getting sandbags to stores in affected areas could take place seamlessly.

Topic 4: Data Accuracy and Analysis

Ensuring and maintaining the accuracy of data is 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.

Data errors can come from some of the following sources, especially in an extended supply chain:

- 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.

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

Acquiring new software without improving the quality of the data will lead to poor ROI 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.

Analyzing Data

Analysis turns data into business information, or information that is placed in context, is relevant and reliable, and upon which actions can be determined. 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 incorporate shifts in strategies, such as moving from distributed warehouses to a centralized warehouse.

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.

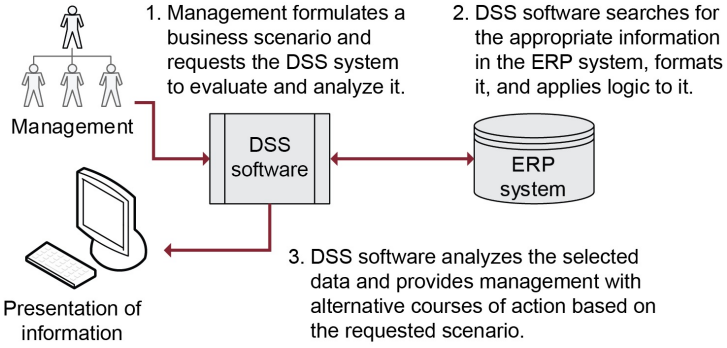
Decision support systems

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" (*APICS Dictionary,* 16th edition). 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 any details that would confuse the issue at hand. Models may not always be purely mathematical versions because a DSS may be needed to help management make tradeoffs between two or more possibly

qualitative objectives.

As shown in Exhibit 1-47, 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 1-47: Decision Support Systems (DSS)



Analysis tools also include data mining, commonly using a data warehouse or a shared interorganizational database. **Data mining** is “the process of studying data to search for previously unknown relationships. This knowledge is then applied to achieving specific business goals” (*APICS Dictionary,* 16th edition).

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.

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 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.

Collaboration with Supply Chain Partners

Collaboration with key supply chain partners is a primary goal of organizations wishing to reach Stage 4 of supply chain development, the extended enterprise. The discussion of the acquisition and use of data should therefore end on this note. Sharing data can help organizations stay competitive by globally optimizing their supply network, sharing both risks and rewards with partners, and using collaborative forecasting and active visibility.

Chapter 7: Electronic Business

This chapter is designed to

- Discuss electronic business fundamentals, including:
    - internet-enabled supply chains
    - e-commerce,
    - business-to-business commerce
    - business-to-consumer sales

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 *APICS Dictionary,* 16th edition, 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 four electronic business models: business-to-consumer (B2C), business-to-business (B2B), consumer-to-consumer (C2C), and consumer-to-business (C2B). All are considered to be types of e-commerce. Since the focus of electronic business is on improving the 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. HTML, which is not a programming language but a way to format text, permits a user to create text, hypertext links, and multimedia elements within a web page. Modern websites also 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 this way, one's website will not appear extremely tiny on a phone or be otherwise difficult to access. In addition to this, some organizations will benefit from developing a downloadable application for smartphones and tablets.

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 1-48 shows how the traditional and electronic business supply chains differ.

Exhibit 1-48: 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.
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.

Topic 1: E-business Considerations

Before we examine the B2B and B2C models, let's look at a number of other considerations related to e-business and e-commerce.

Electronic business strategy

Electronic business was initially so popular that it gained market support even without financially sound business models. Electronic business was touted to reduce costs and increase customer satisfaction and business flexibility, but its lack of profitability was ignored. 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 must be more than a plan to use e-commerce to sell goods. It should enable collaboration with the extended supply chain, including integration of customers and suppliers. Traditional business strategy must still be robust to allow the efficient sourcing, manufacturing, and fulfillment of orders that satisfy actual customer needs. Company and e-business strategy must transform the business and allow 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 the optimization, visibility, and shared planning tools discussed elsewhere in these materials.

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 RFP development, benefit-cost analysis, direct hardware and software costs, hosting, 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. 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 and firms need to ship (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 physical 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 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

Successes—Amazon, Dell, and Alibaba

According to a 2013 eMarketer/InternetRetailer study, U.S. e-commerce sales are expected to reach US$434.2 billion in 2017 and 60 percent of retail sales will involve the web by that date. The European e-commerce prediction is US$248.3 billion in 2017, as reported by Forrester Research.

Although these statistics make e-commerce sound like the answer to assured business growth, different industries and business models have experienced different levels of success from the use of electronic business. Three companies have successfully used it to spur incredible growth: Amazon, originally just an online bookseller; Dell, a pioneer in the direct-to-order assembly of 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, an American businessman, investor, and technology entrepreneur.

- 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 has become the largest retailer on the web, with net sales in 2014 topping $88.99 billion and an average of 175 million monthly unique visitors.
- It serves as a high-performing model of internet-based sales.

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 to 1987.
- 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 cloud, big data, next generation data center, 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.

Mixed results or failures

Other companies have had slower starts. Mega-retailer Walmart's online sales accounted for only two percent of its U.S. revenue in 2012. Walmart grew online revenues at 27 percent in the first quarter of 2015, which put it close to three percent of its revenue. It recently implemented a pay-with-cash method for e-commerce, which allows consumers without credit cards to make online purchases and pay in a store. It has also been piloting same-day delivery (nine percent of consumers rated this as the most important factor in their online shopping experience according to a Boston Consulting Group survey) since 2012, and over 5,000 items qualify for the service. Deliveries are by Walmart's own trucks.

Other companies never figured out how to make e-commerce work to their financial advantage. In the past decade or so, many online retailers made big splashes with national marketing campaigns and expensive TV ads, only to disappear within a few short years: WebVan (a grocery delivery service, 1999–2001); Pets.com (a pet food and supply store, 1999–2002); Geocities (web-hosting services, 1998–2011); and Go.com (created by Disney in 1998 and now used just as the company's related properties hosting site).

Although these companies had high hopes of making it, they were unable to combine their e-commerce skills with long-term, profitable, sustainable business models that could meet their customers' dynamic needs and preferences. Some start-up companies attempted to be pure e-business ventures and survived only by adding a physical layer to their network. Others were the extension of an existing physical network but failed because the company didn't integrate its physical strategy with its e-business strategy. Dividing e-business from the physical business creates an inefficient network that is unable to provide a consistent message to customers.

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 return policy (customers cannot see merchandise until received)
- Reevaluation of wholesale or retail locations on the basis of site profits

Now let’s take a closer look at two types of e-commerce and how they work.

Topic 2: B2B and B2C

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. B2B collaboration technologies are discussed in another section.

Objectives of B2C are to create an additional source of revenue and a wider customer 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, games, or prizes.

Other types of B2B and B2C include virtual services. Virtual service providers are 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.

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 (as well as an intranet or extranet) plus all necessary networking and interface devices. The foundation 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 very expensive, and many companies have formed consortiums to control costs and form a larger community of users.

- **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.

B2C e-commerce

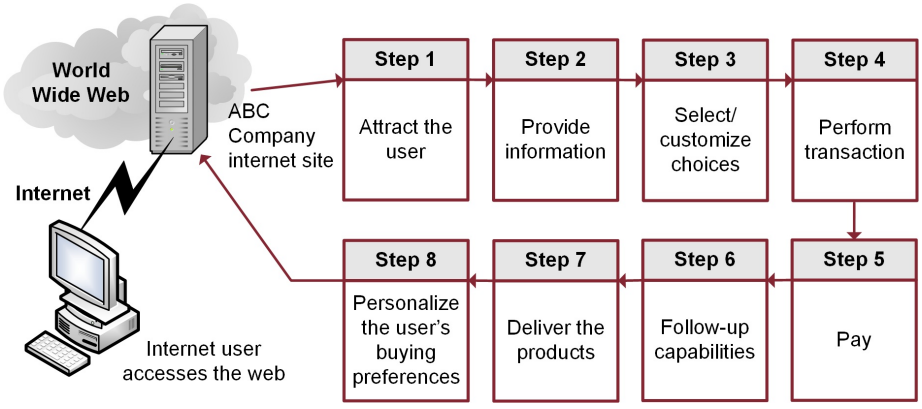
E-commerce was born when websites could be made interactive rather than static. This enabled internet transaction processing and payment acceptance. E-commerce software includes sell-side, buy-side, and content management applications.

