VERSION 4.4

MODULE 2
SUPPLY CHAIN PLANNING AND EXECUTION

Section A: Procure and Deliver Goods and Services

CSCP

CERTIFIED SUPPLY CHAIN PROFESSIONAL

LEARNING SYSTEM 2020

APICS

ASCM ASSOCIATION FOR SUPPLY CHAIN MANAGEMENT

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Section A: Procure and Deliver Goods and Services

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This section covers concepts that help supply chain managers enable long- and short-term demand, supply, and financial planning so that sourcing, acquisition, manufacturing control, delivery, invoicing, and payment form a smooth and fast cycle. Demand needs to be planned (and forecasted), communicated, influenced, and prioritized. Operations planning and control then links supply with demand. Inventory management methodologies need to be selected and supply analyzed using tools such as total cost of ownership or make-versus-buy analysis. Logistics, including warehouse management, capacity forecasting, materials handling, transportation, and delivery patterns are also discussed. The section also includes tips on how to take advantage of free trade zones and trading blocs through an understanding of foreign exchange, the cash-to-cash-cycle, and Incoterms® trade terms.

Processes for procuring and delivering goods and services

The key processes that supply chain managers need to be able to perform related to procuring and delivering goods and services are

- Performing sales and operations planning
- Developing supply chain personnel's knowledge, skills, and abilities
- Developing supply chain infrastructure
- Performing short-term planning and scheduling
- Identifying logistical requirements
- Developing logistical capabilities to support delivery of goods and services
- Executing the plans.

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.

Performing sales and operations planning

The process of performing sales and operations planning (S&OP) involves the following steps:

- Reviewing performance
- Evaluating demand levels
- Evaluating supply capability
- Reconciling demand, supply, and financial plans

Developing supply chain personnel's knowledge, skills, and abilities

The process of developing supply chain personnel's knowledge, skills, and abilities involves the following steps:

- Setting learning goals with one's manager
- Providing opportunities for independent learning, including certification
- Developing formal or informal coaching or mentoring programs
- Providing access to training courses as needed for specific skills or industry-specific knowledge
- Meeting periodically to assess goal progress and set new goals
- Providing an upward career path for individuals who excel

Developing supply chain infrastructure

The process of developing the supply chain infrastructure involves the following steps:

- Completing design of the supply chain infrastructure, including relevant total cost of ownership and make-versus-buy analyses
- For all “make” decisions:
  - Completing supply chain infrastructure or process development projects for manufacturing or service delivery, logistics (including warehousing and transportation), and information and funds flows
  - Staffing new roles
  - Providing training on new processes or systems
  - Using change management to ensure that processes and systems are fully adopted in policies and culture (See Module 3 for information on change management.)
- For all “buy” decisions and key customer relationships:
  - Working toward desired supplier and customer relationships
  - Developing supplier and customer contracts
  - Implementing agreed-upon supplier and customer relationships

Performing short-term planning and scheduling

The process of performing short-term planning and scheduling involves the following steps:

- Planning, communicating, influencing, and managing and prioritizing demand
- Forecasting demand
- Servicing orders
- Prioritizing demand
- Influencing other business functions toward a shared view of demand management
- Performing master planning, including the above demand management activities, resource planning, and master scheduling
- Performing sales and operations planning to develop a consensus plan as an input to master scheduling
- Performing master scheduling to produce the master schedule and rough-cut capacity plan
- Performing material requirements planning
- Performing distribution requirements planning for inventory
- Planning production capacity
- Planning inventory
- Forecasting and planning warehouse and transportation capacity

Identifying logistical requirements

The process of identifying logistical requirements involves the following steps:

- Determining logistics objectives and considerations
- Determining warehousing objectives and considerations
- Specifying warehouse capacity requirements
- Specifying materials-handling requirements
- Determining transportation objectives and considerations
- Selecting preferred modes of transport
- Balancing warehousing, transportation, and other logistics requirements

Developing logistical capabilities to support delivery of goods and services

The process of developing logistical capabilities to support delivery of goods and services involves the following steps:

- For all “make” decisions:
  - Completing projects related to logistics, including warehousing and transportation processes, infrastructure, and equipment
  - Staffing new roles
  - Performing training on new processes, infrastructure, and equipment
  - Using change management to ensure that logistical capabilities are incorporated in policy and culture
- For all “buy” decisions:
  - Selecting logistics service providers
  - Developing contracts with logistics service providers

Executing the plans

The process of executing the plans involves the following steps:

- Performing production activity control
- Measuring, managing, and controlling capacity
- Controlling inventory
- Monitoring and controlling delivery patterns and transportation modes
- Monitoring and controlling third-party service providers
- Expediting supply and transportation processes
- Complying with all legal and regulatory requirements

Chapter 1: Components of Demand Management

This chapter is designed to

- Define demand
- Define demand management
- Describe the components of demand management: planning, communicating, influencing.

This chapter first describes the demand management process. Then it describes ways to manage this demand dynamically by coordinating activities between key internal areas of the organization and with the extended supply chain.

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

> a need for a particular product or component. The demand could come from any number of sources (e.g., a customer order or forecast, an interplant requirement, a branch warehouse request for a service part or the manufacturing of another product).

Demand management is defined by the *Dictionary* as

> (1) The function of recognizing all demands for goods and services to support the marketplace. It involves prioritizing demand when supply is lacking and can facilitate the planning and use of resources for profitable business results. (2) In marketing, the process of planning, executing, controlling, and monitoring the design, pricing, promotion, and distribution of products and services to bring about transactions that meet organizational and individual needs.

The supply and demand functions in an organization or an extended supply chain each make plans for identifying/creating and satisfying demand. Demand management is the art of synchronizing supply and demand plans.

Demand management is necessary at each of the levels at which supply and demand plans are generated:

- Long-term strategic needs, including long-term forecasting, product development, or capacity development
- Medium-term aggregate demand forecasting and sales and operations planning
- Short-term demand forecasting and item-level master scheduling

In organizations with multiple plants and/or supply chain collaboration efforts, demand management can help organize multiple sources of supply and demand. Sources of demand that could require coordination include domestic and foreign demand or wholesale and retail demand; sources of supply that could require coordination include plant capacities or specialization and inventories in plants, warehouses, and retail locations.

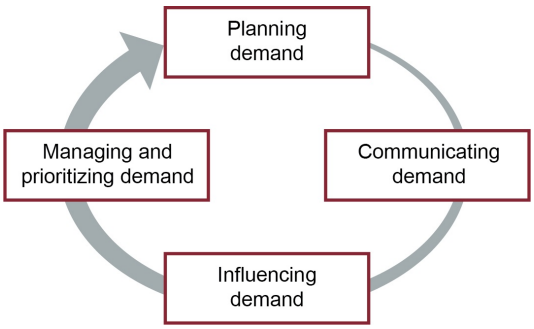
The *APICS Dictionary,* 16th edition, defines the **demand management process** as

> a process that weighs both customer demand and a firm's output capabilities, and tries to balance the two. Demand management is made up of planning demand, communicating demand, influencing demand, and prioritizing demand.

These components of demand management, shown in Exhibit 2-1, are used not only to generate and

communicate a balanced and realistic demand plan but also to proactively ensure that the demand plan is realized.

Exhibit 2-1: Four Components of Demand Management



Topic 1: Planning Demand

Planning demand includes forecasting activities, but that is just its start. Planning demand moves beyond predicting what demand will be because it is a plan for action based partly on those predictions.

Note that planning demand is one component of demand management and is not to be confused with demand planning, which is the larger process of forecasting and demand management.

A key output of the demand planning process should be regular updates to the demand plan.

The demand plan

The demand plan is a consensus document requesting products and services from the supply side of the organization to meet the expected future demand for the organization's products and services in each period. It is an estimate of how many products customers will purchase, at what price, and on what timetable so the organization and its suppliers can determine how much to produce, when to produce it, and when to ship it. The demand plan is based partly on forecasting and partly on commitments by the demand side of the organization to generate the necessary demand to meet the plan and the goals set in the organization's business plan.

Demand plan inputs

The demand plan influences and is influenced by forecasting; by commitments by product and brand management, marketing, and sales to create, influence, manage, and prioritize demand; and by the business plan and strategy. This is shown in Exhibit 2-2.

Exhibit 2-2: Demand Plan Inputs

In addition to the plans listed in Exhibit 2-2, other key inputs to the demand plan are the assumptions used and the level of uncertainty encountered by the persons responsible for preparing the forecasts. These assumptions and uncertainties should be documented, reviewed, and challenged in the monthly S&OP review process to validate that the demand plan is realistic and actionable. Knowledge of assumptions and uncertainties will also help the organization determine the best way to arrive at a consensus regarding demand plan numbers.

Uses of the demand plan

The demand plan is used by multiple areas of the organization because it indicates demand both in units and in monetary amounts such as euros or dollars. In this way, each audience for the demand plan can view the information in the most meaningful terms: operations, logistics, customer service, and product development can view the plan in units; finance can view the plan in monetary amounts; marketing and sales can view both units and monetary amounts.

For example, the plan may provide sales an indication of types and numbers of units that will be available to sell per product family and also provides expected sales goals.

Another use of the demand plan is for validation and control of the plans of individual departments within an organization. Operations and logistics can verify that resource plans are sufficient to meet the expected levels of demand. Finance can use the plan to forecast revenues, product costs, profit margins, and cash flows. Executives can review these projections and determine if the demand plan and related plans of product and brand management, marketing, and sales will have the desired financial and market share results. If not, executives and managers can use the replanning process as a business control. However, the demand plan should not be arbitrarily changed to match the business plan: This would send a signal that the demand analysis and consensus activities at an organization are not valued or respected.

A key control to keep demand plans realistic is to treat the plans as a request for product from the supply side of the organization. In making this request, the demand side of the organization is stating that it is committed to creating this amount of demand and selling the products in the requested amounts. Holding the

demand side of the organization accountable for the consequences of producing too much inventory can be an effective control over unrealistic demand plans.

Close scrutiny of the demand plan can also reveal when inputs may be biased or assumptions unrealistic. For example, if the demand plan input by sales shows a reduction in demand but there is no change in the underlying assumptions from the prior periods, executives could question why the demand was lowered. If the sales force is compensated based on meeting its sales targets, it may have been a case of lowering the target so that success would be easier to achieve.

Planning horizon and revision period

A best practice is to produce a demand plan that has at least an 18-month planning horizon and to revise it by replanning on a regular basis. Many organizations use the S&OP process to incorporate these regular revisions to the plan and to reconcile and synchronize their internal department plans. Regular revision allows the plan to quickly reflect changes in external factors, such as the economy or competitor actions, as well as internal factors, such as branding and product life cycle decisions, lower- or higher-than-expected results from marketing activities or sales promotions, and efforts to bring the plan into alignment with the business plan and strategy.

An 18-month minimum horizon has other advantages:

- It ensures that each period's demand has been planned and reviewed multiple times, with increasing accuracy each time.
- Planned product and brand management and marketing activities typically span at least an 18-month horizon, and sales activities typically span at least a 12-month horizon, so the most current and reliable information on internal plans and likely actions of customers and competitors falls within this 18-month range.
- If the demand plan does not seem to be capable of achieving the goals in the business plan and strategy, a longer horizon allows organizations time to plan and execute additional activities to meet the revenue goals.
- If the demand plan shows a need to increase capacity, it gives the organization sufficient time to approve and execute capital expenditures.
- By midyear the demand plan will show the next year's projected demand and can be used as a key input to the annual business plan.

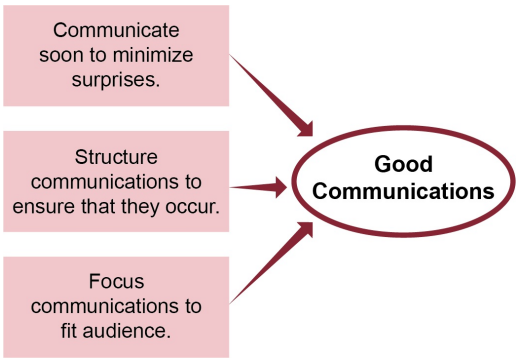
Collaborative planning of demand

Planning demand can be highly collaborative. For example, collaborative planning, forecasting, and replenishment systems help formalize the coordination of forecasting and demand plan creation.

Topic 2: Communicating Demand

Communicating demand, the next component of demand management, rests on the principles of effective communication shown in Exhibit 2-3.

Exhibit 2-3: Principles of Effective Communication



Communicate soon to minimize surprises.

Communicating soon to minimize surprises is the principle that information communicated promptly is of far greater value than communications delayed for any reason. This is true for both good news and bad news as well as for information that is still uncertain. This communications principle is easy to understand but sometimes challenging to put into practice consistently. For example, a marketing person could delay communicating a sales promotion because the effect on demand is proving difficult to quantify. While this is a poor reason not to communicate the promotion, it is also a common example of how people rationalize communications delays. In this case, the promotion might be very successful but the lack of planning for it would contribute to stockouts and the bullwhip effect in later periods. Developing a structure for communicating uncertainty is one mitigating technique for this situation.

Communicating bad news is another example of a communication that would be more useful sooner rather than later but is often delayed. For example, a salesperson may hope that poor sales will turn around or that a big customer will finally commit to an order. A forecast analyst may hope that an economic downturn will turn out to be only temporary. The tendency to delay bad news is compounded by a psychological tendency to blame the messenger of bad news, which makes people less likely to want to share it or fully disclose the extent of the issue. The negative effects of delaying bad news could include products that are built for which there is no demand and use of capacity that could have been devoted elsewhere. Developing a culture that rewards early sharing of good and bad news could improve demand communications significantly.

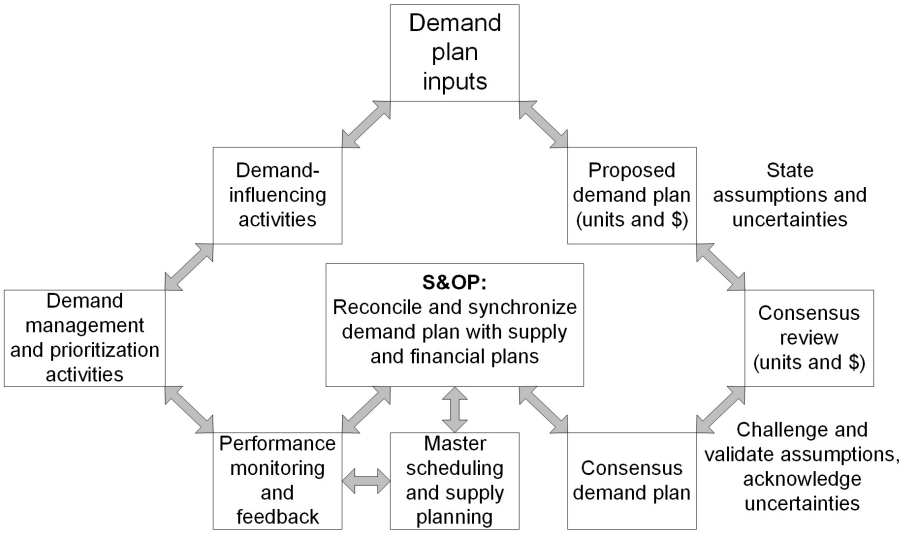
Structure communications to ensure that they occur.

Structuring communications to ensure that they occur means that communications cannot be taken for granted. In the prior example of the failure to communicate a sales promotion, a structured process for communicating uncertainty in estimates would have helped the marketing person to communicate sooner. A structured process must be more than just assuming that transactional data will be forwarded along by the

organization's information systems. While data automation has freed an organization's professionals from spending all of their time on this level of communications, technology is no substitute for interpersonal relationship and consensus building. Person-to-person interaction is needed when setting priorities, explaining nuances, and resolving conflicts.

Exhibit 2-4 illustrates some of the types of communications in the demand planning process that should be structured so they can be reliably repeated.

Exhibit 2-4: Communications Structure for Communicating Demand



The exhibit uses arrows to show the required two-way communications and interactions in the process. Starting with demand plan inputs, communications occur in both directions regarding inputs, including assumptions and uncertainties.

Note that other inputs include demand-influencing and prioritizing activities planned by the demand side of the organization. During the consensus review, a key communication step is to challenge and validate assumptions and to acknowledge uncertainties.

The result of this process is a consensus demand plan that is integrated with finance plans and supply plans during the sales and operations planning process. Communications in the S&OP process of reconciling and synchronizing plans must be structured so that all parties consistently feel listened to and understand the rationale behind the consensus numbers. Communications can lead to greater buy-in and commitment to action that will be needed to realize the plans. An output of the S&OP process is that the supply side of the organization uses the consensus numbers to perform master scheduling and supply planning.

Finally, monitoring performance and providing feedback is a communications process that links to demand-influencing and prioritization activities, to master scheduling and supply planning, and to the S&OP process itself. One way to ensure that these communications occur and feedback is used to keep the plans realistic is to rely on a full-time demand manager.

Demand manager

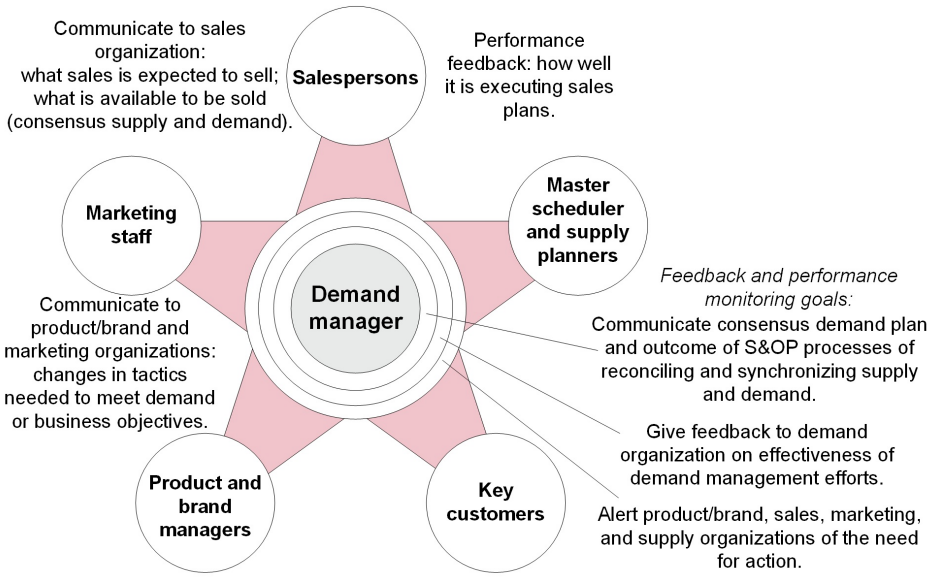
Demand manager is an organizational position that is responsible for:

- Gathering information on demand volume and timing by product, product family, and/or customer segment
- Performing analytical work on the data and the demand plan
- Building consensus on a demand plan
- Communicating demand information to and from the various stakeholders involved in input, planning, execution, monitoring, and revision of the demand plan. The demand manager may also play a lead role in the S&OP process, for example, by creating various scenarios of demand for supply and finance in an effort to tie the demand plan to the business goals.