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 1-49 shows the steps of an adaptive sell-side e-commerce website.

Exhibit 1-49: Adaptive Sell-side E-commerce Website



Note that sell-side e-commerce and customer relationship management applications are converging.

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 requisition,

sourcing, negotiation, and contract phases as well as supply and payment.

Content management e-commerce

The *APICS Dictionary,* 16th edition, 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.

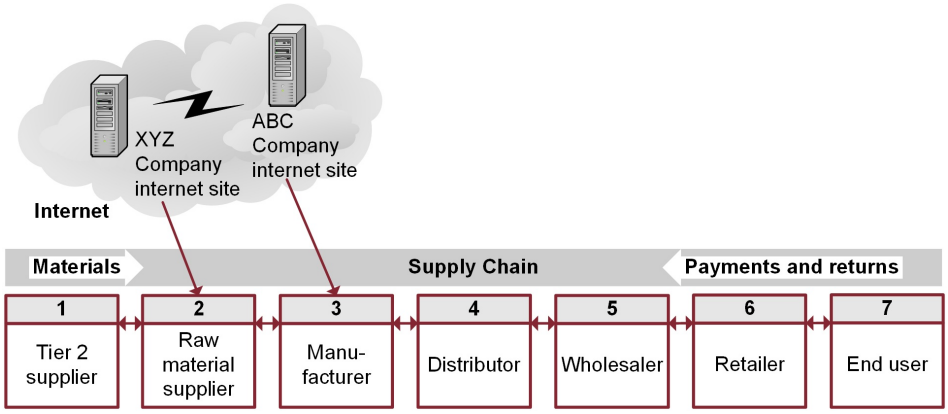
B2B commerce

B2B commerce took off when the internet became viable for data transfer in two directions instead of only one and when smaller businesses could participate due to the low cost of the internet. B2B is characterized by automating traditional business transactions such as formal sourcing.

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.

Exhibit 1-50 shows how B2B commerce facilitates faster and cheaper links in the supply chain.

Exhibit 1-50: Business-to-Business Commerce (B2B)



B2B collaboration

B2B collaboration is an evolution in B2B commerce that 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.

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.

Chapter 8: Implementation Tools—Communications and Projects

This chapter is designed to

- Describe how communications must be tailored to fit the purpose, target audience, and communication channel
- Describe the basic communications model (sender-receiver model) and how to apply it
- Explain when to apply project management to supply chain initiatives and when to manage initiatives as normal operations
- Discuss the basics of project management
- Describe how to manage projects in terms of scope, time, and budget
- Explain what to do in each of a supply chain project's process groups: initiate, plan and design, execute, monitor and control, close.

Topic 1: Communications

Generally defined, **communication** is the two-way process of creating and sending messages and receiving feedback with the goal of influencing the opinions, actions, and decisions of the intended audience. The process includes selecting the appropriate media to best reach the intended audience at the right time.

There are many ways to share and communicate information. Managing communications involves collecting data and information from the various parts of the supply chain or from project team members on supply chain projects, creating discussion guidelines and formal reports, and distributing the information to the right people at the right time. Leadership and management rely heavily on one's ability to communicate effectively.

Stakeholders have different needs, preferences, styles, levels of expertise, and cultural backgrounds, which means that it is doubly important for supply chain managers to adapt to stakeholder needs when it comes to communication. Customizing your communications to reflect these differences shows respect and sensitivity and makes the message more effective. Effective communication strategies that take into account individuals' differing needs and perspectives allow for greater engagement and positivity throughout the process. Achieving supply chain goals and objectives depends heavily upon well-planned and well-delivered communications. Because so much depends upon working with and responding to stakeholder communication needs, it is crucial that time is spent planning for this by collecting information from stakeholders on their communication needs and requirements.

The ability to communicate quickly, succinctly, and accurately can be facilitated by the abundance and diversity of available information, data, and knowledge and by the vast array of technology and media. This abundance can be a gift if it is used wisely, but it can also be a trap in that it can overload your audience with too much information. The basic capability to develop is to know what information needs to be communicated for the given purpose and audience. Ask yourself:

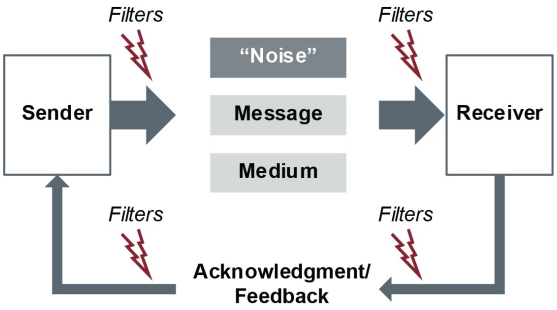
- What does your audience need?
- How does the subject of your communication fulfill the audience's need?
- How can you make the benefits of the presentation clear to the audience?

We will examine how communication occurs as well as the importance of context in influencing the success or failure of the information to achieve intended actions and be put to useful purposes.

The communication process

A basic communication process occurs for all types of communications. This could be when a supply chain manager informally talks with a colleague one-on-one or makes a presentation to multiple people. The intent is always the accurate transfer of the information between individuals or groups. Exhibit 1-51 depicts the elements in the communication process.

Exhibit 1-51: Basic Communication Process



As shown here, communication involves transmitting and receiving information. This is true whether the communication is human or technology-enabled. The following are the key elements in the communication process.

- **Sender—**True to the label, the sender is the person with ideas, concepts, requests, or other information to convey.
- **Message—**This is the subject matter of the process, the translation of the sender's information into a systematic set of symbols or sounds (written, verbal, nonverbal gestures, or some combination). It is sometimes called an "encoding process."
- **Medium—**The medium is the pathway through which the message is sent. It could be oral (conversation, presentation), written (memo, newsletter), or electronic (email, video chat, social media).
- **Receiver—**The receiver is the intended audience, the individual or group that "decodes" or interprets the message in light of previous experiences or frames of reference.
- **Filters—**A filter is any factor influencing how the communication is received or interpreted. Filters may take many forms, such as feelings and emotional states (mood), individual perceptions, experience, and culture. Because of filters, a message may not be received at all.
- **"Noise"—**Noise is essentially anything that distorts a message. Noise can take many forms, including background sounds, another person trying to enter into a conversation, or any other distractions that prevent the receiver from paying attention or accurately understanding what is being communicated. It can also be electronic distortions that corrupt a phone line, file, or program. Similar to filters, noise

interferes with and can inhibit the communication process.

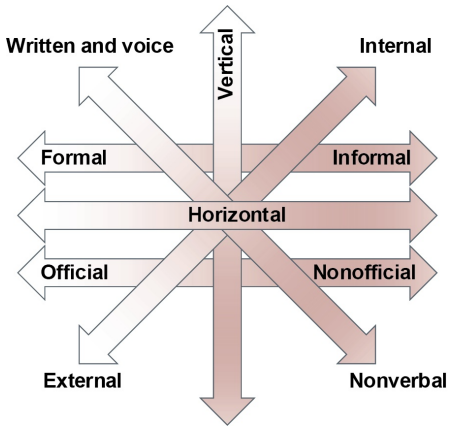
- **Acknowledgment—**The receiver acknowledges the message in a medium to signal that it was received. This does not necessarily imply comprehension or agreement, simply receipt of the message.
- **Feedback—**Feedback is the verbal or nonverbal reply or reaction to the message. It expresses the receiver's understanding of the message. Feedback provides a vehicle for receiver response that allows the sender to assess if the message has been received as intended.