A best practice is to have this be a full-time position because of the importance and multifaceted nature of the responsibilities. A demand manager needs to have good communication skills and sufficient authority to be successful. This is because the position may be required to respectfully challenge managers on their inputs or gain commitments on demand creation efforts and promises to produce goods according to the consensus demand plan. The position is also required to gather feedback on the results of actions taken to forecast, create, influence, or manage and prioritize demand. The demand manager is responsible for ensuring that the feedback is used to change course, preferably while there is still time to positively influence a developing situation in the organization's favor.

Exhibit 2-5 shows how a demand manager can serve as the primary facilitator of communications and feedback.

Exhibit 2-5: Use of a Demand Manager as a Communications Focal Point



The demand manager is at the center of communications because this position serves as an intermediary between supply and demand organizational areas. Note the three primary feedback and performance monitoring goals that are the responsibility of the demand manager. The demand manager is the recipient of

feedback from the demand side of the organization regarding whether their demand-influencing or prioritization efforts occurred as planned or produced less or more demand than was planned for. When actual demand varies from plan, the demand manager could request additional influencing or prioritization efforts or start the process of altering supply, demand, or financial plans as needed. When demand is less than was planned for, the demand manager informs the supply organization so that they can alter the supply plan to keep supply and demand as synchronized as is feasible given the costs to change ongoing operations.

Note that key customers are listed in the graphic as one of the stakeholder groups with which demand managers may need to communicate. While sales and marketing may maintain all customer interactions at some organizations, demand managers are increasingly communicating the organization's supply and demand synchronization efforts with key customers and gathering information from them to better understand actual demand requirements.

Focus communications to fit audience.

Being effective in communicating demand requires ensuring that the right individuals receive timely communications regarding changes in demand or the results of demand-influencing and prioritizing activities. Information must be disseminated to fit the needs of the person receiving the information, such as providing demand data in dollars for finance but in units for operations.

Focusing communications also requires that each person receives just the information he or she needs to make an informed decision. Too little information can lead to an inability to decide on the best course of action. For example, if inputs to the demand plan consist of just a set of demand numbers without the supporting assumptions, risks, opportunities, and uncertainties, the process of synchronizing and reconciling differing estimates will amount to guesswork. Too much information can also hinder decision making. If the demand data used in the demand consensus review meetings consist of multiple pages of detailed graphs and charts, it could result in key problems being hidden from discussion or an inability to get through the entire planning horizon (e.g., all 18 plus months) during the meeting.

A key tool to help focus communications to fit the audience is to use dashboards, which are software presentations of key information from the organization's information systems. Dashboards can be tailored by each user to show just the key performance indicators and information useful to that person. The user can quickly determine when things are running smoothly and when exceptions require attention. For example, an organization might present two dashboards for a demand consensus review meeting, one in units and one in dollars showing the financial results of the unit plan.

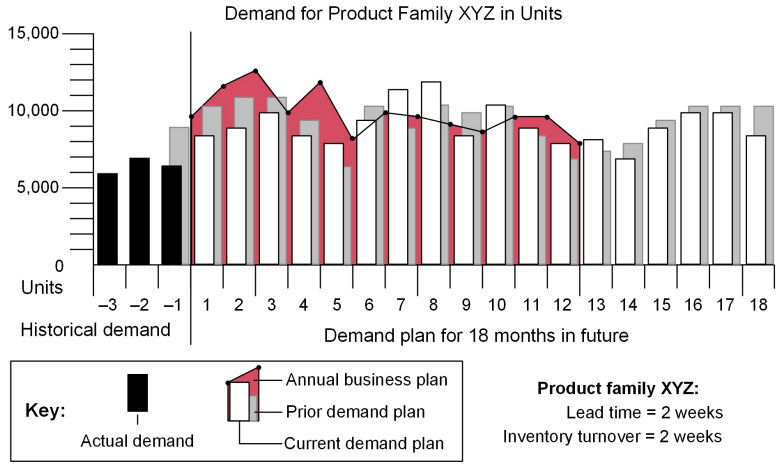
The following elements are important to include in demand dashboards for demand consensus review:

- Historical demand data for the past three months or more, with relevant key performance indicators and metrics for each month
- Demand plan for the next 18 months or more (For each month, this shows the demand plan [actual request for product] and, for comparison, the demand that is necessary to achieve the goals in the organization's business plan.)
- Prior demand plan (Since plans are revised each month, the prior demand plan can be shown as a point of reference and reasons for significant changes can be discussed.)

- Assumptions made in demand numbers and pricing assumptions
- Planned branding, marketing, and sales promotions activities
- Key risks, opportunities, economic trends, and competitor actions
- Subtleties and uncertainties
- Events and issues of note and decisions that were made

Exhibit 2-6 shows just the graphic portion of a dashboard for a demand plan in units. The exhibit illustrates how the revisions from the prior demand plan can be made obvious so that significant changes can be discussed. Note that to be complete, the dashboard would also need the other information listed in the prior bullets. This nuanced information is what enables decision making regarding the true state of demand, plan feasibility, actions that need to be planned and executed to meet the plan and business objectives, and actions to keep supply and demand in synch.

Exhibit 2-6: Example of a Demand Plan Dashboard —Units



Collaborative demand communication

Supply chain managers can counteract supply chain demand variability such as the bullwhip effect by communicating demand effectively to all parties in the supply chain. On a basic level this involves order processing. **Order processing** is “the activity required to administratively process a customer’s order and make it ready for shipment or production” (*APICS Dictionary,* 16th edition).

From a collaborative demand management standpoint, this may involve producing and forwarding a sales order to the most efficient supply channel, such as

- An inventory storage location, authorizing the goods to be shipped
- A production plant, authorizing production and specifying all information required by the master planner (what, how much, and when).

The demand manager or another demand-side professional may also send a copy of the sales order to the

customer to communicate the terms and conditions of the sale. In this way, demand management serves as an intermediary between the customer and production planning.

Organizations can use information-sharing tools such as collaborative planning, forecasting, and replenishment to find a balance between the desire for centralized supply chain planning to provide network integration and optimization and allowing each region to analyze its own market from a local perspective. Each regional partner can be encouraged to share this local expertise with the larger network.

Topic 3: Influencing Demand

Influencing demand describes the activities of product and brand management, marketing, and sales to convince customers to purchase the organization's products and services so that the organization's business objectives are met or exceeded. Another aspect of influencing demand is the requirement for the demand side of the organization to influence the product development and supply sides of the organization to recognize and support actual customer expectations and requirements.

Succeeding at influencing demand requires not only generating and executing marketing and sales initiatives but also determining if the plans are working as intended. If they are not, there must be a process in place to make course corrections during execution. One iterative process that can be used to ensure that demand-influencing activities are being continually adapted to current situations is to use a structured process such as the plan-do-check-action model.

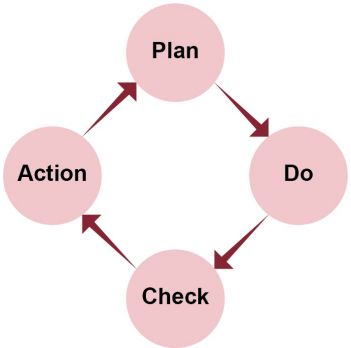
Plan-do-check-action model

The **plan-do-check-action (PDCA)** model is defined by the *APICS Dictionary,* 16th edition, as

> a four-step process for quality improvement. In the first step (plan), a plan to effect improvement is developed. In the second step (do), the plan is carried out, preferably on a small scale. In the third step (check), the effects of the plan are observed. In the last step (action), the results are studied to determine what was learned and what can be predicted.

The PDCA model, shown in Exhibit 2-7, incorporates performance measurement, feedback, and replanning into the processes of planning and executing activities. Note that while PDCA is described here for demand influencing, it can be applied to any process, including the other components of the demand management process and the S&OP integration process.

Exhibit 2-7: Plan-Do-Check-Action Model



Plan phase

During the "plan" phase of the demand-influencing cycle, product/brand management, marketing, and sales perform research and develop detailed strategies and tactics for influencing demand. The plans should

include a budget, a schedule, and a list of tasks assigned to specific individuals for accountability. The plans should also set measurable targets indicating the increase in demand that the activities should generate. The plans are reviewed and approved prior to the S&OP meetings and are adjusted as needed during those meetings, resulting in commitments to execute a consensus plan.

Do phase

During the “do” phase, product and brand management, marketing, and sales execute the plans. Product and brand management professionals launch, manage, and retire products. Marketing professionals work to create demand and reinforce the brand value. Salespersons work to acquire new customers and retain and develop existing customers. Sales and marketing professionals may be required to provide the demand manager with periodic data on their results during execution. The marketing and sales managers and the demand manager exercise management and control during this phase by serving as problem solvers and by verifying that the correct activities are occurring.

Check phase

During the “check” phase, the demand manager and/or other demand-side managers review metrics against the plan and document other feedback, such as customer opinions on product pricing, features, and customer service levels. A key aspect of this phase is to determine the root cause of any differences between plan and actual results, that is, whether they arise from identifiable internal or external factors. These activities are performed periodically rather than waiting until the processes are complete. Dashboards are a common way to track and monitor metrics for demand-influencing activities.

Action phase

During the “action” phase, the demand manager leads replanning efforts to respond to variances from the plan and address root causes of the variances. Replanning may call for increased or decreased investments in various activities depending on what is and is not proving effective. The replanning process could be part of the lead-up to the monthly S&OP process, or it could be performed more frequently if required. However, many marketing efforts take a long time to show measurable results, so a long-term focus is typically necessary.

Using the PDCA model allows organizations to control their demand-influencing activities to the fullest extent possible.

Examples of demand-influencing activities

Positively influencing demand involves product and brand management, marketing, and sales activities such as developing products that customers are actually demanding, settling on the most profitable product mix, setting strategic pricing, placing products at various physical or online distribution points to establish a presence and level of customer convenience, and promoting products through advertisement and other means. These activities can be summarized as the four Ps of marketing (product, price, placement, and promotion), which are discussed in more detail in the section on “Business Considerations.”

The other aspect of influencing demand is to influence the organization to support actual customer expectations and needs. However, this influence must be directed toward the organization’s business objectives. Specifically, this means that the organization should support only products and services that have

a positive contribution margin. A positive contribution margin means that the increased demand will increase net income (profit) rather than simply increasing sales volume or revenue. Expanding product mixes and varieties to satisfy all customers could otherwise result in unsustainable costs and growth.

Demand-influencing activities may also involve convincing customers to accept substitutions or changes in purchase timing. Since the purpose of demand influencing is to support the organization's business objectives, sometimes the best way to support these objectives is to convince customers to purchase an alternative product or to delay purchases. Substitution may occur because one type of product is in surplus or because there is limited capacity and not all customers can be served without making full use of other products in a product family. Convincing customers to delay purchases or wait in some form of queue can also accommodate capacity limitations. In another example, a promotion or discount could be timed to a period in which there is excess production capacity. Similarly, new product introductions or decisions to drop a product line can be timed to minimize the impact on other product lines.

Collaborative demand influence

Influence over departments such as marketing and operations is not a given, and this is especially the case when dealing with multiple organizations. Developing and maintaining influence requires leadership skills and a certain amount of humility. For example, a supply chain partner may have very good reasons for wanting to have a sale in a particular month, and collaboration on influencing demand may require listening, understanding positions, selling the benefits of changes to partners, and reasonable compromise. Managing and prioritizing demand is an important part of demand, this is covered in detail in another section.

Topic 4: Demand Management Functional Responsibilities/Interfaces

Demand management has functional responsibilities and interfaces with other areas in the organization. For example, demand management serves as an intermediary between product development and brand management, marketing, sales, and operations so that all of these functions' plans, communications, influences, and priorities are coordinated to maximize and satisfy demand.

Let's take a closer look at how demand management works with each of these functions.

Product development and brand management

Product development or design and brand management are typically long-term strategic tasks that can benefit from integration with demand management because it promotes the balanced needs of the supply chain. When demand management is allowed to influence product and brand management, products and services can be designed and branded to reflect what is valuable to the customer. Elements that are not perceived as a value to the customer should be eliminated from the design of the product/service package (this is a principle of lean thinking).

Demand management can influence product development and brand management to consider each of the following:

- Satisfying customer requirements on the basis of demand and eliminating features not sufficiently in demand
- Meeting customer requirements for product/service package quality (especially reliability and service responsiveness) and effectiveness of delivery (e.g., timing, convenience, and consistency)
- Meeting customer requirements for price by designing in organizational efficiencies (e.g., acceptable cost and profit)
- Designing production processes and equipment that can accommodate a certain level of increase/decrease in capacity or custom work without loss of profitability
- Creating a brand that expresses the value that the customer places on the product/service package

Demand management can influence product and brand management to consider the processes throughout the whole supply chain, such as the ease and expense of a product's sourcing (of raw materials), manufacturing, warehousing, transporting, displaying, servicing, repairing, returning, and reusing or recycling at the end of its life.

Demand management can provide a collaborative venue for multiple departments or supply chain stakeholders to provide input, consider the feasibility of options or strategies, and, after some amount of iteration, arrive at the product/service package and brand design with the highest potential for mutual profit.

Marketing

Demand management relies on marketing because marketing must provide input to the demand plan. This input is necessary because marketing and sales are the people who are closest to prospects and customers. At some organizations, marketing and sales are considered to "own" the demand plan, while at others this is

the role of the demand manager. At the very least, marketing and sales are typically considered responsible and accountable for forecasting. There is sometimes resistance on the part of marketing and sales to either own the plan or to provide detailed input because this takes away from the time that could otherwise be spent executing marketing and sales activities. The organization must define what inputs are really necessary from marketing and sales and also find ways to make the required inputs more efficient and less time-consuming.

Marketing staff are responsible for finding potential customers and identifying needs the company can solve, creating and maintaining customer demand with communications and promotions, helping to refine product design and packaging to meet customer needs, forecasting demand throughout a product's life cycle, and pricing products and services to be affordable and profitable at the same time.

Marketing traditionally has had little understanding of the processes and requirements surrounding operations management. This lack of understanding works both ways and is the product of the traditional "silo" mentality of departments. Providing a formal demand management function at an organization can provide marketing with expertise on operations and vice versa. Because demand management fits into neither traditional "silo," it is an ideal representative for both interests.

Demand management interfaces with marketing in the medium and short term to tailor demand to meet available capacity. Tailoring demand from a marketing perspective includes setting existing and potential customers' expectations regarding the types of demand that the organization will accept or consider. That is, if customers know the rules of the game, they will be more likely to happily work within those rules. This helps avoid situations such as frustrating a potential customer by having to reject an unprofitable customization request that likely took some time to prepare.

Another way demand can be tailored is by raising or lowering prices either semi-permanently or through promotions. Price reductions can stimulate demand in times of excess capacity, and returns to regular pricing can help when there is insufficient capacity.

Sales

Sales departments work with customers on a daily basis and make delivery promises. The primary interface demand management has with sales is to implement the demand plan commitments regarding influencing or prioritizing demand. Another interface is to ensure that the demand plan supports the organizational strategy. For example, if the organizational strategy is to develop lifetime customers by maintaining excess capacity, it could be the role of sales staff to identify customers on the basis of potential for loyalty and make offers that may not be initially profitable while up-selling to existing loyal customers.

Salespersons desire to eliminate order backlogs, which means sales staff is not typically interested in minimizing inventories. Their priority is to increase sales by providing the right quantity of supplies at the right place. For similar reasons, a high priority for sales is time-to-market, especially if the product or service must be ready for a particular selling season, be presented at a tradeshow or convention, or beat the competition to the market. Demand management can champion these requirements with product development, marketing, and operations.

Demand management can work with sales to manage demand in such ways as convincing product and brand management to raise or lower prices for ordering in bulk or for accepting delayed shipments (within the parameters set by marketing). Another role for demand management is to educate sales staff on the limitations of product development, marketing, and operations, for example, not promising to perform custom work without approval or to supply products in excess of maximum production capacity.

Operations

Interfacing between the demand side of the organization and manufacturing planning and control is a vital task for demand management, because most operations professionals are highly specialized. According to research by Showalter and White, operations management literature “exhibits a pronounced lack of marketing perspective.” They also state that when the marketing perspective is included it is treated “simply as a complicating constraint on the production planning process.” A formal demand management function and/or a demand manager can represent product and brand management, marketing, and sales interests in operations-specific technical terms.

Demand management can also facilitate the understanding between operations and the other parties at S&OP meetings, such as by accommodating the requirements of profitable customer segments in production plans. It also plays a stronger role now than in the past due to the emphasis on replacing safety stocks of inventories with shorter lead times and manufacturing flexibility.

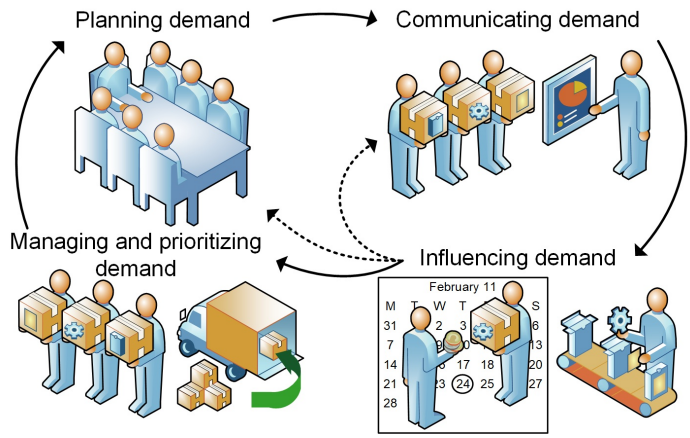
Topic 5: Linking Demand Management Components

Planning, communicating, influencing, and managing and prioritizing demand can be linked in several ways, including cycling through each component iteratively, prioritizing certain components to match organizational strategy, or using powerful business tools such as collaborative planning, forecasting, and replenishment (CPFR®), distributor integration (DI), quick-response programs (QRP), continuous replenishment (CR), and vendor-managed inventory (VMI). These inclusive supply chain management methodologies each integrates point-of-sale (POS) data and forecasting in its own way to reduce lead times, lower inventory costs, and smooth out the bullwhip effect. Note that each also requires building partnerships—and trust—along the supply chain. Partners must be willing to share information (and do it quickly), collaborate in developing a single forecast, and agree to carry out their supply functions according to the forecast. The goal is to replace estimates with data reflecting customers' buying patterns.

Linkages as a cycle

Exhibit 2-8 shows, on a conceptual level, how the demand management components are cyclical. All of the components are necessary for long- and medium-term planning (e.g., product development). However, at the short-term operational level, the dotted lines in the exhibit show how the cycle can be shortened to reduce the need for management and prioritization and/or planning demand when the principles and technologies of demand management are implemented throughout the supply chain. For example, by transferring customer demand data from the point-of-sale immediately to all supply chain partners, the short-term forecasting portion of planning demand can be replaced with actual demand data (i.e., moving from a push system to a demand-pull system). Timely communications will also tend to reduce the need for managing and prioritizing demand because supply will more quickly respond to changes in demand.

Exhibit 2-8: Linkages Among the Components of Demand Management



Linkages to match organizational strategy

Let's look at four organizational strategies that focus primarily on one of the four components of demand

management.

- **Planning demand (fixed high capacity strategy).** This organizational strategy involves meeting demand to the maximum extent possible by providing the necessary capacity to meet peak demand at any time. Ensuring that capacity will be available requires a focus on planning demand, especially in terms of long-term planning. Such a strategy could be pursued if the costs of maintaining excess capacity are considered less than those of losing business.

- **Communicating demand (highly variable capacity strategy).** This organizational strategy involves matching supply to demand as closely as possible by being flexible enough to increase or reduce capacity spontaneously as demand changes. Matching strategies such as these require a focus on communications so that the changes in supply can be proactive rather than reactive. Such strategies may employ a great deal of contract work, outsourcing, and flexible work scheduling.

- **Influencing demand (moderately variable capacity strategy).** This organizational strategy involves leveling production and carefully managing demand to meet optimal capacity. The focus is on influencing demand so that there is little need to change capacity. Sometimes this process is called demand shaping because it involves convincing customers to buy certain models based on excess inventory. (Demand shaping was discussed as part of the discussion of the four Ps.) Demand is influenced by carefully scheduling delivery of products and services (e.g., offering discounts for accepting longer lead times) and timing promotions to operational requirements.

- **Managing and prioritizing demand (fixed average capacity strategy).** This organizational strategy involves controlling demand to the maximum extent possible through scheduling, promotions, queues, and rationing. The focus is on managing and prioritizing demand because fixed average capacity will, by definition, result in periods of insufficient supply. This strategy could be beneficial for products or services that require development and retention of expert personnel or other expensive resources. Airlines that promote early ticket purchases with promotional fares and penalize flyers who buy a ticket at the last minute are examples of companies using this strategy.

Collaborative planning, forecasting, and replenishment

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

The *APICS Dictionary,* 16th edition, defines **CPFR®** as

> (1) A collaboration process whereby supply chain trading partners can jointly plan key supply chain activities from production and delivery of raw materials to production and delivery of final products to end customers. Collaboration encompasses business planning, sales forecasting, and all operations required to replenish raw materials and finished goods. (2) A process philosophy for facilitating collaborative communications.

CPFR® model

Exhibit 2-9 shows the activities and tasks in the CPFR® model. The activities are Strategy & Planning, Demand & Supply Management, Execution, and Analysis. The collaboration tasks appear in the center

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

Exhibit 2-9: CPFR Model

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

The model starts with strategy and planning, where the primary tasks are to decide on how collaboration will proceed and to develop a joint business plan. The joint business plan identifies significant events such as promotions, inventory policy changes, store openings and closings, and product introductions.

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

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

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

Technology

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

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

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

CPFR® scenarios

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

CPFR® challenges

Instituting CPFR® may require meeting several predictable challenges.

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

Distributor integration

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

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

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

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

An obstacle to DI is ownership of inventory. When the distributors are all owned by the same company, there is no problem. However, when distributors are independently owned, there may be no existing relationship

between the distributors and they may not want to provide access to the information. A solution is to allow the manufacturer to act as a middleman to the independent distributors. For example, beer manufacturer Sam Adams has access to its independent distributors' inventory levels. Sam Adams then brokers deals between distributors when inventory shortages or surpluses occur.

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

Quick-response programs

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

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

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

Continuous replenishment

Continuous replenishment (CR), or rapid replenishment, also relies upon sharing of POS data by retailer and supplier. According to the *APICS Dictionary,* 16th edition, **continuous replenishment** is

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

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

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

Vendor-managed inventory

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

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

Specific VMI functions

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

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

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

Vendors can also use historic data and predictive models to forecast stocking demands. The accuracy of the forecasts is carefully monitored and compared with actual data so that the forecasting model can be refined. Inventory levels may be based on sophisticated models that change the appropriate level based on seasonal demand, promotions, or changing consumer demand. Forecasts of demand guide the creation of the master production schedule and the material requirements plan. Work orders are released from the MPS to meet the projected demand plus safety stock.

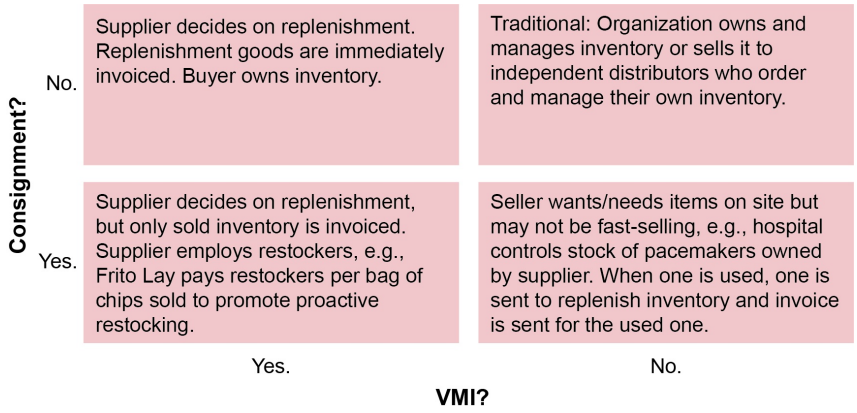
Who owns the inventory—and who benefits?

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

Consignment in relation to inventory is defined in the *APICS Dictionary,* 16th edition, as "the process of a supplier placing goods at a customer location without receiving payment until after the goods are used or sold."

Consignment is sometimes called vendor-owned inventory (VOI). VMI and consignment create four possibilities of how the two can be combined, as shown in Exhibit 2-10.

Exhibit 2-10: VMI and Consignment Combinations



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

When the supplier takes over management of inventory in its customer's location, its incentives also change. The supplier now determines the size and frequency of orders, and if the customer buys inventory upon transfer it may be tempted to transfer as much inventory to the customer's stockroom or shelves as possible. In this way, it keeps its own inventory costs low and, not incidentally, takes up space that might otherwise fill up with a competitor's products. Conversely, consignment arrangements may tend toward optimal inventory since the supplier owns the inventory no matter its location. However, as more total inventory is owned, ordering and carrying costs of inventory will be higher for the supplier.

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

Getting started

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

Steps in the process include the following:

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

Measuring VMI success

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

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

Chapter 2: Forecasting Demand

This chapter is designed to

- Describe how collaborative planning, forecasting, and replenishment (CPFR®) can be used in collaborative demand management
- Describe the principles of demand forecasting
- Discuss factors that affect demand, including trends, cycles, seasonality, promotions/other internal drivers, and random variation
- Describe qualitative forecasting methods, including judgmental/expert judgment forecasting and the Delphi method
- Describe quantitative forecasting methods, including time-series and associative forecasting
- Discuss the basic concepts in measuring forecast error.

This chapter describes some forecasting methods that can help keep supply and demand in balance.

According to the *APICS Dictionary,* 16th edition, **forecasting** is

> the business function that attempts to predict sales and use of products so they can be purchased or manufactured in appropriate quantities in advance.

The purpose of forecasting is to engage in demand planning. The *Dictionary* defines **demand planning** as

> the process of combining statistical forecasting techniques and judgment to construct demand estimates for products or services (both high and low volume; lumpy and continuous) across the supply chain from the suppliers' raw materials to the consumer's needs. Items can be aggregated by product family, geographical location, product life cycle, and so forth, to determine an estimate of consumer demand for finished products, service parts, and services. Numerous forecasting models are tested and combined with judgment from marketing, sales, distributors, warehousing, service parts, and other functions. Actual sales are compared with forecasts provided by various models and judgments to determine the best integration of techniques and judgment to minimize forecast error.

Everything in the supply network depends upon the number of customers that go to the wholesaler, retailer, or website offering your product: manufacturing, capacity, warehousing, transportation, location and type of retail outlets, amounts of raw material to extract—everything. If production outstrips demand, you suffer financial losses and perhaps go bankrupt. If orders exceed supply, your frustrated customers may go instead to your competitor.

Forecasting demand is a necessary part of business planning. You have to have some guidelines when deciding how much product you're likely to sell and how much, therefore, you need to produce. **Demand forecasting** is "forecasting the demand for a particular good, component, or service" (*APICS Dictionary,* 16th edition). Even make-to-order business models need to have sufficient capacity and components prepared prior to receiving customer orders.

But forecasts are subject to uncertainty, and this uncertainty is one potential contributor to the bullwhip effect, the observation that demand fluctuations at the retail level tend to be magnified in orders placed further up the supply chain. The more forecasts miss their target, the more orders vary, with that variation expanding up the supply chain.

Traditional “forecasting” all too often merely assumed that each sales period should yield an increase of some arbitrary percentage of the previous period’s volume. Even the record keeping necessary to determine the baseline was likely to be inaccurate because it failed to account for returns and failures. Today various software programs are available to assist with the complex task of forecasting.

Topic 1: Principles of Forecasting

There are numerous techniques available to use when developing a forecasting process. Whatever the process, however, it needs to be formulated with the following basic forecasting principles in mind.

Forecasts are (almost) always wrong.

No matter how sophisticated the statistical technique, no matter how wise and experienced the experts, a forecast is at best an estimate of what may happen in the future—if there are no surprises. Even if the sales force were able to poll every potential customer for a new product or service, there would be some degree of error in the forecast at the retail end of the supply chain, which in turn would cause greater variability upstream. Circumstances and minds can change. For this reason, forecasts require regular review. Forecasting techniques should be subject to alteration if forecast errors grow too large.

Forecasts should include an estimate of error.

Just as opinion polls often specify a margin of error (e.g., 40 percent favorable rating plus or minus three percent), demand forecasts should include an estimate of how large the forecast error is likely to be. Statistical analysis of the variability of demand around the average demand provides the basis for this error estimate. If your forecast error grows unacceptably large over time, you know that you need to either improve the forecasting process or arrange your supply chain to accommodate a large amount of uncertainty. Error estimates should also be given in terms of the monetary value of the error so that the errors with the most dollars at risk can be addressed first.

Forecasts are more accurate for groups than for single items.

Accuracy generally increases with the size of a product group, assuming that forecasts for each item in the group are as likely to be too high as too low. The low forecasts tend to balance out the high forecasts, at least in sizable groups. **Mix forecast,** as defined by the *APICS Dictionary,* 16th edition, is a

> forecast of the proportion of products that will be sold within a given product family, or the proportion of options offered within a product line…Even though the appropriate level of units is forecasted for a given product line, an inaccurate mix forecast can create material shortages and inventory problems.

For instance, a retailer will have better luck forecasting demand for all blue jeans than for loose-fit Levi brand jeans. A hospital will be better able to forecast numbers of surgeries than numbers of quadruple heart bypass procedures.

In a similar fashion, a manufacturer can improve production forecasting accuracy by pooling the demand forecasts for all customers who order the same product—all wholesalers who order the same brand or style of blue jeans, for example. The manufacturer uses the improved forecast to its advantage if it can send large orders of the trousers to a distributor who serves multiple customers. Any errors on the low side for individual customers may balance errors on the high side for others, and they will all be drawing from the same supply.

The general principle at work in these cases is risk pooling—taking individual risks and combining them into a pool. The overall risk for the pool tends to be less than the average of all the risks that flow into the pool.

Forecasts of near-term demand are more accurate than long-term forecasts.

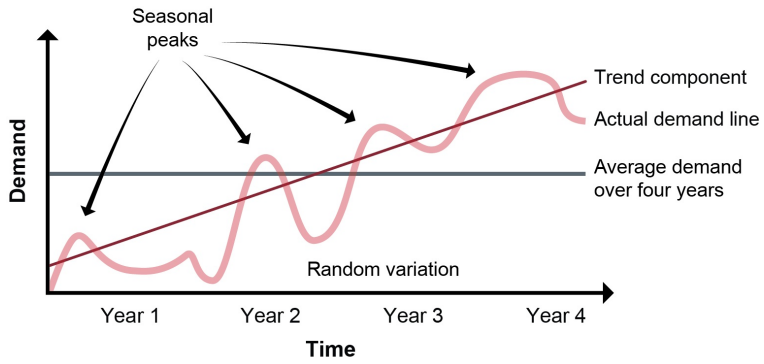
The further you extend a forecast into the future, the more likely that chance and change will derail your estimates. (For similar reasons lenders generally charge more interest for long-term loans than for short-term loans.) Hence, the need for periodic review and update of demand forecasts in comparison to actual results. Long-term forecasts are generally reviewed on an annual or quarterly basis, medium-term forecasts on a monthly basis, and short-term forecasts on a weekly basis. In addition to regular reviews, taking steps to shorten the required lead time for items can shorten the forecasting period and thus improve the accuracy of forecasts.

Topic 2: Factors Affecting Demand

Base demand is the long-term average demand for a product or service. A number of factors can increase or decrease base demand, including trends, cycles, seasonality, random (irregular) variation, and promotions or other internal drivers.

Exhibit 2-11 illustrates several of these factors that influence demand. Base demand is the average demand over four years, seasonality is the large wave effect, and the trend is the increase in the size of the waves over time. (A linear trend line is added.) Random variation is the less-than-perfect shape of the waves.

Exhibit 2-11: Base Demand, Seasonality, Trend, and Random Variation



Trends

A **trend** is the "general upward or downward movement of a variable over time (e.g., demand, process attribute)" (*APICS Dictionary,* 16th edition). A trend is a long-term shift, and two common examples are linear (upward-sloping, neutral, or negative) or exponential (skyrocketing upward or downward). Trends can change direction at any time as a result of internal or external forces.

Cycles and other external drivers

Cycles are periodic upward, neutral, or downward shifts in demand lasting longer than one year. The economic cycles of recession and growth that form a wave pattern are a primary example. The economic cycle might be one of the causes of a trend.

External demand drivers such as economic cycles, population growth, major events, or disasters are sometimes used to qualitatively adjust a quantitative forecast. A particular driver might also be used if its relationship can be tested and shows strong correlation. These drivers can be leading or lagging indicators (which are covered later).

Seasonality

Demand may fluctuate depending on the time of year, e.g., holidays, weather, or other seasonal events.

Seasonality (also known as seasonal variation) is defined in the *APICS Dictionary,* 16th edition, as

> a predictable repetitive pattern of demand measured within a year where demand grows and declines. These patterns are calendar related and can appear annually, quarterly, monthly, weekly, daily and/or hourly.

Seasonality can refer to the seasons of the year or to changes related to any time-based recurring event—lunchtime, the weekend, Christmas, each February, or the first or last week of the month. Whenever seasonality is present to a significant degree, it needs to be removed before forecasting and then added back in later.

Note the difference between seasonality and cycles. Seasonality is a demand pattern that, based on history, will repeat itself on a calendar basis such as month, week, day of the week, hour of the day, etc., and therefore can be predicted. Cycles are demand patterns that repeat but follow a wavelike pattern that can span multiple years and may change at any time; therefore, they cannot be predicted easily.

Promotions or other internal drivers

Promotions, such as discounts or advertising, and other internal drivers of demand, such as deals to gain favorable product placement, will have a measurable impact on demand if they are successful. Promotions that take place in regular patterns will resemble or reinforce seasonality. For many industries, promotions can explain 50 to 80 percent of sales variation. They are worked into forecasts using associative forecasting, for example, by using marketing spend as a driver.

Random (irregular) variation

Random variation is "a fluctuation in data that is caused by uncertain or random occurrences" (*APICS Dictionary,* 16th edition). Random variation is what is left after seasonality is removed. It is the unpredictable part of a data series that cannot be explained by the other factors, basically the remaining variation after the other factors are accounted for. The idea is to minimize this component by finding more and more explainable factors.

Two terms from statistical process control can be used to help understand how random variation differs from the other components of demand. In statistical process control, which is used to track variations in manufacturing or other processes, all variations are categorized as either common cause (general cause) or special cause (assignable cause). Random variation is akin to a common cause. These are the multitude of small factors that affect demand but cannot be added to the model due to the need for simplicity. Demand that is stripped of everything but random variation should conform to a normal distribution (bell curve). Trends, seasonality, cycles, and promotions are akin to special causes, or causes that have an identifiable effect on demand. If the special causes in a data set can be identified prior to their use, a decision can be made about whether or not that data should be included in the forecasting process with or without modifications. In many cases, the impact of these special causes can be removed from the data temporarily prior to forecasting. An example of this is the deseasonalizing process, as is discussed later.