This last element, feedback, is, in fact, the main point of this model. There are things that can get in the way of communication being successful (filters, noise), but insisting on getting acknowledgment and especially feedback as appropriate are the communicator's methods of making messages fail-safe. Close attention to the recipient's feedback will signal comprehension or lack thereof. If the message wasn't received as intended, the sender should revise the message accordingly and repeat the communication process.

Forms of communication

To further illustrate what makes for effective and successful communication, it is helpful to recognize the different forms of organizational communication. As shown in Exhibit 1-52, there are various dimensions of communication.

Exhibit 1-52: Communication Dimensions



Source: Holmes Corporation. Used with permission.

Official/nonofficial communication relates to whether the information is on or off the record. Reports within the company or for public consumption are often considered official, while newsletters, press releases, or annual reports are on the nonofficial side of the spectrum.

Formal/informal refers to the expected level of decorum adopted in a communication and the communication's format.

Formal communication is officially sanctioned and considered informative and factual. Such communication is planned and carried out according to organizational structure and the official chain of command. Because formal communication is highly documented, amendments and changes are restricted. Even if the tone or

format seems casual, a formal communication is designed to convey an official message that should be adhered to. Typical examples of formal communication include mission and vision statements, goals and objectives, organizational brand, policies and procedures, organizational or departmental meetings, staff meetings, publications and newsletters, public relations information, official notices, signage, and training materials and events.

Informal communication is not officially sanctioned information and does not follow any official chain of command. However, the majority of communication in an organization is informal, so its importance should not be underestimated. A wealth of information is spread through informal communication media such as personal conversations, telephone conversations and voice messages, emails, text messages, social gatherings, social media, and impromptu meetings. Such informal communication helps to create and sustain open communication in an organization. Oftentimes, informal communication plays a vital role in tandem with formal communication (e.g., team bonding, networking).

Vertical/horizontal communication refers to the orientation of the communication in relation to a project's or organization's hierarchy. These communications are often between people at different levels in the organization, unlike horizontal communications, which are peer-to-peer.

Internal/external communication refers to whether the communication involves people who are subject to supply chain management direction or, more broadly, to organizational employees (internal) or persons in other departments or other organizations (external). How internal versus external is defined may therefore differ, depending on the subject of the communications. External generally includes regulators, interest groups, the customer, or the public.

Written and voice/nonverbal communications are different modes. Physical cues, body language, expressions, and body movements that are present in face-to-face communication can provide a more complete understanding of how a certain message is received or intended. The ability to give and interpret nonverbal communication can provide a more complete understanding of a message. Unlike an email, which, if short and to the point, could be seen as cold and impersonal, the same message when given in person could be received completely differently. This is one reason why emoticons have become popular in informal written communication; a wink of the eye—even a virtual one—can change the tone of a message. It is important to remember in written and some verbal communication modes that nonverbal cues are missing. When writing emails and reports or when speaking on phone or conference calls, take extra care when conveying your intended message to ensure that it is received appropriately.

Communication management plans

The *APICS Dictionary,* 16th edition, defines a **communication management plan** as "a document that describes the communications needs and expectations within a project, including format, dates, locations, and responsibilities." These plans are especially important in supply chain projects due to the need for everyone to work together to stay within scope and budget and achieve deadlines. Planning your communications and how they will be conducted creates an environment that encourages stakeholder involvement and support. A plan can be brief, especially when few stakeholders are involved, but when supply chain teams and projects are large and there are many people involved, a communication plan becomes paramount.

The following describes the steps in creating a communication management plan.

Identify target audience(s)

The first step when planning communications is to determine your target audience. Due diligence regarding the who, what, when, why, where, and how of communications can help in avoiding many potential issues, including delayed communications, communicating to the wrong audience, and misinterpreted messages. A strong plan can strengthen the effectiveness of your communications. Communication should also be efficient by providing the right amount of information, no more and no less, than the receiver needs. This strategy ensures that the important points of your message are received and are not lost in an overabundance of irrelevant data.

The process of managing stakeholder relationships is key for your communications plan. The *APICS Dictionary,* 16th edition, defines **stakeholder relationship management** as

> addressing and managing the competing priorities, needs and concerns of internal and external stakeholders in a proactive and sustained manner resulting in decreased cost and enhanced stakeholder acceptance or buy-in.

When collecting information about your stakeholders' communication preferences, the following should be gathered:

- Preferred communication types, media, formality, and formats
- Information needs

By interviewing stakeholders, you can determine their communication preferences. You can collect this information in the same meetings you have with stakeholders regarding requirements and risks.

Analyzing RACI (responsible, accountable, consult, and inform) and organizational charts can also provide information on how to structure your communications. RACI charts spell out who needs to do each task (responsible), which one person will answer to its success or failure (accountable), who needs to be given a chance to review (consult), and who simply needs to be told about what's going on (inform).

Organization culture and policy can also influence your communication strategies, and you may receive guidance regarding how to communicate with internal staff as well as guidelines for contractor, public, and media interactions.

Use expert judgement when assessing information needs—including determining what information will be sufficient and necessary. Good questions to ask include

- Is the subject matter relevant for the person in this role?
- Is the level of technical detail appropriate?
- Is the level of content complexity sufficient to successfully complete the assigned activities?
- Is any confidential information being disclosed, and, if so, is it necessary and are appropriate precautions being taken?

It is important not to underestimate general communications, as these often motivate people and keep them informed, and this minimizes the risks of supply chain initiative or project failure.

Identify communication channel(s)

Communications channels refer to the number of potential two-way interactions that can occur between stakeholders. These are important because they indicate the relative complexity of communication in a team or project. The greater the number of stakeholders, the higher the number of possible lines of communication, and the more careful the manager and team must be to ensure thorough communication of issues.

The number of communication channels can increase quickly. The communication channels formula helps supply chain managers grasp this point.

$$\text{Communication Channels} = \frac{n(n-1)}{2}$$

In this formula, n stands for number of stakeholders.

So, in a project that has only four stakeholders, there are six possible channels of communication:

$$\frac{4(4-1)}{2} = \frac{4 \times 3}{2} = \frac{12}{2} = 6$$

What happens if there are 16 project stakeholders instead of four?

$$\frac{16(16-1)}{2} = \frac{16 \times 15}{2} = \frac{240}{2} = 120$$

Note that quadrupling the stakeholders leads to a 20-fold increase in communication channels. With each channel of stakeholder communication, costs and risks increase and productivity is reduced, and there is an increased risk that a stakeholder may forget to communicate with another key stakeholder or an incorrect communication may be relayed in an improper manner. As complexity increases, so do the risks of communication. When the number of authorized representatives is reduced, complexity can also be reduced.

Create message(s)

Communication requires effort for both the sender and the receiver; it should always have a purpose. A clear message purpose addresses the reason why you are communicating and what you want to accomplish with the communication. Are you announcing a new service or process? Are you hoping to influence attitudes or achieve consensus? Are you seeking feedback? Do you want the audience to make a decision or take action? Or do you have some combination of motives in mind?

Whether the message is intended to inform or educate, persuade or inspire, initiate action or some other motive, make clear what you're wishing to convey from the outset. People need to know in advance what you expect from your communication.

Relating the message in ways that are understandable to the intended audience

Crafting an understandable message involves tailoring the message to the audience. With a clear picture of the intended audience, ask yourself questions such as

- Does the audience need background information and, if so, how much?
- What aspects of the topic matter to them?
- What information would be distracting, confusing (e.g., jargon), or irrelevant?

- Are there specific benefits for audience members?
- Why should the topic be of interest to the audience?
- If the intention is to persuade or initiate action, how difficult will that be for the given audience?
- How much does the audience already know about the topic?

Different audiences may require different information. As you think about what the audience needs to know, vary your messages accordingly. For example, when unveiling a new supply chain process, strategic and financial information would be of interest to the board and senior management and staff members would need to know what they need to do to support process success.

Using the appropriate media

What is the best way to communicate the message? When selecting an appropriate delivery method, consider factors such as

- **Physical constraints—**size of the audience, how dispersed audience members are, time zones, and the technology and resources available
- **Urgency—**whether the message is routine, important, critical, or time-sensitive
- **Cost—**cost constraints, image and brand considerations
- **Message distribution—**who needs to receive the information; the number and makeup of the receivers
- **Security/privacy/sensitivity considerations—**any legal, risk, professional, or proprietary aspects
- **Preference—**for example, a telephone call in lieu of an email or vice versa
- **Need for retention/retrieval—**whether the information should be retained and for how long, plus the methods for storing, maintaining, updating, retrieving, and disposing of the information.

Recall how many times you have received an email blast (irrelevant to you) that was sent to the entire organization with the hope that the intended audience will notice it. An inappropriate media choice can dilute the message intent, lead to indifference and confusion, or create many other problems. Great media choices, on the other hand, can grab people's attention, spur creativity, and encourage healthy conversation.

Ensure understanding/gather feedback

Intended receivers should not be thought of as passive absorbers of messages. As noted above, feedback is essential in communication so you know whether the recipient has understood the message in the same terms you intended and whether he or she agrees with the message.

Check with the members of your audience. In face-to-face communication, the opportunity to observe nonverbal cues or ask and answer questions helps to assess if the intended meaning equals the perceived meaning. If not a face-to-face communication, follow-up queries and feedback received can help to determine if the communication was clear and useful to the audience.

Feedback is your audience's response; it enables you to evaluate the effectiveness of your message and whether you achieved your purpose. If your audience doesn't understand what you mean, you can refine the message accordingly. Any opportunity to garner feedback is important in increasing communication effectiveness.

Do not neglect to consider lessons learned through feedback. To improve or sustain effective communication, consider what you will do differently the next time. Failure to do so may compromise your credibility and the potential of receiving critical feedback in the future. As much as feasible, you should act on feedback. Be grateful for the opportunity to do so.

Close the loop

The final step in any communication plan is to ensure that communications are continually monitored for completeness, accuracy, and tone. It is also important to monitor the release and timing of messages—this may even include involving the legal department for any messages intended for consumption by the general public.

Controlling communications is itself a feedback loop. Communications improvements or error corrections may be fed back into a new iteration of communications planning and management.

Topic 2: Project Management

Supply chain managers may be involved in planning, organizing, delegating, and monitoring and controlling projects. The supply chain manager's role may vary, depending on the specifics of the project and his or her capabilities and availability. Common roles include

- Being the project manager
- Delegating work to a project manager and being accountable for results
- Being a team member on the project (e.g., a different business unit's project or a project for the entire organization).

The ability of the supply chain manager to accurately estimate project schedule and costs, develop a feasible and properly organized project schedule and budget, and keep a project on schedule and on budget strongly affects his or her credibility with senior executives or clients and ability to get funding for future projects. A supply chain manager may be a skilled project manager or can acquire a skilled project manager for a project. Staffing this role with a skilled professional will greatly improve the chances of accomplishing all project objectives.

The overarching goal is to ensure that the interests of the organization and its customers are represented throughout a project's life cycle.

What are projects?

The *APICS Dictionary,* 16th edition, definition of a **project** is

> an endeavor with a specific objective to be met within predetermined time and dollar limitations and that has been assigned for definition or execution.

The Project Management Institute (PMI®) defines projects as "temporary endeavors undertaken to create a unique product, service, or result." Note that project deliverables can be tangible (product) or intangible (service or result). The two most important words in this definition are "temporary" and "unique":

- **Temporary.** All projects have a start and an end and are never ongoing. The start is when a project charter is developed and approved; the end may be achievement of objectives and handoff of deliverables or project termination (e.g., the sponsor runs out of funds, the objectives cannot or will not be met). A project could take years to finish and its deliverables or societal impact could last indefinitely, such as the pyramids, but the project itself is still temporary.
- **Unique.** The products, services, or results differ in one or more ways from the organization's prior work. Parts of deliverables could be similar, but the remaining differences make them unique. For example, even if the same architectural design is used for a warehouse, it is still constructed on a different plot of land and may be built by different contractors.

Projects vs. operations

Operations and projects are different, and it is important to distinguish between them. Operations are repetitive and ongoing processes of an organization that are used to produce saleable products or services. Operations, like projects, require planning, execution, and control to manage constraints on people and

resources. However, unlike projects, operations are neither temporary nor do they produce unique deliverables.

Exhibit 1-53 shows the differences between projects and operations.

Exhibit 1-53: Projects versus Operations

Distinguisher	Operations	Projects
Duration	• Ongoing, indefinite, repetitive	• Always temporary, but varies
Deliverables	• Standardized • Make-to-stock, make-to-order, assemble-to-order • Formalized, repeated process results (e.g., regular reports) • For example, review monthly vendor scorecard reports and take action on poor-performing vendors; send quarterly scorecards to vendors	• Unique • Makes a finished deliverable or component(s), e.g., engineer-to-order • Improves an existing product, service, or result • Builds service capability, for example, establish criteria for vendor scorecards including necessary report templates
Human resources	• Permanent positions • Aligned to departments in organizational structure	• Temporary teams • May be cross-functional
Manager	Functional manager	Project manager

Project attributes

All projects share certain characteristics. They

- Have a definite beginning and end
- Create a unique product, service, or result
- May be progressively elaborated (A plan framework is elaborated upon as additional information becomes known.)
- Are based on and perhaps contain some assumptions
- Are planned and executed given certain constraints
- May be influenced by internal and/or external environmental factors
- Make use of existing internal assets and project documents.

What is project management?

The *APICS Dictionary,* 16th edition, defines **project management** as

> the use of skills and knowledge in coordinating the organizing, planning, scheduling, directing, controlling, monitoring, and evaluating of prescribed activities to ensure that the stated objectives of a project, manufactured good, or service are achieved.

Project management can also be thought of as an organized process for increasing the chances of project success. This process generally has the following components:

- **Objectives.** Project management has a set of results to achieve defined by its scope and its constraints on cost, time and quality.
- **Management processes.** Project management follows predetermined processes, such as scheduling

or budgeting, and a project cycle that encompasses organizing, planning, executing, and controlling.

- **Levels.** Project management incorporates both strategic and tactical planning levels.

Organizations can achieve additional benefits from project management, including

- Encouraging innovation and creativity via cross-functional teams and cultivating collective organizational wisdom ("lessons learned")
- Leveraging existing and external resources wisely to do more with fewer resources
- Efficiently securing more informative data regarding projects, allowing management to terminate projects that would otherwise fail to implement strategy or negatively impact business value

Some organizations use a PMO (project management office) to ensure project best practices and standards. Project managers can then reach out to the PMO for support.

Avoiding common pitfalls

Simply claiming to use project management is not the same as properly managing a project. Organizations need to fully commit to a rigorous process, get the support of top management, train their project managers and teams, and use change management to instill best practices into the organization's culture. Here are some common causes for the failure of projects:

- Budget or schedule (or other important constraint) is significantly missed.
- Project results are ineffective (e.g., unacceptable deliverables).
- Deliverables have no valid purpose (e.g., the project used resources without adding to business value).
- Project sponsors or managers allow scope creep, the uncontrolled expansion of project scope. (For example, many ERP projects fail when the scope continues to expand without allocation of additional time or funds.)

Exhibit 1-54 shows some common pitfalls along with some corresponding best practices described in *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*—Fifth Edition, Project Management Institute, Inc., 2013.

Exhibit 1-54: Pitfalls and Best Practices

Common Pitfalls	Project Management Best Practices
Harangue and coerce.	Lead and coach.
Micromanage team members.	Clearly delegate responsibility.
Treat personnel changes as emergencies due to unclear roles and responsibilities.	Assign activities to specific functional responsibilities for clear personnel transitions.
Guess at variances until too late.	Control and account for resources.
Fail to set plan baselines (e.g., schedule, budget).	Routinely measure against the plan.
Hold meetings to gather percent complete estimates (guesses).	Hold meetings to discuss substantive issues and risks.
Allow change and have unrealistic optimism about any consequences.	Control change and analyze tradeoffs between constraints.
Produce static documentation and never use it because it is out of date.	Keep live documentation updated.
Fail to send out new plan versions (so	Ensure that everyone is using the current plan

everyone is using different versions).	(configuration management).