Topic 3: Forecasting Process

Here are the steps in the forecasting process:

1. **Determine the purpose of the forecast.** For example, to determine manufacturing or purchasing targets, capacity, or service staffing.
2. **Determine level of aggregation and what will be forecasted.** Specify units of measure and product family, product, or stock keeping unit (SKU).
3. **Determine the time horizon.** Specify a short-, medium-, or long-term forecast and the planning bucket (e.g., by week, month).
4. **Visualize the data.** Map any available historical data on a graph to see if they have obvious trends or seasonality. This will help when selecting the forecasting method.
5. **Choose the forecasting method or model.** You can choose qualitative or quantitative methods or both. For quantitative methods, decide if a time-series forecast or an associative forecast would work better, and choose a subtype. If historical data are available and the trend appears to be relatively steady, a time-series forecast is a good choice. If no data are available or the trend changes frequently, it may be best to develop an associative forecast based on elements that appear to be driving the changes in the trend.
6. **Prepare the data.** Gather data to be used as forecast inputs. If the visualization showed strong seasonality, remove this temporarily. (How to do this is discussed later.)
7. **Test the forecast using historical data.** If historical data are available, prepare a forecast for a few periods back from the present and compare the forecast results to the actual historical results. Forecast using multiple methods to find the most accurate one.
8. **Forecast.** After making any necessary adjustments, use the model. If seasonality was removed from the data (the data were deseasonalized), add it back in. Any qualitative adjustments would be made at this point.
9. **Perform sales and operations planning.** This process is discussed later, but the result is that demand-side, supply-side, and financial professionals arrive at a single demand forecast that everyone agrees to use. This is called a one-number system (one forecast).
10. **Periodically review and improve models for accuracy.** Monitor and control error levels and continually improve models.

Topic 4: Forecasting Methods

Now let's look at some of the qualitative and quantitative forecasting methods.

Qualitative methods

Qualitative forecasts rely on judgment rather than math. These methods lack scientific precision but can be used on their own in volatile situations or when there are no historical data available, such as for a new product. Sometimes a similar product might be used as a proxy, and this possibility should be explored prior to resorting to a pure qualitative forecast. Qualitative forecasts depend on the experience level of the forecasters, so results can vary widely. This can be true even when a qualitative method is used to adjust a quantitative method.

Bias is also a real risk when using qualitative forecasting on its own or after quantitative forecasting. Estimators may be motivated to estimate too high or too low depending on their incentives. For example, a salesperson could estimate too low to make a sales target easy to reach, while a culture of optimism might lead to aggressive sales goals. One way to mitigate bias is to ask estimators to provide a pessimistic estimate, a most likely estimate, and an optimistic estimate. The three estimates can be combined and divided by three (the simple average), or the most likely estimate can be given more weight. A common way is to multiply the most likely result by four but then divide the total result by six:

$$\frac{\text{Optimistic} + (4 \times \text{Most Likely}) + \text{Pessimistic}}{6}$$

Two common types of qualitative forecasting are judgmental/expert judgment forecasting and the Delphi method.

Judgmental/expert judgment forecasting

Executives, salespersons, market analysts, and others can use their detailed knowledge of their products and their customers, along with their memory of the differences between prior forecasts and actual results, to generate a forecast or, more often, to adjust a quantitative forecast. Tracking these adjustments separately from any quantitative component will help in determining whether these modifications are increasing or decreasing accuracy and in showing whether they are introducing bias by being consistently high or low.

Delphi method

A more involved and sophisticated qualitative forecast can be created by surveying experts and collating their responses into a document that keeps the responses anonymous. The compiler continues to work toward consensus in successive rounds by highlighting areas where there is disagreement and allowing responders to change their responses after reading the current group opinion. Anonymity is used for two reasons. First, it helps prevent dominant personalities or emotions from influencing the group opinion, called the "groupthink" effect. When the groupthink effect is in play, otherwise independent thinkers might become emotionally committed to an unrealistic forecast. The other problem anonymity prevents is a "stake in the ground" mentality. This is when a person has already publicly committed to a forecast result and doesn't want to lose face by changing his or her declared position. Since the position is anonymous, it is easier to change given more information. This method has had good success at arriving at reliable forecasts, but it is time-consuming and labor-intensive. It is often used only for strategic-level estimation.

Quantitative methods: time-series forecasting

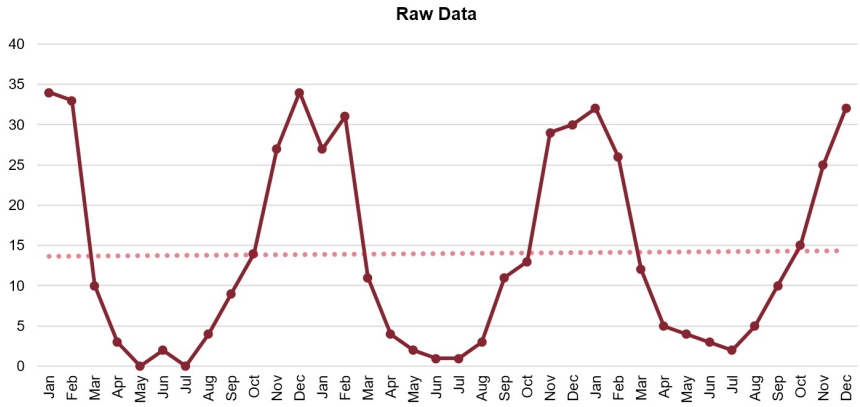
Quantitative forecasting uses mathematical formulas to predict future results based on past trends. Two basic categories are time-series and associative. Time-series forecasting is more commonly used because the methods are less complex mathematically and thus easier to explain to decision makers. Time-series methods assume that the factors that influenced the past will continue on into the future. When that trend is unlikely to be stable, associative forecasting may be needed. Associative forecasting is discussed later in another section.

There are a number of types of time-series forecasting, ranging from the very simple to the relatively complex. Naive forecasting simply assumes that the last period's demand will be this period's forecast. It can be cost-effective but does not account for trends, and any random spike or trough in demand would be carried forward. The naive method is not discussed further in this text. Other time-series methods include the simple moving average, the weighted moving average, and exponential smoothing. We'll examine these in a moment, but first we'll look at some of the steps in time-series forecasting.

Visualizing

Visualizing the data is an important part of forecasting because you can often spot seasonality or other trend or cycle information very quickly and decide how best to forecast. Exhibit 2-12 shows some visualized raw data for a product with strong demand in the winter months and very low demand in the summer months.

Exhibit 2-12: Visualize the Raw Data



In this case, the data for three years were placed in Microsoft Excel™ and one of the features was used to generate a chart automatically. An additional option was selected to automatically calculate the linear trend, shown as the dotted line. It is slightly upward-sloping. However, the waves are very strong, showing strong seasonality, and this will need to be removed or the results will be of little use.

A time-series forecast done during a seasonal upswing would predict this upswing to keep on going upward, while your visual review clearly shows that the upswing will very likely go to a downswing in a predictable manner. Therefore, deseasonalizing is the next step.

Deseasonalizing

The process of deseasonalizing data, or removing the seasonality, involves generating a seasonal index. Calculating a seasonal index requires several years' worth of data (for seasonality that occurs over an annual period). The data used to create the chart in Exhibit 2-12 are shown in Exhibit 2-13 below along with the calculations required to find the seasonal index.

Exhibit 2-13: Creating a Seasonal Index

	A	B	C	D	E	I
1		Raw Data				
2	**Month**	**Year 1**	**Year 2**	**Year 3**	**Month Average**	**Seasonal Index**
3	Jan	34	27	32	31.00	2.214
4	Feb	33	31	26	30.00	2.143
5	Mar	10	11	12	11.00	0.786
6	Apr	3	4	5	4.00	0.286
7	May	0	2	4	2.00	0.143
8	Jun	2	1	3	2.00	0.143
9	Jul	0	1	2	1.00	0.071
10	Aug	4	3	5	4.00	0.286
11	Sep	9	11	10	10.00	0.714
12	Oct	14	13	15	14.00	1.000
13	Nov	27	29	25	27.00	1.929
14	Dec	34	30	32	32.00	2.286
15	**SUM**	170	163	171	168	
16	**Year Average**	14.17	13.58	14.25	14.00	

If you would like to experiment with an interactive version of the worksheet used as a running example for both time-series forecasting and error calculations, download the "Forecasting Model" spreadsheet from the Resource Center.

The index is calculated as follows, using monthly time buckets with three years of data. (Other time periods and buckets could be used instead.)

1. **Calculate the month average for each month.** The month average is the sum of each year's results for a given month divided by the number of years. For example, January results for year 1, year 2, and year 3are summed and divided by 3 to find the month average of 31 units. This is then done for each of the other months.
2. **Calculate the year average.** Sum the 12 month averages and divide by 12. In the example, this is 168/12 = 14 units. This year average is deseasonalized because it averages out the rise and fall in sales.
3. **Calculate the seasonal index.** Divide each month average by the year average. In Exhibit 2-13, the seasonal index for January is 31/14 = 2.214. This is repeated for each other month. Note how the months with higher-than-average demand have an index over 1.0 while months with lower-than-average demand have an index of less than 1.0.

The general formula for calculating the seasonal index is

$$\text{Seasonal Index} = \frac{\text{Average Demand for Period(e.g.,Month)}}{\text{Average Demand for allPeriods(e.g.,Year)}}$$

The next step in the deseasonalization process is to apply the seasonal index to the raw data, which will result in deseasonalized data.

Deseasonalizing data involves dividing the raw data by the seasonal index for the given month. Exhibit 2-14 shows this for the year 1, year 2, and year 3 data. For example, the January year 1 data of 34 units was divided by 2.214, resulting in 15.35 units. The process is repeated for each of the 36 data points.

Exhibit 2-14: Generating Deseasonalized Data

	A	B	C	D	E	I	J	K	L
1		Raw Data					Deseasonalized Data		
2	**Month**	**Year 1**	**Year 2**	**Year 3**	**Month Average**	**Seasonal Index**	**Year 1**	**Year 2**	**Year 3**
3	Jan	34	27	32	31.00	2.214	15.35	12.19	14.45
4	Feb	33	31	26	30.00	2.143	15.40	14.47	12.13
5	Mar	10	11	12	11.00	0.786	12.73	14.00	15.27
6	Apr	3	4	5	4.00	0.286	10.50	14.00	17.50
7	May	0	2	4	2.00	0.143	0.00	14.00	28.00
8	Jun	2	1	3	2.00	0.143	14.00	7.00	21.00
9	Jul	0	1	2	1.00	0.071	0.00	14.00	28.00
10	Aug	4	3	5	4.00	0.286	14.00	10.50	17.50
11	Sep	9	11	10	10.00	0.714	12.60	15.40	14.00
12	Oct	14	13	15	14.00	1.000	14.00	13.00	15.00
13	Nov	27	29	25	27.00	1.929	14.00	15.04	12.96
14	Dec	34	30	32	32.00	2.286	14.88	13.13	14.00
15	**SUM**	170	163	171	168				
16	**Year Average**	14.17	13.58	14.25	14.00				

Simple and weighted moving averages, exponential smoothing

Once the data are deseasonalized, they are ready for use in forecasting with the simple and weighted moving averages and exponential smoothing.

- The **simple moving average** is the average of demand from several preceding periods. Three- and six-month periods are commonly used. For example, a three-month moving average would be calculated as follows, where M1, M2, and M3 are the three most recent months:

$$\text{3-Month Moving Average} = \frac{(M1 + M2 + M3)}{3}$$

  This is a moving average because it is recalculated using the most recent set of months (or other periods), dropping the oldest month and adding the just-ended month to the list.

  The simple moving average can be useful when demand is relatively constant from period to period. The method can be used to prevent an overreaction to a random or irregular spike or dip in a given month because it smooths out these variations. However, if there is a change in a trend, this method would be slow to respond to it. It would lag the trend, in other words, so is best used when a trend is relatively flat. Using more periods. such as a six-month moving average, will make the method even less sensitive to random variation by smoothing more, but it would also make it lag a trend more. One disadvantage of averaging multiple periods is that data collection and organization can be complex when multiple products in a product family need to be forecasted.

- The **weighted moving average** (or weighted average) forecasting method places weights on the periods being averaged, usually to put greater emphasis on the more recent periods and relatively less emphasis on the more distant periods. Thus it allows trends to have more of an impact on the forecast. The weights are usually selected using expert judgment and trial and error. While any weighting system can be used, only testing against historical data can prove whether a given set of weights is a better predictor than another set.

  When calculating the average, you divide by the sum of the weights rather than the number of periods. For example, if the third month out is given a weight of 1, the second month out a weight of 2, and the most recent month a weight of 3, you would divide this three-month weighted moving average by (1 + 2 + 3) = 6, for example:

$$\text{3-Month Weighted Moving Average} = \frac{(1 \times M1) + (2 \times M2) + (3 \times M3)}{6}$$

- **Exponential smoothing** uses three inputs in its equation: the last period's forecast, the last period's demand, and a smoothing constant, a number greater than 0 and less than 1 represented by the Greek letter alpha (α), which is basically a percentage weighting where 1 = 100 percent. One way to calculate exponential smoothing is

$$\text{New Forecast} = (\alpha \times \text{Last Period's Demand}) + [(1 - \alpha) \times \text{Last Period's Forecast}]$$

  Using this equation produces a weighted average of previous results. As you increase α closer to 1.0 or 100 percent, you get closer and closer to a naive forecast, with 1.0 being a naive forecast since it is 100 percent weighted on last period's demand and 0 percent weighted on the prior period's forecast. A constant of 0.3, on the other hand, would put 30 percent of the weight on the last period's demand and 70 percent on the last period's forecast. This constant smooths out random or irregular spikes or dips in actual demand by placing more weight on the prior forecast. Most organizations select a smoothing constant between 0.05 and 0.5. A constant of 0.05 would give minimal weight to the preceding period's actual demand, while 0.5 would equally weight the actual and forecast results. The constant value is selected by experience, trial and error, and testing against historical data.

  This method is often used when you want to minimize the lag that exists when trends shift, but, like all time-series models, it cannot eliminate this lag.

Exhibit 2-15 shows how the simple and weighted moving averages and exponential smoothing would be calculated in a worksheet. All of the data shown in the exhibit are still deseasonalized. The data would be entered in columns, and formulas would be entered (or dragged down) wherever the numbers are bold. The last column in the left-side version shows deseasonalized actual results, including 2016 results. Also in this version, each month's forecast would be created as soon as the actuals for the necessary number of periods become available.

The smoothing constant selected for exponential smoothing in this example is 0.3. Exponential smoothing cannot be calculated unless the prior period's actuals are known, but you can use the other forecasting methods to project farther into the future. To do this, you would substitute forecast data for demand data for

those future periods, as is shown in the right-hand version.

Note, however, how the forecast quickly becomes repetitive; after a few periods, everything is based on forecast data and an average or weighted average of the same three numbers results in the same number. Therefore, these methods are less useful the further out into the future you go.

Note that the three methods produce fairly accurate results, but there is some variance from the actual results for all three methods. The exponential method seems to do better in most periods, but the actual results of 14.64 units (cell I58) is lower than the predicted 15.64 units (cell E58), which will have an impact on the error for that period. However, it bounces back to being more accurate in March because of the 70 percent weight placed on the last period's forecast. We will revisit this particular forecast result later after the data have been reseasonalized.

Exhibit 2-15: Comparison of Forecasts (Deseasonalized Data)

$$\text{Exponential Forecast} = (\alpha \times \text{Last Period's Demand}) + [(1-\alpha) \times \text{Last Period's Forecast}]$$

$$16.86 = (0.3 \times 14.92) + [(0.7) \times 17.71]$$

	A	C	D	E	I
19			Deseasonalized		
20		Moving Average	Weighted Average	Exponential	Actual Demand
45	Jan	14.45	14.45	**13.43**	14.45
46	Feb	12.13	12.13	**13.74**	12.13
47	Mar	15.27	15.27	**13.26**	15.27
48	Apr	17.50	17.50	**13.86**	17.50
49	May	28.00	28.00	**14.95**	28.00
50	Jun	21.00	21.00	**18.87**	21.00
51	Jul	28.00	28.00	**19.51**	28.00
52	Aug	17.50	17.50	**22.05**	17.50
53	Sep	14.00	14.00	**20.69**	14.00
54	Oct	15.00	15.00	**18.68**	15.00
55	Nov	12.96	12.96	**17.58**	12.96
56	Dec	14.00	14.00	**16.19**	14.00
57	Jan	**13.99**	**13.82**	**15.54**	15.87
58	Feb	**14.28**	**14.76**	**15.64**	14.64
59	Mar	**14.84**	**14.94**	**15.34**	15.68
60	Apr	**15.40**	**15.36**	**15.44**	15.51
61	May	**15.27**	**15.42**	**15.46**	19.73
62	Jun	**16.97**	**17.65**	**16.74**	18.61
63	Jul	**17.95**	**18.47**	**17.30**	17.37
64	Aug	**18.57**	**18.17**	**17.32**	18.61
65	Sep	**18.19**	**18.19**	**17.71**	14.92
66	Oct	**16.97**	**16.56**	**16.87**	15.79
67	Nov	**16.44**	**15.97**	**16.55**	15.51
68	Dec	**15.41**	**15.50**	**16.23**	15.08

20		Moving Average	Weighted Average
45	Jan	14.45	14.45
46	Feb	12.13	12.13
47	Mar	15.27	15.27
48	Apr	17.50	17.50
49	May	28.00	28.00
50	Jun	21.00	21.00
51	Jul	28.00	28.00
52	Aug	17.50	17.50
53	Sep	14.00	14.00
54	Oct	15.00	15.00
55	Nov	12.96	12.96
56	Dec	14.00	14.00
57	Jan	**13.99**	**13.82**
58	Feb	**13.65**	**13.74**
59	Mar	**13.88**	**13.81**
60	Apr	**13.84**	**13.79**
61	May	**13.79**	**13.79**
62	Jun	**13.84**	**13.79**
63	Jul	**13.82**	**13.79**
64	Aug	**13.82**	**13.79**
65	Sep	**13.82**	**13.79**
66	Oct	**13.82**	**13.79**
67	Nov	**13.82**	**13.79**
68	Dec	**13.82**	**13.79**

$$\text{3-Month Moving Average} = \frac{M1 + M2 + M3}{3}$$

$$14.84 = \frac{14.00 + 15.87 + 14.64}{3}$$

$$13.88 = \frac{14.00 + 13.99 + 13.65}{3}$$

$$\text{3-Month Weighted Average} = \frac{(1 \times M1) + (2 \times M2) + (3 \times M3)}{6}$$

$$18.47 = \frac{(15.51) + (2 \times 19.73) + (3 \times 18.61)}{6}$$

$$13.79 = \frac{(13.79) + (2 \times 13.79) + (3 \times 13.79)}{6}$$

Reseasonalizing

Reseasonalizing involves multiplying the deseasonalized data by the given period's seasonal index to find the seasonalized forecast values. In Exhibit 2-16, the deseasonalized data for the moving average (the "Moving Year 4" column) is multiplied by the seasonal index and the resulting forecast in units is shown in the "Moving Average" column (column R). For example, the seasonal index of 2.214 for January is multiplied by the moving average January forecast of 13.99, resulting in 30.97 units (which would be rounded up to a forecast of 31 units). The weighted average and exponential columns are similarly calculated.