Source: A Guide to the Project Management Body of Knowledge (PMBOK® Guide), Fifth Edition.

The role of the project manager

The project manager gains consensus on project objectives; achieves these objectives; acquires, manages, and leads the project team; and integrates or coordinates the project management process. A functional manager, on the other hand, is responsible for a specific organizational unit with similar processes—such as IT, marketing and sales, accounting, human resources, or manufacturing.

To fulfill the project management role successfully, the project manager should possess certain qualities.

First, the project manager needs management authority, such as the ability to make purchases within certain constraints and to hire, discipline, and remove or terminate employees or contractors who directly report to the project manager.

Second, the project manager role requires that the supply chain manager have both theoretical knowledge and field experience. This knowledge and experience needs to be in two areas: technical project aspects and project management processes and techniques.

Supply chain managers can assess their own skills when deciding whether they would make a good project manager for a given project. If supply chain managers are responsible for internally staffing, hiring, or contracting out the project manager role, they should review and customize their organization's project manager job description to reflect the specific project work to be done. In either case, the project manager should have strengths in the following areas.

- **Leadership and influence.** The project manager role requires development of leadership and influence to create a team. Project managers accept accountability for the project and its mission. They adapt their leadership style to the situation and audience, from asserting, to listening, to using facts and reason, to persuading. Project managers understand that the goal of influence is to inspire others to want do the right things rather than to overtly control them.
- **Self-assessment and experience.** Supply chain managers assess whether they or the candidates they are considering have enough learning and field experience for a given project. The ability to work well with others is a difficult skill to build without certain innate personality traits. Therefore, it is important that supply chain manager or project manager candidates have and continually improve people skills, including coaching, negotiation, and conflict management. Project managers must also fairly evaluate their own skills and performance abilities, ask for help as needed, admit to mistakes, learn from mistakes and successes, and vary approaches to fit team member and stakeholder personalities as well as teams as a whole.
- **Recruiting and organizing a team.** The project manager needs to recruit and organize the project team by assessing the strengths and weaknesses of team members and staff/contractors to encourage teamwork and fill needed areas of expertise. For example, a project manager may ask a detail-oriented logical thinker to work on process audits and assign a people person as a department contact. Project managers ensure that the project team represents key stakeholders, including

    - Management
    - Suppliers
    - Customers
    - The supply chain manager if different from the project manager (e.g., final approver for changes and supervisor of big picture)
    - Project team members (e.g., accounting, IT, manufacturing, purchasing, marketing departments)
    - Professional services that provide expertise (e.g., third-party logistics providers).

- **Management.** The project manager is a planning agent who integrates and coordinates the work of others. Effective project managers delegate appropriately and avoid being a bottleneck by micromanaging team members or delaying the approval process unnecessarily. Project managers treat controlling and directing work as a full-time job and avoid doing activities that should be assigned to team members. Instead they manage the project as a whole and track its components. If the project manager accomplishes a task more efficiently than someone else could but misses that a team member has added an unauthorized step in a process, the team effectively has no project manager. Project managers spot-check schedule details because they understand that people who are behind schedule may report being on schedule if they believe that they can make up the time later. Project managers understand that you can't manage what you can't measure and so find ways to measure the details that need managing. For example, if a task stays at 90 percent complete despite the continued output of work, project managers may break down how the task is reported so it can be better measured and then managed.

- **Communication and problem solving.** The project manager is the primary liaison between the project team and the executive team as well as with customers, suppliers, superiors, and other managers. Project managers maintain regular, personalized communication and show sensitivity to organizational culture. Project managers use varied modes of communication to reinforce messages, including project management software, meetings, reports, email, printed bulletins, conversations, and nonverbal cues. Project managers resolve conflicts and regularly negotiate with stakeholders to help balance the needs of all constituents.

Project planning

Depending on the scope and complexity of a project, planning can be informal or formal. Informal project planning involves asking questions such as

- What needs to be done?
- How should it be accomplished?
- How long should it take to complete?
- How much will it cost?
- Who needs to do it?
- How well should it be done?

Asking these questions will help plan a simple project, but complex projects need formal project planning. Such projects often use a standardized project management process and model to ensure that all project planning elements are included. Most standardized processes use the concept of project life cycles. The *APICS Dictionary,* 16th edition, defines **project life cycle** as follows:

> In project management, a set of project phases (objectives definition, requirements definition, external and internal design, construction, systems test, and implementation and maintenance), whose definition is determined by the needs of those controlling the project.

The project life cycle helps conceptualize the idea that projects are developed iteratively, starting with a framework and returning to add details as they become known or changes as they are approved. This iterative development is also called progressive elaboration.

Projects are divided into phases to control the work and to integrate the project's final product, service, or result into the ongoing organizational operations.

Standardized project management processes use consistent terminology and provide a framework that can be changed to fit project specifics.

It may take some effort and some change management to get an organization to adopt a standard set of processes and commit to a larger amount of planning work. Organizational resistance to change cannot be underestimated, and the benefits of the extra work need to be demonstrated on a small project before the standard process can be used on all projects. If the project manager wants to use a specific project methodology, he or she may need to get buy-in from superiors and the project team.

A widely accepted standardized project management process is PMI's Project Management Body of Knowledge (*PMBOK® Guide*). The remainder of this topic reviews the *PMBOK® Guide* process, including its Knowledge Areas, Enterprise Environmental Factors and Organizational Process Assets, and Process Groups.

PMBOK® Guide Knowledge Areas

A **process** is a systematic series of activities directed toward causing an end result such that one or more inputs will be acted upon to create one or more outputs. Processes are a group of interrelated actions and activities that are planned in advance. The result could be a deliverable (a product, service, or result) or an input to another process.

Project management processes keep the project flowing correctly throughout its life cycle. The project manager transforms the data collected from processes into information by placing the data in context and uses the information to produce reports and change requests. Transforming process results into actionable information helps the project manager create a feedback loop and control the project as it is ongoing.

Project management processes also all have a set of inputs (what teams need to start the process), some tools and techniques (what teams can use to perform the process better or faster), and some outputs (the documents or deliverables that teams create). The outputs of one process often become the inputs to one or more later processes.

The *PMBOK® Guide* has a set of project management Knowledge Areas that represent the process categories used on most projects most of the time.

The Knowledge Areas are

- **Project Integration Management.** Begin with the end in mind (objectives) and get authorization for the project and the project manager. Coordinate activities, control changes, and formally close the project.
- **Project Scope Management.** Say what you will do (scope) and will not do and validate that only what was in scope was done.
- **Project Time Management.** Specify the activities to do, put them in order, and specify resources. Make a realistic schedule and control variances against this baseline.
- **Project Cost Management.** Estimate the cost of activities and materials, make the budget, measure variances, and correct.
- **Project Quality Management.** Define quality metrics and processes, audit processes, and control quality of deliverables.
- **Project Human Resource Management.** Plan, acquire, develop, manage, and release the team.
- **Project Communications Management.** Plan who gets what messages and how, make communications, and get feedback.
- **Project Risk Management.** Identify and prioritize risks, calculate probability and impact, plan responses, and control risk and responses.
- **Project Procurement Management.** Identify what to procure using which types of contracts, send RFPs, control, and close procurements.
- **Project Stakeholder Management.** Identify persons who can influence or be influenced by the project, judge their impact, and manage their engagement and expectations.

All key processes to follow in a project fall within one of the above 10 Knowledge Areas. For example, one process is Develop Project Charter, and this is an integration task.

PMBOK® Guide environmental factors and process assets

There are several considerations that can impact your project. Two common types that are often inputs to the project processes are Enterprise Environmental Factors and Organizational Process Assets.