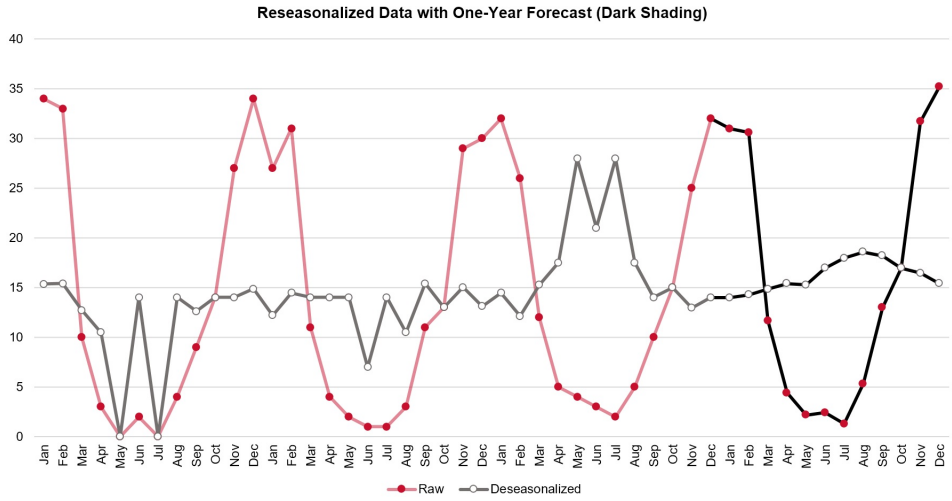
Exhibit 2-16: Comparison of Forecasts (Reseasonalized Data)

	A	I	O	P	Q	R	S	T	U
1			Deseasonalized			Year 4 Reseasonalized Forecasts			
2	**Month**	**Seasonal Index**	**Moving Year 4**	**Weighted Year 4**	**Expon. Year 4**	**Moving Average**	**Weighted Average**	**Exponential**	**Year 4 Raw Actuals**
3	Jan	2.214	13.99	13.82	15.54	30.97	30.60	34.40	34
4	Feb	2.143	14.28	14.76	15.64	30.60	31.64	33.51	29
5	Mar	0.786	14.84	14.94	15.34	11.66	11.74	12.05	13
6	Apr	0.286	15.40	15.36	15.44	4.40	4.39	4.41	5
7	May	0.143	15.27	15.42	15.46	2.18	2.20	2.21	5
8	Jun	0.143	16.97	17.65	16.74	2.42	2.52	2.39	3
9	Jul	0.071	17.95	18.47	17.30	1.28	1.32	1.24	2
10	Aug	0.286	18.57	18.17	17.32	5.31	5.19	4.95	6
11	Sep	0.714	18.19	18.19	17.71	13.00	13.00	12.65	11
12	Oct	1.000	16.97	16.56	16.87	16.97	16.56	16.87	16
13	Nov	1.929	16.44	15.97	16.55	31.71	30.80	31.91	30
14	Dec	2.286	15.41	15.50	16.23	35.21	35.44	37.11	33

Note the February year 4 actual results—only 29 units were sold. While all of the forecasts were high, the exponential forecast was off by the most. On the other hand, it returns to low amounts of variance right after that month of irregular demand and otherwise has lower error rates; this will be explored later.

When you are done creating a forecast, it is generally useful to finish by visualizing the data again in chart form. You can also use charts to present the forecast to decision makers since they can make your forecast easier to digest. Exhibit 2-17 shows a chart with both the raw data and the deseasonalized data and uses dark shading to show a one-year forecast of demand using the three-month moving average method applied to the deseasonalized actual demand (which would become available month by month). The resulting forecast is then reseasonalized. Note that the deseasonalized data would normally not be shown in a chart at all since it is not useful for making decisions in and of itself. It is simply used to produce the reseasonalized forecast for demand planning.

Exhibit 2-17: Deseasonalized and Reseasonalized Data with Forecast



When trends vary too much for these time-series methods to be useful in predicting demand (or anything else being forecasted), associative forecasting can be used.

Quantitative methods: associative forecasting

Associative forecasting (also called causal, correlation, explanatory, or extrinsic forecasting) uses data gathered from one or more internal or external sources as a predictor of something that is presumed to be correlated. The predictor is called the independent variable. The element being predicted is called the dependent variable, and it could be demand for a product family or for total organizational sales.

While the time-series method is best for short- or medium-term forecasting, the associative method is best for long-term forecasting, especially at the aggregate level. Part of the reason for this is that these models require larger data sets and generally have higher costs; they use information with predictive value to form a forecast rather than just looking at past results.

Prior to discussing specific associative methods, let's look at the distinction between correlation and causation. We'll also examine leading versus lagging indicators, since they are often the predictors used in an associative forecast.

Correlation versus causation

Correlation is an observation that the change in an independent variable has a measurable effect on a dependent variable. However, just because the effect can be reliably observed over time does not mean that the one thing caused the other thing. It could be that some third force is affecting both of them, or the correlation could be a coincidence that would be proven incorrect after a longer period of study.

Leading and lagging indicators

According to the *APICS Dictionary,* 16th edition, a **leading indicator** is "a specific business activity index that indicates future trends." Leading indicators provide information that enables organizations to anticipate

or predict micro- or macroeconomic changes in the future. Acknowledging trends allows a company to prepare to take action to achieve a certain outcome and avoid undesirable circumstances. For instance, if a residential hardware manufacturer researches the residential home market and sees that building permits are down and a recession is near, it may decide that it should order more inexpensive components from its suppliers for its faucet products, since consumers will probably be more interested in making repairs to existing hardware rather than buying brand-new faucets.

The following are some leading economic indicators:

- Building permits issued for new production facilities, housing, warehouses, utilities (Building permits imply future construction, and construction leads to other types of production.)
- Initial unemployment insurance claims (Initial claims for unemployment are more dependent upon business conditions than other unemployment metrics.)
- Orders for plant equipment or manufacturers' orders for durable goods and materials (New orders indicate increased production, which decreases inventory and increases unfilled orders.)
- Changes to the total amount of money in an economy that is available at a specific point in time—the money supply adjusted for inflation (Bank lending typically declines when inflation rises faster than the money supply, and this harms economic expansion.)
- Standard & Poor's 500 stock index (Investors' expectations about the economy and interest rates are reflected by changes in the stock prices of the 500 largest U.S. companies.)
- The difference between long- and short-term interest rates (The line that results from plotting, at a certain time, the market interest rates of a financial instrument, for instance, a bond, over a range of maturity dates is called a yield curve. An inverted yield curve indicates that shorter-term yields are higher than longer-term yields, a possible sign of an upcoming recession. Changes to the yield curve usually accurately predict economic swings.)
- The level of consumer optimism about the economy (Consumer expectations often indicate future changes in spending.)

Lagging indicators are the economic and financial factors that reflect the changes that have already occurred in the economy. They usually confirm a pattern and often provide data or actionable information about six months after the fact and therefore are more reactionary. For example, the unemployment rate is one of the most widely used lagging indicators. Generally, the unemployment rate will fall after a few months of economic growth. If a leading indicator of hours worked is increasing, after a few months the lagging indicator of unemployment should fall.

Some other lagging economic indicators include the following:

- Outstanding business and commercial loans (Demand for loans generally peaks about a year after a peak in the overall economy.)
- Comparison of inventory to sales (Increases in inventory usually mean that sales goals were missed, indicating a slowing economy.)
- Changes in company profits (Decreases in profitability have a domino effect often felt by many members of a supply chain.)
- Spending by businesses (Decreases in customer spending, particularly manufacturers' customers, ultimately result in a downturn in the manufacturers' business, too.)
- Consumer price index (CPI) (Increases in the prices of consumer-related service products usually

occur within the first few months of a recession and taper off at the start of a recovery.)
- Average duration of unemployment (This is the average number of weeks an unemployed person has been out of work.)

By paying attention to both leading and lagging indicators, a company can reinforce that it is on the right track.

It is important to apply common sense when selecting indicators to use as independent variables (predictors). The indicators selected should be easy to measure, objective, pertinent to the strategy, cost-efficient, and embraced by the group whose processes are being analyzed. For example, a roofing shingle company might predict sales of its roofing materials using data on the prior month's housing starts, total marketing spend, or extreme weather events like hurricanes. These make sense. However, even if data on recent college graduation rates correlate with roofing material sales, they are less likely to be a good predictor. Remember that chosen predictors need to make sense to decision makers, too.

Simple regression

Simple regression (also called linear regression) uses a formula to make an association between the dependent variable y (the element being predicted) and the independent variable x (the predictor), with two other elements, alpha and beta. Beta (β) is the slope, which is a value used as a multiplier to find the correct placement of the forecast result. Alpha (α) is the intercept, which is where the slope intercepts 0 on a chart. In the case of the housing starts to roofing sales example, if there were 0 housing starts the prior month, what would roofing sales be? That is the intercept. These two values can be calculated manually for a data set, but often forecasters calculate them quickly using the free add-on data analysis toolset for Microsoft Excel.

Once you know these values, it is a simple matter of plugging the value for x (e.g., housing starts) into the formula below to find the forecast, y. Exhibit 2-18 shows the prior month's housing starts against the organization's total roofing sales and helps to explain how those two variables work.

$$y = \alpha + \beta x$$

$$\text{Roofing Sales} = \alpha + (\beta \times \text{Prior Month's Housing Starts})$$

Exhibit 2-18: Simple Regression Slope and Intercept Defined for Roofing Sales Example

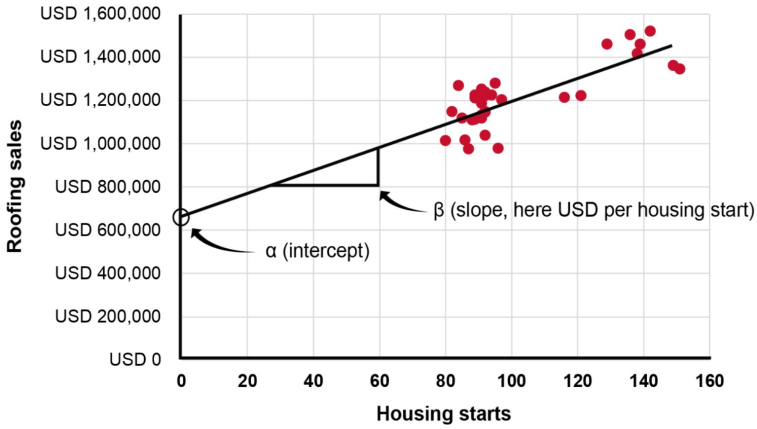
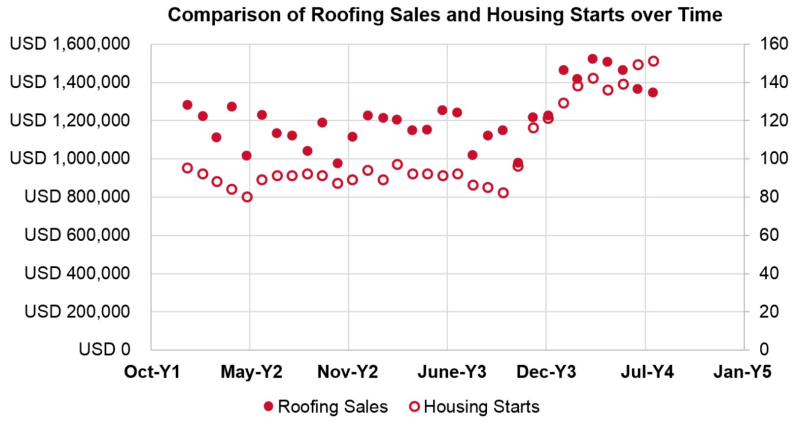


Exhibit 2-19 shows the same data, but now both housing starts and roofing sales are shown over time. This visualization shows that there is some correlation, so further analysis is worthwhile.

Exhibit 2-19: Simple Regression Slope and Intercept Defined for Roofing Sales Example



So, how do we tell whether there is enough correlation to use this predictor in our sales forecast? The statistical term that defines the strength of correlation is called the coefficient of correlation (r). Basically, it is a number between –1.0 and +1.0 where

- –1.0 is perfect negative correlation: An increase in the predictor causes an equal decrease in the predicted element.
- +1.0 is perfect positive correlation: An increase in the predictor causes an equal increase in the

predicted element, and a decrease in the predictor causes an equal decrease in the predicted element. (They rise and fall together.)

- 0.0 is not correlated at all.

In this example, the value is +0.79, which means that the element is positively correlated at about 79 percent, which is a strong positive correlation worth pursuing. Another way of stating this is that this predictor explains about 79 percent of the change in roofing sales, with the remaining factors being other causes. Weaker values would indicate that you should find some other predictor.

Multiple regression

Multiple regression is an extension of simple regression; there are multiple predictive variables rather than just one. For example, one could add marketing spend as another predictor to the roofing sales analysis to see if this increases or decreases the predictive value of the model.

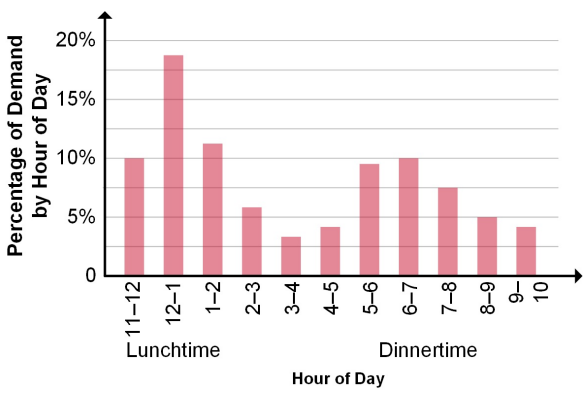
Service-sector forecasting

Some service businesses present special forecasting challenges, since their demand may fluctuate hour by hour rather than on a monthly basis. These rapid changes in demand have significant implications for scheduling and ordering.

Restaurants, for instance, must take into account variations in amount and type of demand by hour of the day, day of the week, and season of the year. They require sophisticated demand planning in more ways than one, since they have to guess right about not only the level of aggregate demand but also the amount of demand for each of the menu items. Running out of an item means disappointing some customers; stocking too much of a perishable item means financial losses—and waste.

Computers can be invaluable in tracking point-of-sale data as they occur. Before automation, detailed tracking meant keeping a manual log during the day or sorting through receipts. Exhibit 2-20 illustrates the forecast for a fast-food restaurant's demand requirements from lunchtime through dinner.

Exhibit 2-20: Restaurant Demand by Hour of Day



These projections are useful in determining all the capacity requirements of a restaurant—numbers of workers to put on each shift, number of registers to maintain, number of tables, space requirements, and so on—as well as in making decisions about food items to stock.

Combination methods

Good forecasting is best done with a combination of quantitative and qualitative considerations. For example, a forecaster for an electronics company might use a mathematical model to estimate demand for future periods. The forecaster should then modify the projection with all pertinent and available intelligence. This could include knowledge of competitor sales promotions or product launches, the state of the economy, trends in discretionary spending, and so on.

When using combination methods, both the quantitative forecast and the qualitatively adjusted forecast can be measured separately for error to determine the degree to which qualitative methods are helping or hindering forecasting.

Topic 5: Measures of Forecast Error

Since the first principle of forecasting is that forecasts are (almost) always wrong, organizations need to track forecasts against actual demand results and find ways to measure the size and type of error. Note that the size of an error can be measured in units or percentages, but often finding a way to put a monetary value on the error can help in focusing on the most expensive errors. (Being off by 1,000 on an item that costs a cent will differ significantly from the same amount of error for an item that costs US$100.) Forecasters can use error measurements to modify forecasts to reduce the amount (and costliness) of error. If software does your calculations, the program can select the smoothing constant that will reduce your historical forecast errors to a minimum.

This section looks at forecast error and accuracy and the effect of bias and random variation along with five error-tracking methods: mean absolute deviation, the tracking signal, standard deviation, mean squared error, and mean absolute percentage error.

Forecast error

Forecast error is "the difference between actual and forecast demand" (*APICS Dictionary,* 16th edition).

The formula for forecast error as an absolute value follows (returning to the prior time-series forecasting example showing February 2016 actual demand of 29 units and forecast demand of 33.51 units):

$$\begin{aligned}\text{Forecast Error} &= |A - F| \\ &= |29\ \text{Units} - 33.51\ \text{Units}| \\ &= |-4.51\ \text{Units}| = 4.51\ \text{Units}\end{aligned}$$

Where
A = Actual demand
F = Forecast demand

An absolute value is a number that is stated without regard to positive or negative signs, so the absolutes of +4.51 and –4.51 are both 4.51. The equation above expresses the absolute value mathematically using vertical bars, e.g., $|-4.51| = 4.51$. Absolute values of forecast error are used in some of the error tracking methods discussed later such as mean absolute deviation.

When expressing forecast error as a percentage (also known as absolute percentage error [APE]), the equation is as follows (with a continuation of the prior example):

$$\begin{aligned}\text{Forecast Error as a Percentage} &= \frac{|A - F|}{A} \\ &= \frac{|29\ \text{Units} - 33.51\ \text{Units}|}{29\ \text{Units}} \\ &= \frac{4.51\ \text{Units}}{29\ \text{Units}} \\ &= 0.155 = 15.5\%\ \text{Error}\end{aligned}$$

Forecast accuracy

Forecast accuracy is simply the complement of the forecast error as a percentage, expressed as follows (with a continuation of the prior example):

$$\text{Forecast Accuracy} = 1 - \text{Forecast Error as Percentage}$$
$$= 1 - 0.155 = 0.845 = 84.5\,\% \text{ Accuracy}$$

Bias and random variation

Forecast error can be the result of bias or random variation.

- **Bias.** Bias is "a consistent deviation from the mean in one direction (high or low). A normal property of a good forecast is that it is not biased" (*APICS Dictionary,* 16th edition). Bias exists when the cumulative actual demand differs from the cumulative actual forecast. For example, if actual demand is 34, 29, and 13, cumulative actual demand adds these amounts to arrive at 76. If the forecast demand is 34.4, 33.51, and 12.05, the cumulative forecast demand is 79.96. Calculating bias can use a variation on the forecast error calculation, but it doesn't use absolute amounts because the plus or minus sign can show the direction of the bias:

  $$\text{Cumulative Forecast Error} = \text{Cumulative Actual Damage} - \text{Cumulative Forecast Demand}$$
  $$= 76 - 79.98 = -3.96$$

  Any answer that does not result in zero reflects a bias. The size of the number reflects the relative amount of bias that is present. A negative result shows that actual demand was consistently less than the forecast, while a positive result shows that actual demand was greater than forecast demand.

  Bias could be the result of a temporary situation or an unaccounted-for change in a trend or seasonal effect. Tracking the circumstances surrounding each significant bias can help distinguish between the two. For example, bias caused by a one-time bulk sales order would not require modifying the forecasting model, but a significant shift in a trend or seasonal effect (or shifts in the timing of these effects to earlier or later periods) requires changes to the forecasting model (e.g., seasonal index or smoothing constant) or process (e.g., could be a result of overly optimistic qualitative adjustments).

- **Random variation.** In terms of measuring errors, random variation is any amount of variation in which the cumulative actual demand equals the cumulative forecast demand. For example, if actual demand is 100 for three periods, cumulative actual demand is 300, and if forecast demand is 90, 110, and 100, the cumulative forecast demand is 300. Because of the zero net difference, the error over this period can be said to be the result of random variation. Note that wide swings in either direction that just happen to balance out would still be difficult to plan around.

Mean absolute deviation (MAD)

A common way of tracking the extent of forecast error is to add the absolute period errors for a series of periods and divide by the number of periods. This gives you the mean absolute deviation (MAD). Note: In the formula below, the Greek uppercase letter ∑ stands for "the sum of."

$$\text{MAD} = \frac{\Sigma |A - F|}{n}$$

where:
$|A - F|$ = Total of absolute forecast errors for the periods
n = Number of periods

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

> the average of the absolute values of the deviations of observed values from some expected value. It can be calculated based on observations and the arithmetic mean of those observations. An alternative is to calculate absolute deviations of actual sales data minus forecast data. These data can be averaged in the usual arithmetic way or with exponential smoothing.

With absolute values, whether the forecast falls short of demand or exceeds demand doesn't matter; only the magnitude of the deviation counts in MAD.

We can see how this works by continuing the prior time-series demand and smoothing forecast example, in Exhibit 2-21. Note that error rates for all three methods are shown, but we will focus on the exponential smoothing method primarily.

Exhibit 2-21: Mean Absolute Deviation with Smoothing

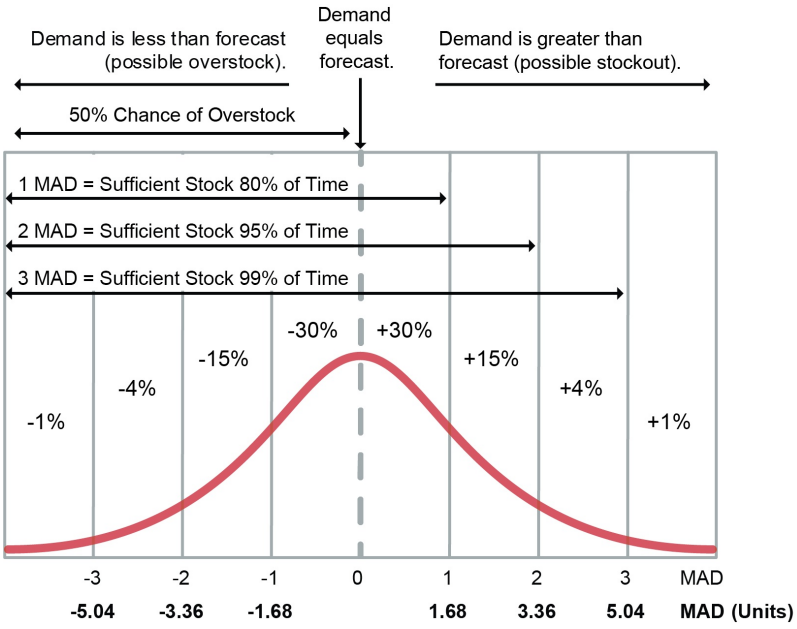
	R	S	T	U	V	W	X
1	**Year 4 Reseasonalized Forecasts**				Absolute Errors		
2	**Moving Average**	**Weighted Average**	**Exponential**	**Year 4 Raw Actuals**	**Moving Error**	**Weighted Error**	**Expon. Error**
3	30.97	30.60	34.40	34	3.03	3.40	0.40
4	30.60	31.64	33.51	29	1.60	2.64	4.51
5	11.66	11.74	12.05	13	1.34	1.26	0.95
6	4.40	4.39	4.41	5	0.60	0.61	0.59
7	2.18	2.20	2.21	5	2.82	2.80	2.79
8	2.42	2.52	2.39	3	0.58	0.48	0.61
9	1.28	1.32	1.24	2	0.72	0.68	0.76
10	5.31	5.19	4.95	6	0.69	0.81	1.05
11	13.00	13.00	12.65	11	2.00	2.00	1.65
12	16.97	16.56	16.87	16	0.97	0.56	0.87
13	31.71	30.80	31.91	30	1.71	0.80	1.91
14	35.21	35.44	37.11	33	2.21	2.44	4.11
15				**SUM**	18.25	18.45	20.20
16				**MAD**	**1.52**	**1.54**	**1.68**

$$\text{MAD} = \frac{\Sigma \text{ Absolute Errors}}{\text{Number of Periods}}$$
$$= \frac{0.40 + 4.51 + 0.95 + 0.59 + 2.79 + 0.61 + 0.76 + 1.05 + 1.65 + 0.87 + 1.91 + 4.11}{12}$$
$$= \frac{20.20}{12} = 1.68 \text{ Units}$$

A MAD of 1.68 units implies that forecasts are off on average for the review period by about plus or minus 1.68 units. Exhibit 2-22 shows MAD from Exhibit 2-21.

MAD may be used as the basis for safety stock calculations. This is because when a forecast is in error and lower demand is planned for than the actual demand that occurs, stockouts could result. Higher levels of safety stock will be needed to safeguard against those less probable events at the stockout end of the normal distribution curve.

Exhibit 2-22: Normal Distribution Curve for MAD of 1.68 Units



In Exhibit 2-22, the center is the average or central tendency, which would be a forecast matching actual demand in this example. The left-hand side of the curve is the likelihood that demand will be less than the forecast, which means that 50 percent of the time there will be sufficient inventory or possibly an overstock situation. The right-hand side of the curve is the likelihood that demand will be greater than the forecast, or a potential stockout situation if not enough safety stock is held.

Note that this is a normal MAD distribution curve of MAD. In the exhibit, ±1 MAD, or up to ±1.68 units in error, should be experienced 60 percent of the time (plus or minus 30 percent from the mean). For a stockout probability, 1 MAD adds the 50 percent overstock probability to the 30 percent zone for 1 MAD for an 80 percent probability that there will still be sufficient stock if 1.68 units are held as safety stock (two units if rounded up). Moving further out in the curve, ±2 MAD means that in some instances the error will be up to two mean absolute deviations, and adding the two 15 percent zones means that 90 percent of results should be within ±2 MAD, or ±3.36 units (1.68 × 2). Again, for a stockout probability, 2 MAD adds the 50 percent overstock probability to the 30 percent zone for 1 MAD and the 15 percent zone for 2 MAD, to equal a 95 percent probability that sufficient inventory will be in stock if at least 3.36 units are held as safety stock (four units rounded up). Similarly, 98 percent of all results should fall within ±3 MAD, or ±5.04 units (1.68 × 3), which equates to a 99.87 percent probability that there will be no stockouts if at least 5.04 units (six units rounded up) of safety stock are held. The chance of a stockout is calculated as one minus the percent chance of sufficient inventory. For 2 MAD, this is 1 − 0.95 = 0.05 = 5 percent chance of stockout.

Note that an analyst would provide actual MADs for a given service level. If a specific service level is desired, such as 98 percent of orders with no stockouts, analysts can calculate the exact MAD to use as the multiplier in the calculation of units of safety stock. This multiplier is called a safety factor. Exhibit 2-23 shows that a 98 percent service level has a safety factor of 2.56 MAD (or 2.05 if standard deviation in units is

known).

1.68 MAD in Units × 2.56 Safety Factor = 4.3 Units of Safety Stock
(or 5 units if rounding up is the rule the organizationdecidestofollow)

Exhibit 2-23: Safety Factor Table

Percentile Customer Service Level	Standard Deviation Units x Factor Below	MAD Units x Factor Below
50.00	0.00	0.00
75.00	0.67	0.84
80.00	0.84	1.05
84.13	1.00	1.25
85.00	1.04	1.30
89.44	1.25	1.56
90.00	1.28	1.60
93.32	1.50	1.88
94.00	1.56	1.95
94.52	1.60	2.00
95.00	1.65	2.06
96.00	1.75	2.19
97.00	1.88	2.35
97.72	2.00	2.50
98.00	2.05	2.56
98.61	2.20	2.75
99.00	2.33	2.91
99.18	2.40	3.00
99.38	2.50	3.13
99.50	2.57	3.20
99.60	2.65	3.31
99.70	2.75	3.44
99.80	2.88	3.60
99.86	3.00	3.75
99.90	3.09	3.85
99.93	3.20	4.00
99.99	4.00	5.00

Source: www.supplychainchannel.org

Tracking signal

According to the *APICS Dictionary,* 16th edition, the tracking signal is “the ratio of the cumulative algebraic sum of the deviations between the forecasts and the actual values to the mean absolute deviation.”

The tracking signal can be calculated as shown in Exhibit 2-24.

Exhibit 2-24: Tracking Signal

	R	S	T	U	V	W	X	AD	AE	AF
1	Year 4 Reseasonalized Forecasts				Absolute Errors					
2	Moving Average	Weighted Average	Exponential	Year 4 Raw Actuals	Moving Error	Weighted Error	Expon. Error	Moving Error +/-	Weighted Error +/-	Expon. Error +/-
3	30.97	30.60	34.40	34	3.03	3.40	0.40	3.03	3.40	-0.40
4	30.60	31.64	33.51	29	1.60	2.64	4.51	-1.60	-2.64	-4.51
5	11.66	11.74	12.05	13	1.34	1.26	0.95	1.34	1.26	0.95
6	4.40	4.39	4.41	5	0.60	0.61	0.59	0.60	0.61	0.59
7	2.18	2.20	2.21	5	2.82	2.80	2.79	2.82	2.80	2.79
8	2.42	2.52	2.39	3	0.58	0.48	0.61	0.58	0.48	0.61
9	1.28	1.32	1.24	2	0.72	0.68	0.76	0.72	0.68	0.76
10	5.31	5.19	4.95	6	0.69	0.81	1.05	0.69	0.81	1.05
11	13.00	13.00	12.65	11	2.00	2.00	1.65	-2.00	-2.00	-1.65
12	16.97	16.56	16.87	16	0.97	0.56	0.87	-0.97	-0.56	-0.87
13	31.71	30.80	31.91	30	1.71	0.80	1.91	-1.71	-0.80	-1.91
14	35.21	35.44	37.11	33	2.21	2.44	4.11	-2.21	-2.44	-4.11
15				SUM	18.25	18.45	20.20	1.30	1.60	-6.69
16				MAD	1.52	1.54	1.68			
19				Tracking Signal	0.85	1.04	-3.98			

$$\text{Tracking Signal} = \frac{\text{Algebraic Sum of Forecast Errors}}{\text{Mean Absolute Deviation (MAD)}}$$

$$= \frac{(-0.40)+(-4.51)+(0.95)+(0.59)+(2.79)+(0.61)+(0.76)+(1.05)+(-1.65)+(-0.87)+(-1.91)+(-4.11)}{1.68}$$

$$= \frac{-6.69}{1.68} = -3.98$$

Note that the algebraic sum of forecast errors is a cumulative sum that does not use absolute values for the errors (thus the necessity of a new set of columns in the worksheet example). Therefore the tracking signal could be either positive or negative to show the direction of the bias.

Organizations use a tracking signal by setting a target value for each period, such as ±4. If the tracking signal exceeds this target value, it would trigger a forecast review.

Many organizations calculate and track each SKU on a monthly basis. This helps measure two aspects of the forecast:

- **Forecast bias.** If the tracking signal is continually negative, we are consistently over-forecasting. If it is consistently positive, we are under-forecasting. Ideally, the tracking signal should oscillate between positive and negative values. If not, it should be the first thing to work to eliminate.
- **Suitability of the forecasting method.** If the tracking signal remains in a range of +4 to −4, then, as a rule of thumb, the method being used to forecast that SKU should be considered to be working correctly. If it is outside this range, review the forecasting methodology to find something more suitable.

Standard deviation

As seen in Exhibit 2-25, another way to calculate forecast error would be to use standard deviation, which is commonly provided in most software programs.

An approximation for standard deviation when you know the MAD follows (using the MAD in units from the running example):

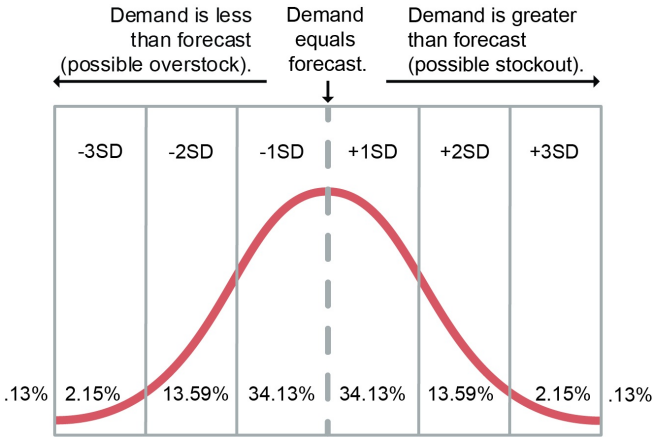
$$\begin{aligned}\text{Standard Deviation (approximate)} &= \text{MAD} \times 1.25\\ &= 1.68\ \text{Units} \times 1.25\\ &= 2.1\ \text{Units}\end{aligned}$$

If standard deviation is the information you have at your disposal, you can use the middle column of Exhibit 2-23 to calculate the safety stock at a given service level.

For SD of 2.1 units at a 98 percent service level:

$$2.1\ \text{SD in Units} \times 2.05\ \text{Safety Factor} = 4.3\ \text{Units of Safety Stock}$$
(or 5 units if rounding up is the rule the organization decides to follow)

Exhibit 2-25: Normal Distribution Curve for Standard Deviation



Mean squared error (MSE)

Another method of calculating error rates, the mean squared error (MSE), magnifies the errors by squaring each one before adding them up and dividing by the number of forecast periods. Squaring errors effectively makes them absolute, since multiplying two negative numbers always results in a positive number.

Note that the errors are squared before being summed, which requires new columns in the worksheet, as shown in Exhibit 2-26. The formula for mean squared error follows (with an example from the exhibit below):

$$\text{MSE} = \frac{\text{Sum of (Errors for Each Period)}^2}{\text{Number of Forecast Periods}} = \frac{55.57}{12} = 4.63$$

MSE and MAD comparison

Note that the process of squaring each error gives you a much wider range of numbers (20.31 as opposed to –4.51 in February on the high side and 0.16 instead of –0.40 in January on the low side).

The greater range gives you a more sensitive measure of the error rate, which is especially useful if the absolute error numbers are relatively close together and reduction of errors is important.

Exhibit 2-26: Mean Squared Error and MAD Compared

	U	V	W	X	AD	AE	AF	AG	AH	AI
1		Absolute Errors								
2	Year 4 Raw Actuals	Moving Error	Weighted Error	Expon. Error	Moving Error +/-	Weighted Error +/-	Expon. Error +/-	Squared Moving Error	Squared Weighted Error	Squared Expon. Error
3	34	3.03	3.40	0.40	3.03	3.40	-0.40	9.16	11.54	0.16
4	29	1.60	2.64	4.51	-1.60	-2.64	-4.51	2.55	6.95	20.31
5	13	1.34	1.26	0.95	1.34	1.26	0.95	1.80	1.58	0.90
6	5	0.60	0.61	0.59	0.60	0.61	0.59	0.36	0.37	0.35
7	5	2.82	2.80	2.79	2.82	2.80	2.79	7.94	7.82	7.79
8	3	0.58	0.48	0.61	0.58	0.48	0.61	0.33	0.23	0.37
9	2	0.72	0.68	0.76	0.72	0.68	0.76	0.52	0.46	0.58
10	6	0.69	0.81	1.05	0.69	0.81	1.05	0.48	0.65	1.10
11	11	2.00	2.00	1.65	-2.00	-2.00	-1.65	3.98	3.98	2.72
12	16	0.97	0.56	0.87	-0.97	-0.56	-0.87	0.93	0.31	0.76
13	30	1.71	0.80	1.91	-1.71	-0.80	-1.91	2.91	0.64	3.66
14	33	2.21	2.44	4.11	-2.21	-2.44	-4.11	4.90	5.93	16.87
15	SUM	18.25	18.45	20.20	1.30	1.60	-6.69	35.87	40.47	55.57
16	MAD	1.52	1.54	1.68						
17	MSE	2.99	3.37	4.63						
19	Tracking Signal	0.85	1.04	-3.98						

Measuring the extent of deviation helps determine the need to improve forecasting or rely on safety stock to meet customer service objectives.