Enterprise Environmental Factors (EEFs)

EEFs refer to conditions outside the control of the project team that influence or constrain the project. It is vital to think about EEFs right from the start of a project, because they can influence whether the project is even feasible at the given time given things such as the economy, demand, or organizational readiness. EEFs put a project in context and highlight constraints so that the project can be planned to avail itself of opportunities and mitigate threats.

EEFs are both the terrain over which the organization runs and the type of animal the organization has become. The ground may be firm, rocky, crowded, or fertile. The organization may be specialized and thus more adept in certain areas but less so in others.

When project managers work to understand both external and internal conditions, they will better comprehend organizational strategy and will be able to develop charters and plans that reflect the actual situation.

EEFs include communications, organizational culture and governance, structures, systems, and external influences. The key is that they cannot be controlled, only understood.

Organizational Process Assets (OPAs)

OPAs are the policies, procedures, processes, plans, and organizational knowledge base of the organization. OPAs are common inputs to planning processes and are created during some processes and so also may become outputs.

OPAs include

- Policies, procedures, and processes: rules, standards, templates, and methodologies (e.g., best practices)
- Organizational knowledge base: historical information from organizational activities and lessons learned from prior projects.

PMBOK® Guide Process Groups

Project management processes ensure the effective flow of a project throughout its life cycle. The *PMBOK® Guide* identifies 47 processes. These processes are organized into the 10 Knowledge Areas listed above but are mainly categorized by Process Group. The Process Groups are Initiating, Planning, Executing, Monitoring and Controlling, and Closing.

If you are interested in the 47 processes and where they are located in each Knowledge Area and Process Group, refer to the *PMBOK® Guide*.

The order of the processes is important. For example, in the Planning Process Group, one plans the schedule and defines the activities before putting them in sequence and estimating resources and durations in order to finally develop a schedule. While the specifics of each process are beyond the scope of this course, some processes are discussed at a high level later in this topic. Having an understanding of the Process Groups provides a good context for understanding the purpose of each set of processes.

The Process Groups overlap: Some ramp up as others slow down. Some processes are ongoing tasks that can recur in later Process Groups. Since Planning is progressively elaborated, it often overlaps Executing. Monitoring and Controlling overlaps all Process Groups because one needs to measure and adjust at all points in a project. Closing may be needed early on in a project to close some contracts and/or accept some deliverables.

Each Process Group is addressed in more detail next.

Project initiation

The Initiating Process Group includes two processes performed to define a new project or a new phase of an existing project.

- **Develop Project Charter.** This process entails activities such as
  - Understanding the project context (the environmental factors, assumptions, and constraints)
  - Reviewing the project's business case and strategic goals
  - Choosing the project manager and delegating resource and expenditure authority to this person
  - Clarifying high-level objectives and success criteria (beginning with the end in mind).

  The charter formally authorizes the project to begin and allows funds to be expended.

- **Identify Stakeholders.** This process entails activities such as
  - Developing a stakeholder register (e.g., a spreadsheet listing stakeholders and their areas of expertise, interests, assignments, and communication preferences and requirements)
  - Listening to and getting buy-in from stakeholders
  - Building a shared understanding of project scope and objectives
  - Aligning stakeholders' expectations to the project's purpose
  - Clarifying the link between each stakeholder's level of participation and the attainment of his or her expectations.

Project planning and design

The Planning Process Group has the most processes, since planning occurs for each of the Knowledge Areas. Planning turns strategy into tactical action and reveals how to get to successful project completion. It is the guide that shows all stakeholders (including team members) what they need to do. A good planning document will be realistic and feasible, which will help stakeholders believe that the project's goals can be achieved. Planning involves selecting detailed requirements and scope, refining objectives, and defining what activities are needed to accomplish these objectives.

Project planning encompasses all aspects of project work:

- Scoping to show what things will be done, documented in the form of a work breakdown structure
- Scheduling what work needs to be done, in what order, and within which periods
- Budgeting to estimate project costs and the timing of expenditures
- Specifying quality policies and processes, including process improvement
- Staffing teams by defining team roles needed to do project work and how to assign work and responsibilities
- Deciding on communicating what to whom on the team and to stakeholders, how, when, and by whom
- Determining how to identify, prioritize, and manage risks and proactive responses
- Deciding what services and materials to procure under contract and how to conduct the contracting process
- Deciding how to develop and maintain stakeholder relationships and expectations

A plan is typically generated for every Knowledge Area. (Some plans could be quite short on small projects.) These plans together become the **project management plan.** These plans do not contain specifics such as particular team member assignments or project schedule details since they are frameworks, but they do contain baselines. Baselines are the high-level official scope, schedule, and budget information that become the basis against which to measure whether the project is progressing as desired or not. Aside from these baselines, the project management plan is a "how to" guide. It shows how to plan for the area, what

performance to measure and when, what tools and techniques to use, and how to execute and control the elements in the Knowledge Area. Specific project details such as schedule breakdowns, staff assignments, and so on are stored in separate project documents. These documents are revised as needed and allowed throughout the project. Some changes will require approval through an official change request procedure.

The project schedule and budget are among the first things done after the project management plan is completed, but these will be incomplete after the first pass. Only after all subsidiary plans have been completed can the project schedule and budget be finalized. This is because later information on, for example, risks or quality, will impact the schedule and budget. This is an example of progressive elaboration—elaborating the high-level summary milestone schedule and budget included in the project charter based on information in the subsidiary plans. Organizational process assets provide guidance on what is an appropriate amount of time to spend on planning.

Plans and baselines are subject to revision as needed, but a change to the baseline is an example of something that generally requires review and formal sign-off before it can be changed. The idea is to prevent scope creep (unauthorized addition of work without corresponding increases in schedule and budget) while accommodating necessary change. New information or unexpected events may require changes to project scope, schedule, and budget. Available team members could need training before they can be fully productive. New stakeholders or risks could be identified. Quality data may show a need for new types of testing.

Project scope

The primary processes for developing the project scope are collecting requirements and developing a work breakdown structure. The project charter will contain high-level project requirements, but these need to be refined at a more granular level to define the work to be done before the project can be considered completed.

Gathering requirements involves reviewing historical requirements documents and interviewing all stakeholders to develop a full list of expectations for the project deliverables or the means to be used to produce the deliverables. Missing a stakeholder or group of stakeholders creates a risk that the final deliverable will fail to satisfy all constituents. If this missing group is a customer segment, for example, it could result in a product or capability that fails to be in demand. Therefore, thorough stakeholder identification is a prerequisite for gathering requirements.

Stakeholders will often have more requirements than can be accommodated in the current project due to constraints on time, cost, and so on. In addition, some requirements will contradict other requirements. Therefore, this becomes a process of satisfying as many requirements as is feasible. It is often described as a process of separating needs from wants.

Each requirement should be necessary, and the set as a whole should be sufficient to define the project scope. Good requirements need to be measurable, meaning that it should be clear how to set acceptance criteria for each requirement. Acceptance criteria are the conditions customers will need to verify are present before they will accept the final deliverables. (Customers are here broadly defined as the recipient of the project deliverables; they could be internal to the organization.)