Mean absolute percentage error (MAPE)

There is a drawback to the MAD calculation in that it is an absolute number that is not meaningful unless compared to the forecast. Mean absolute percentage error (MAPE) is a useful variant of the MAD calculation because it shows the ratio, or percentage, of the absolute errors to the actual demand for a given number of periods. The example continues the study of the exponential forecast error in Exhibit 2-27.

$$\text{MAPE} = \frac{\Sigma\left(\frac{|A-F|}{A}\right)[\%]}{n} = \frac{206.8\,\%}{12} = 17.2\,\%$$

Exhibit 2-27: Mean Absolute Percentage Error (MAPE)

	R	S	T	U	V	W	X	Y	Z	AA
1	**Year 4 Reseasonalized Forecasts**				Absolute Errors					
2	**Moving Average**	**Weighted Average**	**Exponential**	**Year 4 Raw Actuals**	**Moving Error**	**Weighted Error**	**Expon. Error**	**Moving APE**	**Weighted APE**	**Expon. APE**
3	30.97	30.60	34.40	34	3.03	3.40	0.40	8.9%	10.0%	1.2%
4	30.60	31.64	33.51	29	1.60	2.64	4.51	5.5%	9.1%	15.5%
5	11.66	11.74	12.05	13	1.34	1.26	0.95	10.3%	9.7%	7.3%
6	4.40	4.39	4.41	5	0.60	0.61	0.59	12.0%	12.2%	11.8%
7	2.18	2.20	2.21	5	2.82	2.80	2.79	56.4%	55.9%	55.8%
8	2.42	2.52	2.39	3	0.58	0.48	0.61	19.2%	16.0%	20.3%
9	1.28	1.32	1.24	2	0.72	0.68	0.76	35.9%	34.0%	38.2%
10	5.31	5.19	4.95	6	0.69	0.81	1.05	11.6%	13.5%	17.5%
11	13.00	13.00	12.65	11	2.00	2.00	1.65	18.1%	18.1%	15.0%
12	16.97	16.56	16.87	16	0.97	0.56	0.87	6.0%	3.5%	5.5%
13	31.71	30.80	31.91	30	1.71	0.80	1.91	5.7%	2.7%	6.4%
14	35.21	35.44	37.11	33	2.21	2.44	4.11	6.7%	7.4%	12.4%
15				**SUM**	18.25	18.45	20.20	196.3%	192.0%	206.9%
16				**MAD**	**1.52**	**1.54**	**1.68**			
18				**MAPE**	**16.4%**	**16.0%**	**17.2%**			

Exhibit 2-27 shows how the absolute percentage error (APE) is first determined for each period by taking the absolute error divided by the actual demand (A). This is done for each month in a new set of columns. Then, the sum of the APE (percent) for periods 1 through 12, which is 206.8 percent for the exponential method in the example, is divided by the number of periods, 12 in the example, to calculate the MAPE. On average, MAPE is 17.2 percent.

Note that the result is expressed as a percentage. Exception rules for review can be applied to any stock keeping unit or product family that has a MAPE above a certain percentage value.

Percentage-based error measurements such as MAPE allow the magnitude of error to be clearly seen without needing detailed knowledge of the product or family, whereas when an absolute error in units (or an error in dollar amounts) is provided it requires knowing what is considered normal for the product or product family.

Chapter 3: Demand Prioritization

This chapter is designed to

- Describe demand prioritization
- Discuss the linkages among the components of planning, communicating, influencing, and prioritizing demand
- Describe the demand management functional responsibilities and interfaces with product development, marketing, sales, and operations.

Since supply is often constrained or lacking, demand needs to be prioritized to guarantee that the supply chain as a whole is well served and the organization uses its resources wisely so that operations lead to profitable business results. Demand prioritization starts at the level of master scheduling and also occurs at the material requirements planning level.

Topic 1: Demand Prioritization Policies and Processes

Demand prioritization may include setting time fences to keep operations running on time and on budget once they are committed rather than allowing disruptive last-minute changes. It also includes allocation of supply, and it must be measured and managed to ensure that customer service levels are met.

Managing and prioritizing demand requires an organization- or supply chain-wide view. It involves optimizing demand across the system as measured by optimum organizational profit, demand volume, sales revenue, and customer service (including customer retention). This is a management activity because it involves setting and enforcing policies to promote this optimization process; it is a prioritization activity because it involves making judgment calls to decide what actions or customers are more important than others when capacity is limited.

Organizations must manage and prioritize demand because sales will differ on a regular basis from planned demand in total volume and/or in product mix and because supply often cannot produce products in the exact timing and mix specified by the demand plan.

Management and prioritization can be based on customer segmentation strategies, such as fulfilling orders to the most valuable customer segments first. Another example is rationing supply so that each warehouse or retailer receives a portion of the full demand but no entity goes without a certain minimum amount. Managing and prioritizing demand could also involve prioritizing production to increase supply of certain items or prioritizing items within distribution systems to better distribute supply to meet demand. For service industries or for customer service attached to products, prioritizing demand can involve queues (waiting in line or waiting on hold).

Exhibit 2-28 shows some situations in which managing and prioritizing demand is usually necessary.

Exhibit 2-28: Situations Requiring Managing and Prioritizing Demand, with Examples

Situation	Example
When conducting sales and operations planning and the	An organization with fixed capacity starts with high inventory demand for a hot-weather product. Rather than continuing to

supply organization cannot meet the demand plan without changes	try to predict the weather far in advance, they prioritize how product is distributed so that only areas currently forecasting or experiencing hot weather are allocated more product, reducing capacity pressures and inventory.
When the demand plan overstates actual demand and plan changes will impact sales revenue and product costs	An organization resolves a situation of too much supply by establishing a series of decision points (time fences) for production activities such as purchasing so that some operations can be delayed until more accurate demand information is available. Demand that does not materialize prior to the decision points can be de-expedited (moved back in the production queue).
When the demand plan understates actual demand and plan changes will impact sales revenues and product costs	An organization resolves a situation of insufficient capacity by extending its planning horizon to give it more time to increase capacity. For current capacity issues, it provides incentives for substitute products and offers discounts for taking delayed delivery.
When a large, one-time sales opportunity arises that would impact regular orders, production costs, and profits	An organization prioritizes unusual demand by establishing a process of recognizing and reporting the demand as soon as possible to allow time for decision making. Both demand and supply organizations develop cost and profit margin projections for accepting and rejecting the order, including impact on customer service. Sales management determines how to prioritize other orders if the order is accepted.

Since demand management and prioritization often involve thinking beyond an internal department focus or beyond a single organizational focus, successful implementation can benefit significantly by setting a clear prioritization policy and implementing it using a structured process.

Demand management and prioritization policy

A demand management and prioritization policy should clearly indicate who is allowed to manage and prioritize demand. Responsibility should be restricted to appropriate management levels in the supply organization based on the level of risk involved in the decision. The highest prioritization decisions involving strategic risks should be made at the executive level, while supply managers should be responsible and held accountable for lower-level demand management and prioritization decisions. A key policy best practice is to retain responsibility for these lower-risk decisions at the management level rather than delegating this responsibility to individual salespersons. Delegating to individual salespersons tends to create organizational conflicts because each salesperson will naturally be motivated to act in his or her own customers' best interests rather than in the overall best interests of the organization. This policy should be documented and clearly communicated to the sales force.

Another policy best practice is to retain this management and prioritization power in the demand side of the organization rather than delegating it to the supply organization. While the supply side will provide critical input to decisions regarding the cost of changing ongoing production activities, only the demand side has information on the most valuable customers and marketing and sales goals.

Demand management and prioritization process

A demand management and prioritization process rests on several principles. One is that the organization's intent is to fulfill demand whenever it is feasible and will result in an increase in marginal profits, even when

this demand comes from unexpected sources. The prioritization process involves finding ways to make the unexpected orders become profitable if they would not be otherwise. This may involve fulfilling the demand later than is requested, delaying other orders to meet the customer's request date, or offering a substitute product. An order is declined only if these measures are not acceptable to the customer or the sales manager. Sales and customer service must be trained in such an exception process so that these orders can be analyzed as soon as possible, while multiple options still exist.

Another principle is that when demand differs from supply within a time frame that allows for supply capacity or operations to be changed without impact on costs or other operations, prioritization is not necessary. It is the supply organization's responsibility to manage supply in this case. When there are cost implications to a supply and demand mismatch (such as when materials have already been purchased or work is in process), management and prioritization are necessary to match supply.

The process should involve determining ways to delay commitments until the last possible moment so that prioritization is necessary for as few operations as possible. This is done by delaying decisions until a necessary decision point is reached, such as when raw materials need to be ordered or a batch process must be started to keep operations running smoothly and at acceptable cost. These decision points when they relate to operations are called time fences. Time fences are discussed next. Decision points such as time fences should be set in consultation with both the supply and demand sides of the organization so that they reflect the optimum balance between production costs and customer service. Strategic decision points may include questions such as whether to increase capacity. Delaying such a decision until it is absolutely necessary to start the related capital projects will allow the organization to have the most current information on projected demand.

Collaborative demand management and prioritization

Tools for collaborative demand management and prioritization include sharing information on actual capacity or working with retailers well in advance of perceived shortage periods.

Measures of customer service levels

Customer service represents the supply chain's role in fulfilling marketing objectives. A customer service strategy must identify and prioritize all activities required to fulfill customer logistical requirements as well as —or better than—the competition does.

When developing a customer service strategy, the key question to ask is "Does the cost associated with achieving specified service performance represent a sound investment?" Comprehensive evaluation of competitive performance and customer response to service attributes can be used to formulate a basic strategy.

The fundamental measures of basic customer service are fill rates, lead time monitoring, order status monitoring, and customer satisfaction. These measures are addressed in more detail in Module 3.

Topic 2: Time Fences

As defined in the *APICS Dictionary,* 16th edition, a **time fence** is “a policy or guideline established to note where various restrictions or changes in operating procedures take place.” A time fence marks off a zone in which otherwise available product may not be promised-to-deliver without escalation to senior leadership.

Time fences in master scheduling

There are two types of time fences: the demand time fence (DTF) and the planning time fence (PTF). The two time fences create three zones, as shown in Exhibit 2-29.

Exhibit 2-29: Time Fences and Zones in Master Scheduling Grid

		Frozen Zone			Slushy Zone					Liquid Zone	
Period		1	2	3	4	5	6	7	8	9	10
Forecast		20	22	21	25	24	23	21	21	25	25
Customer orders		19	17	15	11	9	5	2	1	0	0
Project available balance (PAB)	50										
Available-to-promise (ATP)											
Master production schedule (MPS)											

Demand Time Fence

Planning Time Fence

Source: APICS Master Planning of Resources, Version 3.1

- **Demand time fence/frozen zone.** In a frozen zone, capacity and materials are committed to specific orders. Orders are therefore “frozen” inside the fence. Any changes require the approval of senior management. Frozen time zones are bounded by a demand time fence like the one in Exhibit 2-29.
- **Planning time fence/slushy zone.** A zone marked off by a planning time fence is slushy rather than frozen. Capacity and materials are not as strongly committed as those inside a frozen zone. There is room to negotiate in a slushy zone in the form of tradeoffs, and the master scheduler is allowed to make these decisions.
- **Liquid zone.** In the liquid zone created by the remaining planning horizon after the planning time fence, all changes are permissible as long as they don’t violate the limits set in the production plan or by the policy in the sales and operations plan.

Time fences for material requirements planning

Time fences for material requirements planning (MRP)—basically, planning for components or subcomponents of a production unit—work similarly to those described for master scheduling, except that each planned component will have its own set of time fences. The purpose of using time fences in MRP is to ensure that materials needed for orders are committed to those orders and not used for other purposes. The

planning time fence is usually set when the material is ordered or production is begun on the component; the demand time fence is usually set when the material is received or production of the component is complete.

Time fences in MRP help manage the end item's cumulative lead time because the operation will have its requisite materials available when they are needed. **Cumulative lead time** (or end-to-end lead time) is defined by the *APICS Dictionary,* 16th edition, as

> the longest planned length of time to accomplish the activity in question. It is found by reviewing the lead time for each bill of material path below the item; whichever path adds up to the greatest number defines cumulative lead time.

Complex products or services often have lengthy production or rollout cycles and thus multiple time fences. For example, a service providing implementation of an ERP system would need a time fence to commit to a particular ERP version, a time fence to stop product customization or configuration, and a time fence for changes to customer training materials. In another example, a ship's hull may have one set of time fences, its engines another, and the furnishings for the cabins could have another set much later in production than the first two.

Benefits of time fences

Time fences can help balance the need for a production system to maintain schedules and control costs against the need for it to be flexible. Costs for changes dramatically increase when nearing the final deadline of a time horizon. Rescheduling, additional setups, rerouting, expediting, overtime, and disrupted schedules for other items can all be direct costs of late changes, not to mention the toll it takes on the perceived reliability of the master production schedule and on customer service.

However, flexibility is needed because customers can cancel orders or request changes, equipment can experience failures or other capacity problems could occur, raw materials could be used at a higher rate than expected (e.g., scrap), or suppliers could fail to deliver goods on time.

Topic 3: Allocation of Supply

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

> 1) The classification of resources or item quantities that have been assigned to specific orders but have not yet been released from the stockroom to production. It is an "uncashed" stockroom requisition. 2) A process used to distribute material in short supply.

Allocation of supply involves giving sales staff or downstream supply chain partners a view into the projected available balance and what is available-to-promise to customers. It includes finding ways to commit inventory and scheduled production to specific customer orders (intermediate customers or ultimate customers), including order promising by salespersons, without needing to move the items from inventory until they are needed for production. As per the second definition, allocation also refers to the demand management and prioritization activities.

The master scheduling grid that is created during the master scheduling process includes the projected available balance and available-to-promise. Exhibit 2-29, is a master scheduling grid with a planning horizon of 10 weeks, minimum order quantities of 50, and a safety stock level of zero units. (As defined in the *APICS Dictionary,* 16th edition, the **planning horizon** is "the amount of time a plan extends into the future." It should be at least equal to the cumulative lead time for the product.)

Projected available balance

The **projected available balance** (PAB) is "an inventory balance projected into the future" (*APICS Dictionary,* 16th edition). Whenever the PAB in a given period falls to a negative value or below the safety stock level, the master production schedule (MPS) must be reevaluated. Exhibit 2-30 shows an amount of 50 to the left of the PAB for period 1. This represents the available inventory at the start of this planning horizon.

The MPS logic calculates the PAB for all future periods based on the beginning inventory and the demand for each period. In its simplest form, the PAB is based on a calculation of

Beginning Inventory + Any Additional Supply – Any Demand = Ending Inventory

For the MPS, this is complicated by having a formula for the periods before the demand time fence and another for after the demand time fence.

Exhibit 2-30 uses the data from Exhibit 2-29 to complete the PAB. Prior to the demand time fence, the calculation is as follows (with an example from period 1 in the exhibit):

PAB Prior to DTF = Prior Period PAB + MPS – Customer Orders
Period 1 PAB = 50 Units + 0 Units – 19 Units = 31 Units

After the DTF, the calculation is as follows (with an example from period 6):

PAB After to DTF = Prior Period PAB + MPS – Greater of Forecast or Customer Orders
Period 6 PAB = 0 Units + 50 Units – 23 Units = 27 Units

Exhibit 2-30: Projected Available Balance

		Frozen Zone			Slushy Zone					Liquid Zone	
Period		1	2	3	4	5	6	7	8	9	10
Forecast		20	22	21	25	24	23	21	21	25	25
Customer orders		19	17	15	11	9	5	2	1	0	0
Project available balance (PAB)	50	31	14	49	24	0	27	6	35	10	35
Available-to-promise (ATP)											
Master production schedule (MPS)				50			50		50		50

Demand Time Fence

Planning Time Fence

Source: APICS Master Planning of Resources, Version 3.1

As you can see, prior to the DTF we are concerned only with the known component of demand (customer orders). After the DTF it is the greater of forecast or orders. The obvious question is why. Recall that, in the frozen zone, materials are committed to orders and orders are frozen. The MPS logic therefore considers that only orders we have in hand will consume the on-hand inventory. Beyond the DTF, we can expect to receive more orders than those already booked.

As noted, the MPS logic uses the PAB level to determine when additional product is needed and proposes an MPS activity. (The MPS has to be checked with the rough-cut capacity plan to verify that capacity is available.) In Exhibit 2-30, the MPS reflects a quantity of 50 units in period 3. This was developed by calculating the PAB for each period. Using the PAB formula, the first period that goes negative is period 3. (The calculation would result in –1 units in period 3 if no MPS activity had been proposed.) Therefore, production of 50 units (recall that the replenishment for this product is fixed at 50 units) is required in period 3. Calculations for the remaining periods proceed in the same manner. Note the PAB of zero in period 5. Many planners may feel that we need to have replenishment at this point for many valid reasons. Understand, however, that the basic MPS logic is for the PAB to go negative before ordering. In an actual software configuration, planners could make adjustments to system variables to include replenishment at this point.

Available-to-promise

The *APICS Dictionary,* 16th edition, defines available-to-promise (ATP) as “the uncommitted portion of a company’s inventory and planned production maintained in the master schedule to support customer order promising.” The *Dictionary* defines **order promising** as “the process of making a delivery commitment (i.e., answering the question ‘When can you ship?’).”

The methods used to compute ATP are discrete ATP (or noncumulative), cumulative ATP with look-ahead, and cumulative ATP without look-ahead. For our example, we will use the noncumulative (discrete) method, because it is the base method that the other methods build upon. Noncumulative methods are used for products that have an expiration date, such as milk, vegetables, pharmaceuticals, or beer. Beer, for example, has a six-month time frame. The other methods account for unsold ATP from prior periods and backlogs in

their calculations and are used for nonperishable items.