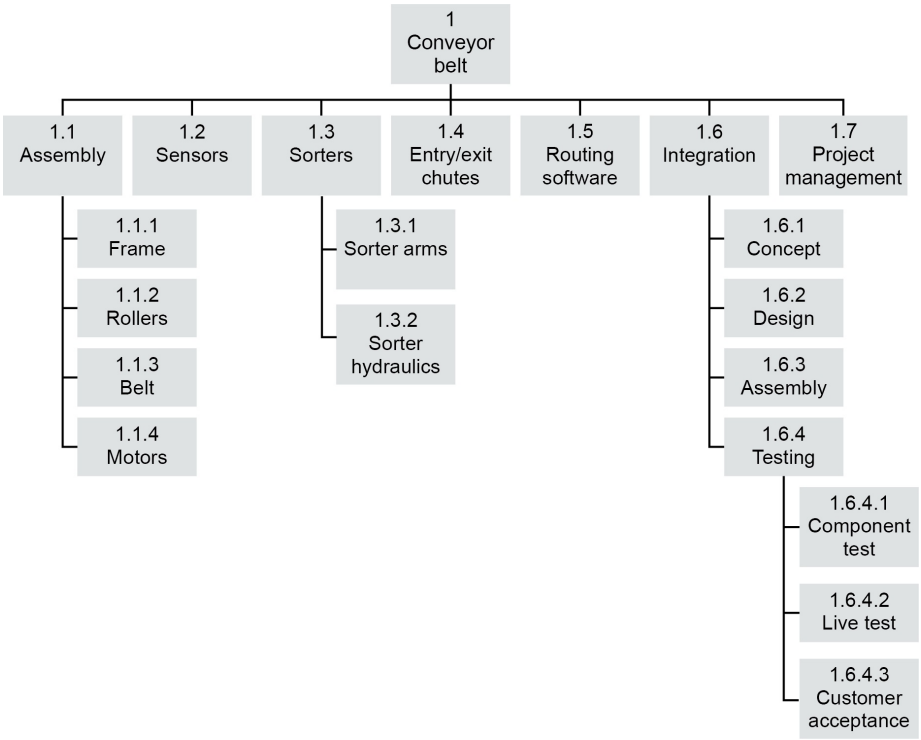
Once a set of requirements is agreed upon by all decision makers, including the customer, the next step is to formalize them into a work breakdown structure (WBS). The *PMBOK® Guide* defines a **WBS** as "a hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables."

The WBS focuses on what will be created more than how it will be created. It looks like an organizational chart, with the project at the top and major categories of deliverable components listed below it. For each component, the work is further broken down into subcomponents. The lowest level will be items that are best planned separately. The idea is to divide up the work into manageable parts. If an item can be planned or executed independently, it is a good bet that it should be its own WBS item. Splitting up work into units smaller than this would add complexity without improving the ability to plan. The WBS is a map of 100 percent of the work that will be done on the project. If it isn't on the WBS, it isn't being done.

A WBS uses hierarchical labels to show how components interrelate and their level in the hierarchy. If the top level (project) is labeled as 1, then the next level is given an additional decimal place, such as 1.1, 1.2, 1.3, etc. If 1.2 has subcomponents, they are given an additional decimal place, like 1.2.1, 1.2.2, and so on. Exhibit 1-55 shows an example of a WBS for a conveyor belt project.

Once the WBS and other scope description documents are complete and approved, they become the scope baseline.

Exhibit 1-55: Work Breakdown Structure (Conveyor Belt Example)



Project schedule

The project schedule defines the activities that need to be done to complete the scope, places the activities in the order in which they need to be done, estimates resources to be used for each activity, and estimates how long each activity will take. The order of these steps is important. For example, before being able to estimate activity durations, the project manager first needs to know how many resources (e.g., team members) will be assigned to the activity and their level of expertise, since these will greatly impact the duration of the activity.

The project manager first defines activities that are needed to create each item on the WBS. The WBS contains no activities; one or more activities may be needed to accomplish each WBS item. An activity is a distinct element of work that contributes to the completion of a deliverable and can be scheduled and budgeted.

Once all activities are defined, they can be placed in sequence. The project manager may arrange for activities to be done concurrently if they don't depend on the completion of other activities or have resource conflicts. In other cases, some activities can partly overlap. Activities that must be done in sequence (e.g., pouring a foundation before building a wall) are arranged as such.

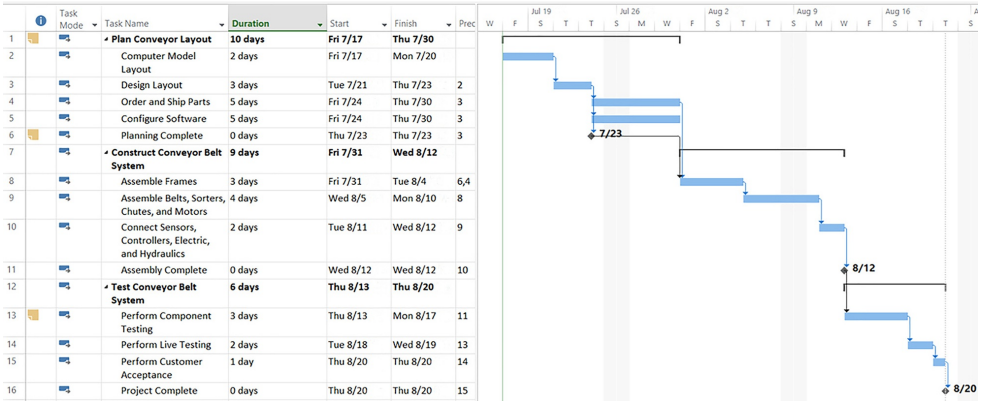
Estimating activity resources involves determining the quantity of labor and level of expertise that is required to complete each activity. For example, this could be 100 hours of expert labor. The project manager can determine if these will be all one person's efforts or if two or more people can work on the activity simultaneously. The project manager factors in weekends and holidays and other work availability issues.

Next, the project manager calculates activity durations. The total project duration is then how long it will take to do the longest string of activities that need to be done sequentially. This is the shortest possible project duration and is called the critical path.

Oftentimes, there will be a constraint on time, in other words, a hard deadline to meet. When this is the case, project managers may need to rearrange some additional activities to allow them to be done concurrently (called fast tracking) when possible or will add workers on activities to shorten their duration (called crashing) as is feasible from a cost and human resources perspective. These changes may result in a new and shorter critical path, but there may be a need for additional team members and/or increased costs to achieve this shorter schedule.

Project schedules and budgets are often managed using project management software. Microsoft Project is an example. This software still requires project managers to accurately estimate durations and costs, put activities in the correct sequence, and specify whether some activities can overlap and so on, but it does automate many of the other project management activities, such as rearranging the rest of the schedule when something is moved or an estimate for a particular activity is updated. The final schedule can be viewed as a Gantt chart, which is an easy-to-understand way to show how activities interact and overlap over time. Exhibit 1-56 shows an example of a Gantt chart produced in Microsoft Project, using the same conveyor belt project example as the previous exhibit.

Exhibit 1-56: Project Schedule (Gantt Chart View) for Conveyor Belt Project



	Task Mode	Task Name	Duration	Start	Finish	Prec
1		**Plan Conveyor Layout**	**10 days**	**Fri 7/17**	**Thu 7/30**	
2		Computer Model Layout	2 days	Fri 7/17	Mon 7/20	
3		Design Layout	3 days	Tue 7/21	Thu 7/23	2
4		Order and Ship Parts	5 days	Fri 7/24	Thu 7/30	3
5		Configure Software	5 days	Fri 7/24	Thu 7/30	3
6		Planning Complete	0 days	Thu 7/23	Thu 7/23	3
7		**Construct Conveyor Belt System**	**9 days**	**Fri 7/31**	**Wed 8/12**	
8		Assemble Frames	3 days	Fri 7/31	Tue 8/4	6,4
9		Assemble Belts, Sorters, Chutes, and Motors	4 days	Wed 8/5	Mon 8/10	8
10		Connect Sensors, Controllers, Electric, and Hydraulics	2 days	Tue 8/11	Wed 8/12	9
11		Assembly Complete	0 days	Wed 8/12	Wed 8/12	10
12		**Test Conveyor Belt System**	**6 days**	**Thu 8/13**	**Thu 8/20**	
13		Perform Component Testing	3 days	Thu 8/13	Mon 8/17	11
14		Perform Live Testing	2 days	Tue 8/18	Wed 8/19	13
15		Perform Customer Acceptance	1 day	Thu 8/20	Thu 8/20	14
16		Project Complete	0 days	Thu 8/20	Thu 8/20	15

Once the schedule is approved, it becomes the schedule baseline.

Project budget

The project budget is often developed at the same time as the schedule, since each affects the other one, as the prior examples of crashing and fast tracking demonstrated. Costs are estimated from the bottom up starting at the activity level. The cost of the materials and resources is estimated for each activity, and then these costs are rolled up (aggregated) to determine the budget. As with the schedule, often this results in costs that are unacceptable to cost constraints. At that point, the project manager can work on the project budget from the top down, starting with the cost constraint or target budget and then determining whether it is feasible to get the same work done for less by using fewer resources (and likely a longer schedule) or if the project scope needs to be adjusted to fit within the available budget.

The project manager's responsibility is to produce a feasible budget and schedule. Agreeing to a project with a budget or schedule that is sure to be exceeded is a sure way to fail before the project even starts. The project manager will be held accountable for achieving the schedule and budget, and therefore must push back when project sponsors or others insist that a project can be done for less than the best planning estimate. If the scope and schedule or other constraints cannot be altered, then it is the project manager's responsibility to secure the necessary additional funding or refuse to lead the project.

The project budget and schedule will need to be revisited once the other project plan elements are finished. For example, there is a section in these materials that contains a great deal of information on risk management, much of which can be directly applied to project risk management. The time and costs involved for any planned risk responses need to be added to the schedule and budget. This is also true for quality, human resources, communications, procurement, and stakeholder management.

Once the budget is approved, it becomes the cost baseline.

Project execution

Processes in the Executing Process Group are used to complete the work defined in the project management plan as needed to fulfill the project objectives.

The Executing group has fewer processes than Planning, but, in fact, the largest portion of project time and resources are spent in this Process Group, specifically in the Direct and Manage Project Work process. The project manager integrates and coordinates team activities to ensure that project work is moving along smoothly. To do this, project managers need to see the big picture and how all the pieces interact.

Executing is where data are collected for later analysis. Executing involves doing quality audits, because these are audits of the processes as they are being performed. Quality audits show whether processes are effective, efficient, and being applied as intended. The project manager may need to file change requests during Executing if efforts or processes need better coordination.

Project monitoring and controlling

Processes in the Monitoring and Controlling Process Group are required to

- Track, review, and control project progress and performance
- Identify required changes to the plan
- Initiate the necessary and approved changes
- Verify that deliverables conform to scope and requirements and that the customer can accept them.

Monitoring and Controlling is a special Process Group, because it runs alongside the other groups. The project manager reviews work and corrects course during Initiating, Planning, Executing, and Closing. If a project has multiple phases, the project manager also integrates Monitoring and Controlling across the phases to coordinate overall events.

Through oversight and measurement, the project manager and team can regularly compare activities against plans, assess the need for course correction or refinement, propose solutions and assess the consequences on all parts of the project, get changes approved, make changes, and verify that changes have been done correctly and are effective. If a change is implemented incorrectly, isn't done at all, or is ineffective, another feedback loop detects this situation and gets the changes done right.

Process audits are an especially important Monitoring and Controlling activity, because reviewing processes as they are occurring during Planning and early in Executing can prevent problems from occurring in the first place. Inspection of deliverables, while necessary, is less efficient, since at this point most of the executing is done and corrections would require rework. Problems are much more expensive and time-consuming to fix in later stages.

In other words, it is best to spend most of your time on influencing the factors that result in changes being necessary than on making necessary fixes. Recommending preventive or corrective action before problems occur is far more cost-effective, because there will be fewer issues to find during inspections.

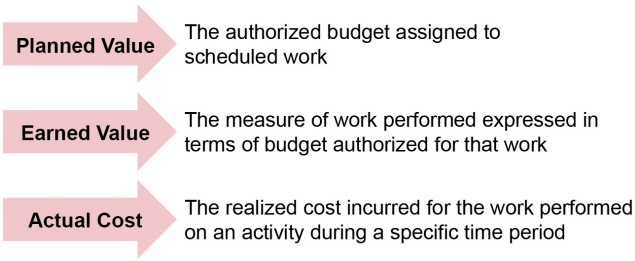
When changes are required, the project manager analyzes the impact of these changes on other constraints, such as time, cost, and quality, and recommends a solution that balances stakeholder needs to the degree possible.

It is vital that the project manager carefully control changes and avoid needless change. Unnecessary change (scope creep) has caused innumerable projects to go far over budget and far over schedule and, sometimes, to fail entirely.

Variance analysis

The key activity in Monitoring and Controlling is measurement, and variance analysis is the key to effective measurement. Earned value measurement (EVM) is a technique that allows project managers to measure scope, schedule, and cost variances. EVM uses three input measurements to produce a large number of variance measurements and ratios. These inputs are shown in Exhibit 1-57, as quoted from the glossary of the PMBOK Guide®.

Exhibit 1-57: Earned Value Measurement Inputs



Source: A Guide to the Project Management Body of Knowledge (PMBOK® Guide), Fifth Edition.

Planned value (PV) can be determined by referring to the project management plan, since it will show how much work should be done at any given point during the project. (Work budgeted to be done from period to period could vary.) If the project has equal amounts of work to be done in each period, then a simple calculation can be used to determine PV. For example, if the project is to build four identical walls, on week 3 of 4 of a $2,000 project budget, then the calculation is as follows:

$$PV = \frac{\text{Schedule Completed}}{\text{Total Schedule}} \times \text{Budget} = \frac{3}{4} \times \$2,000 = \$1,500$$

Earned value (EV) requires an estimate of actual percent complete. If that same wall project was behind schedule and only had two walls done by the end of week three, the EV calculation is:

$$EV = \text{Budget} \times \text{Actual Percent Complete} = \$2,000 \times 50\% = \$1,000$$

Actual cost (AC) is the actual expenses incurred to date on the project. Assume for the continuing example below that actual costs are $1,250 as of the end of week 3.

While many useful ratios can be calculated based on these input values, this discussion will focus on just two important variances—the schedule variance (SV) and the cost variance (CV)—along with two related indexes—the schedule performance index (SPI) and the cost performance index (CPI). The variance measurements are expressed in monetary values. Negative values are bad (e.g., behind schedule or over budget); positive values are good.

The following formulas are used to calculate the schedule variance and the cost variance. The examples continue the simple wall building project:

$$SV = EV - PV = \$1,000 - \$1,500 = -\$500$$

$$CV = EV - AC = \$1,000 - \$1,250 = -\$250$$

This project is both off schedule and over budget, but since the project manager has two types of variances and both are expressed in monetary terms, it is easy to see that the schedule issues are more significant. Because these variances can be calculated at any point during a project, project managers can control small variances as they are occurring rather than waiting until later to correct course. Correcting course sooner is both more effective and less expensive than attempting to do so later.

The same three inputs can also be used to create index values for cost and schedule performance. An index is basically a ratio in which one value is divided by another. An index or ratio is useful because it can be compared to other ratios regardless of the size of the amounts. Like a percentage, it is easy to see by how much a project is on or off budget or schedule. The same examples are used to illustrate the two types of indexes, the schedule performance index and the cost performance index:

$$SPI = \frac{EV}{PV} = \frac{\$1,000}{\$1,500} = 0.67 \text{ or } 67\%$$

$$CPI = \frac{EV}{AC} = \frac{\$1,000}{\$1,250} = 0.8 \text{ or } 80\%$$

An SPI or CPI of less than 1.0 or 100 percent shows that a project is off schedule or budget; values greater than 1.0 or 100 percent mean that the project is ahead of schedule or under budget.

Project closure

Closing includes formal finalization processes performed for all activities across all Process Groups:

- Handing the product, service, or result over to the customer and supporting a transition into operations as necessary
- Completing administrative tasks
  - Executing final payments to contractors
  - Closing out procurement contracts
  - Providing a final report to the project sponsor and stakeholders
  - Doing individual and team performance reviews
  - Releasing team members
  - Going over “lessons learned” from the project and updating organizational process assets
  - Archiving project documents and plans

Once all of this is complete, the project manager officially indicates that the project is complete. Projects or phases are formally closed even if they are terminated early or are postponed indefinitely.

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