At the beginning of the planning horizon, the ATP amount includes inventory on hand plus the items scheduled to arrive in the form of a MPS receipt or scheduled receipts from a supplier. As customer orders come in and consume the uncommitted inventory, the number of available items goes down. When all the items have either been delivered or committed for delivery, nothing is left to promise.

Exhibit 2-31 uses the data from Exhibit 2-30 to complete the ATP row. ATP for the first period of the planning horizon is calculated as follows (with an example from period 1 of the exhibit):

First Period ATP = Inventory on Hand + MPS − Sum of Customer Orders Before Next MPS
Period 1 ATP = 50 Units + 0 Units − (19 Units + 17 Units) = 14 Units

Exhibit 2-31: Available-to-Promise

		Frozen Zone			Slushy Zone					Liquid Zone	
Period		1	2	3	4	5	6	7	8	9	10
Forecast		20	22	21	25	24	23	21	21	25	25
Customer orders		19	17	15	11	9	5	2	1	0	0
Project available balance (PAB)	50	31	14	49	24	0	27	6	35	10	35
Available-to-promise (ATP)		14		15			43		49		50
Master production schedule (MPS)				50			50		50		50

Demand Time Fence

Planning Time Fence

Source: APICS Master Planning of Resources, Version 3.1

For all other periods in which there is an MPS, the ATP does not include inventory on hand, so the formula is as follows (with an example from period 3 of the exhibit):

Following Period ATP = MPS − Sum of Customer Orders Before Next MPS
Period 3 ATP = 50 Units − (15 Units + 11 Units + 9 Units) = 15 Units

Commitment decision points

Two situations could frustrate buyer-supplier relationships when actual demand data and demand plans are shared:

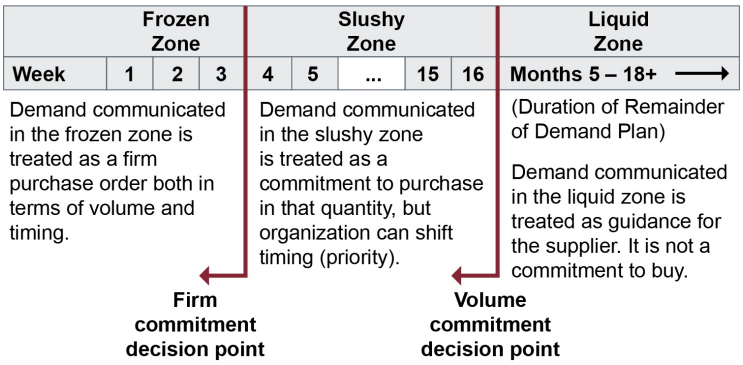
- When the supplier apparently does not use the demand information and has not developed sufficient capacity (or maintains too much capacity) despite being given time and motivation make the necessary changes
- When the supplier builds sufficient capacity or inventory but the organization fails to order in that quantity because the plans overstate demand (or they understated demand and the supplier has insufficient capacity)

Since these problems affect both ends of the relationship, organizations that choose to collaborate should

clearly set expectations and obligations in the form of a bilateral contract or trading partner agreement. Such agreements can specify how demand information will be communicated and what is expected of each organization in terms of building capacity or ordering what was requested. The agreement should specify development of formal processes to support the collaborative effort.

Such an agreement should specify when demand information represents a commitment to purchase goods or services and when it does not. This can be done using decision points similar to the time fences that were introduced previously. Exhibit 2-32 shows how decision points could be used to create three zones of purchase commitment so that sellers can feel comfortable committing to produce the requested orders on schedule.

Exhibit 2-32: Use of Decision Points to Create Purchase Commitment Zones



In this example, the organization negotiates two decision points with a supplier: a firm commitment decision point and a volume commitment decision point. The firm commitment decision point is set three weeks out, and this creates a frozen zone where the buyer commits to communicate purchase orders and makes firm requests for delivery timing on specific days. The buyer and the supplier negotiate a second decision point at 16 weeks out, a volume commitment decision point, which creates a slushy zone before the point and a liquid zone after the point. Within the slushy zone, demand that is communicated is treated as an agreement to specify weekly quantities to deliver. The buyer can rearrange priorities or change timing of orders but must buy the specified quantity of goods or services during those weeks. The liquid zone is used to communicate updates to the demand plan over whatever remains of the demand plan's planning horizon (five to 18 months in this example). Demand information communicated for these periods represents no contractual commitments for purchasing or production on the part of the buyer or the supplier.

If negotiations take this format, the subjects for negotiation will include where each decision point should be placed, based on the given industry, supplier and buyer lead times, and the amount of flexibility or continuity each partner desires in the relationship. These negotiations should occur at the executive level with input from both organizations' supply and demand professionals. This will ensure that the plan encompasses all technical requirements for order timing while getting top support for the agreement.

This type of agreement allows the organizations to have a long-term focus and provides some amount of stability for the buyer and the supplier and perceived fairness for both parties.

Chapter 4: Operations Planning and Control

This chapter is designed to

- Define master planning, sales and operations planning (S&OP), demand plan, and production plan
- Review the role of strategy in operations planning and control and its overall process
- Identify the purpose and elements of S&OP
- Describe what occurs in the meetings and steps of the S&OP process
- Explain how to use a demand plan dashboard
- Explain that S&OP balances the requirements of multiple areas: demand, supply, and financial plans
- Describe ways to promote and implement S&OP at an organization
- Describe the purpose and objectives of master scheduling.

The *APICS Dictionary,* 16th edition, defines **master planning** as

> a group of business processes that includes the following activities: demand management (which includes forecasting and order servicing); production and resource planning; and master scheduling (which includes the master schedule and the rough-cut capacity plan).

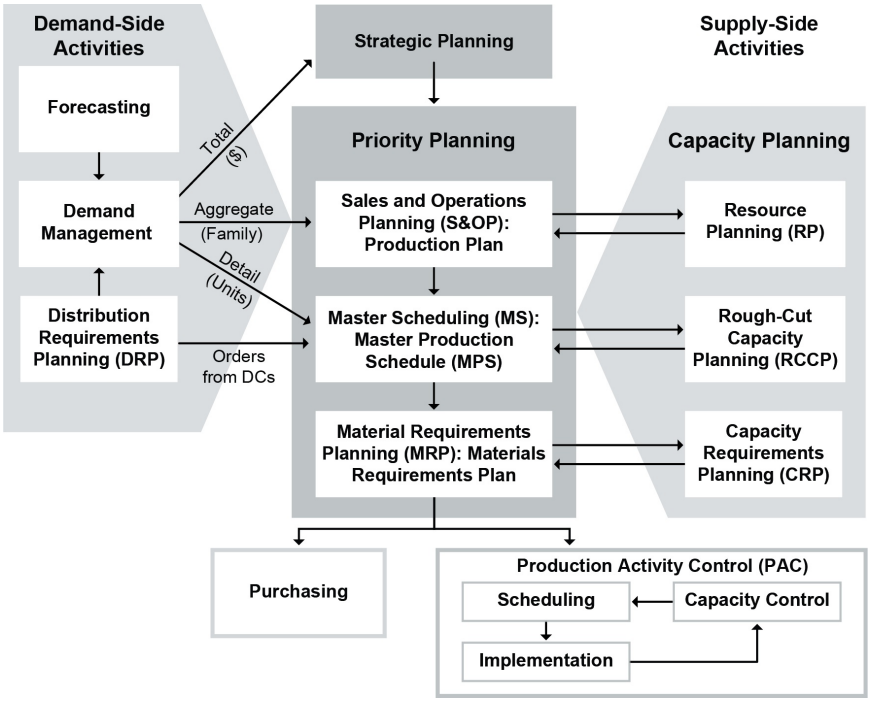
Exhibit 2-33 provides an overview of how master planning is based on strategic planning and business planning, a consensus demand plan and a production plan from S&OP, and inputs from the demand and supply sides of the organization: the forecast, production planning, and resource planning.

The center column shows the supply-side outputs: The production plan, based on a consensus demand plan, is developed to guide master scheduling, which produces a master production schedule and plans for the necessary raw materials in material requirements planning and for controlling production and scheduling assembly (production activity control and final assembly scheduling). The exhibit shows how both the demand and supply organizations have continuing input as plans grow more and more detailed and time horizons grow shorter and shorter.

The high-level demand-side activities of forecasting and demand management involve demand sensing and creation activities and result in a demand plan. (Demand management and forecasting were covered elsewhere.) The distribution requirements planning process involves determining the inventory replenishment needs at branch warehouses/distribution centers.

The supply-side activities start with resource planning, which determines the need for capital investments or capacity modifications. The remaining activities in the right-hand column of the exhibit address whether evolving plans are feasible from an operations capacity standpoint.

Exhibit 2-33: Operations Planning and Control



To expand upon Exhibit 2-33, the basic steps in operations planning and control can be summarized as follows. (Some terms used below are defined later.)

- Demand history data are gathered and cleansed. A statistical forecast is run and analyzed for events or outliers that are not expected to repeat in the future.
- The statistical forecast with associated errors is reviewed with the product and brand management, marketing, and sales teams. The teams add information to the demand plan that will improve forecast accuracy.
- The demand plan is finalized with the demand-side teams and passed on to supply.
- The supply team reviews the demand plan and constrains it based on capacity availability.
- Both supply and demand review the constrained plan with the finance team and executive management.
- When the executive S&OP meeting is held, the result is the communication of a single plan: Sales sells to the plan and supply produces to the plan.
- One of the outputs of S&OP is the production plan, which provides the rate of production at the family level. Resource requirements are evaluated with the resource plan.
- The production plan is the input to master scheduling, and its output is the master production schedule (MPS). The MPS is typically a weekly plan at the item level with an evaluation of capacity through rough-cut capacity planning.
- Then material requirements planning uses bill-of-material data, inventory data, and the MPS to calculate requirements for materials, resulting in planned production and purchase orders.
- Production activity control receives the output of material requirements planning and detail planning,

and final assembly scheduling is done.

The following topics cover strategic and business planning, master planning, resource planning, sales and operations planning, and master scheduling.

Topic 1: Strategic, Business, Master, and Resource Planning

Strategic and business planning

The organization's strategic and business plans are the foundation for the organization's master planning, sales and operations planning, and resulting production plan. The strategic plan is a long-term plan, extending over five to ten years or more, that focuses on how to marshal resources and determine actions to support the mission and goals of the organization. It clearly identifies the mission, goals, and objectives and sets the high-level direction of the organization, including broad goals for market share, revenue, profits, and growth.

The objectives of organizational strategy indicate what value the organization will provide to customers or constituents in terms of products/services and what value operations should generate for the owners. While organizational strategy is set for the long term, it is updated periodically in response to the organization's strengths and weaknesses and the opportunities and threats in the current operating environment.

An organization's business plan states organizational strategy in more specific terms and sets goals for achieving the strategy over the next one to three years or more. The business plan specifies how value will be created for both customers and owners and what the results should be in terms of market share, revenue, cash flow, profits, and measurements such as customer satisfaction.

The business plan is typically stated in dollars and grouped by product family. There may be overly optimistic projections from marketing at some points, but the numbers are there for later review as well as to specify projected revenues, costs, profits, and objectives for the product families—all to support the long-range strategy proposed for entering the marketplace. Key inputs to the business plan include the demand plan and its long-term forecasts. Budgets and projected financial statements are key outputs. A business plan should:

- Clarify strategy by stating an explicit vision for the business—a reason for being.
- Provide a point of reference for the sales and operations plan.
- Describe long-term strategies that will be used to guide shorter-term tactical plans for producing and selling the product.

As the organization begins spending the lender's or stockholders' money and the market heats up (or doesn't heat up), the plan sometimes disappears into a file and becomes part of history. It shouldn't. An objective for business planning is to update the business plan annually to reflect changes in strategy and to use the disciplined sales and operations planning process on a monthly basis to evaluate progress against the plan and make adjustments as needed. Thus the business plan is the parent of every operations planning and control activity described in this chapter.

Master planning

The next step after the business plan is development of a master plan. This is a long-term resource plan and a near-medium-term sales and operations plan based on the longer-term views of the business plan. Master planning encompasses many of the steps discussed below. It starts by taking the forecast and determining what production can accomplish using available capacity (S&OP) and by directing investments in capacity (resource planning). The overarching goal is always to satisfy the organization's stakeholders. In a for-profit organization, this means providing the lenders and investors with the return on investment they anticipated when they signed on as financial partners in the enterprise.

Resource planning

Resource planning (RP), or resource requirements planning (RRP), takes the longest view of the system's capacity, typically going out 15 to 18 months but sometimes requiring much longer planning horizons for capital investments.

Resource planning is defined as follows according to the *APICS Dictionary,* 16th edition:

> Capacity planning conducted at the business plan level. The process of establishing, measuring, and adjusting limits or levels of long-range capacity. Resource planning is normally based on the production plan but may be driven by higher level plans beyond the time horizon for the production plan (e.g., the business plan). It addresses those resources that take long periods of time to acquire. Resource planning decisions always require top management approval.

The duration of the planning horizon depends on the lead time of the needed resources, which may be a machine to produce the planned product. The total lead time needed would include not only installation time but also the lead time needed to conduct operations. Equipment or facility construction with long development lead times may be driven primarily by the business plan, while realigning existing facilities and the workforce to change capacity is more likely to be based on the production plan generated during the S&OP process. Note that capital expenditures in facilities or expensive equipment is an executive-level decision, while the resource planning that is based on the production plan is more likely to be a supply chain management decision. Resource planning is revisited later in the discussion of capacity.

Topic 2: Sales and Operations Planning

The *APICS Dictionary,* 16th edition, defines **sales and operations planning (S&OP)** as follows:

> A process to develop tactical plans that provide management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain. The process brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans. It is performed at least once a month and is reviewed by management at an aggregate (product family) level. The process must reconcile all supply, demand, and new-product plans at both the detail and aggregate levels and tie to the business plan. It is the definitive statement of the company's plans for the near to intermediate term, covering a horizon sufficient to plan for resources and to support the annual business planning process. Executed properly, the sales and operation planning process links the strategic plans for the business with its execution and reviews performance measurements for continuous improvement.

S&OP stands both for the sales and operations plan and sales and operations planning. It is both a plan and the process that creates, implements, monitors, and continuously improves the plan.

S&OP meetings

The S&OP process involves a series of meetings to arrive at consensus demand and production plans that reflect the results of demand-side sensing and influencing activities and supply- and finance-side capabilities and constraints.

Wallace and Stahl, authors of *Sales and Operations Planning: The How-to Handbook,* list the following meetings in S&OP:

- Data gathering
- Demand planning
- Supply planning
- Pre-meeting
- Executive meeting

Crum and Palmatier, in *Demand Management Best Practices,* discuss two additional meetings. The first is a product review after the data-gathering step, and the second is a financial review after the supply planning step.

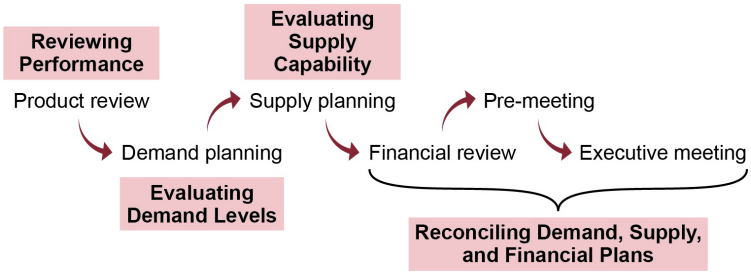
S&OP process

These meetings map to an overall S&OP process. The steps in this process are

- Reviewing performance
- Evaluating demand levels
- Evaluating supply capability
- Reconciling demand, supply, and financial plans.

The sequence of processes and activities is shown in Exhibit 2-34.

Exhibit 2-34: S&OP Process and Meetings



S&OP culminates in a monthly executive meeting to get agreement on a plan to balance supply with demand, but it requires two weeks or more of team member preparations and preliminary meetings. S&OP can be run on a different timetable, but monthly data collection, analysis, and meetings are typical.

The results of the prior month's meetings are used as the basis for the current month's meetings: Replanning is used in each review meeting as well as in the overall process.

The purpose of these meetings is to give each area of the organization sufficient time to prepare tactical plans and study the plans submitted to them so they can assess what impact the plans would have on their area of concern. In this way, the S&OP process ensures that detailed reviews are occurring, that decision makers from each part of the organization get a reliable understanding of the organization's current needs and capabilities, and that checks and balances are in place to give executives understanding of and control over the direction of the organization.

Reviewing performance

The product review meeting involves updating the status of new product developments, product changes, or other organizational process change initiatives that could affect supply or demand. This meeting involves product and brand management, but other managers involved in process change initiatives could also attend as needed, such as involving an IT professional if the organization is implementing a new ERP system. Since a product or product feature's time-to-market strongly impacts demand management activities, this meeting provides demand-side professionals with vital information on which to base their assumptions. The quality of this review rests on the quality of the data gathering that is done.

Shortly after the end of the month, all the files necessary to develop the new statistical forecast should be updated. This needs to be done quickly to keep the process moving ahead on time. Timing the S&OP process to begin after the best data are available each month is a best practice.

Evaluating demand levels

The demand planning phase includes a demand review meeting (or demand consensus review meeting), which is a meeting held between product and brand management, marketing, and sales professionals to agree to a single set of demand numbers and to document the assumptions used to make the decisions.

The highest ranking demand-side professional, such as the vice president of sales or marketing, not the

demand manager, typically chairs this small, brief meeting between representatives of each department. The demand manager serves more as a facilitator in this meeting, such as by combining the individual plans of product and brand management, marketing, and sales into a single document prior to the meeting with recommended consensus numbers and areas with differences of opinion listed in the notes.

The meeting is not intended to be a lengthy detailed review (this should have occurred prior to the meeting) but a way for the responsible and accountable leaders of each demand-side area to review the “big picture” and commit to a consensus view of demand that can be passed down to their subordinates and to the financial and supply sides of the organization.

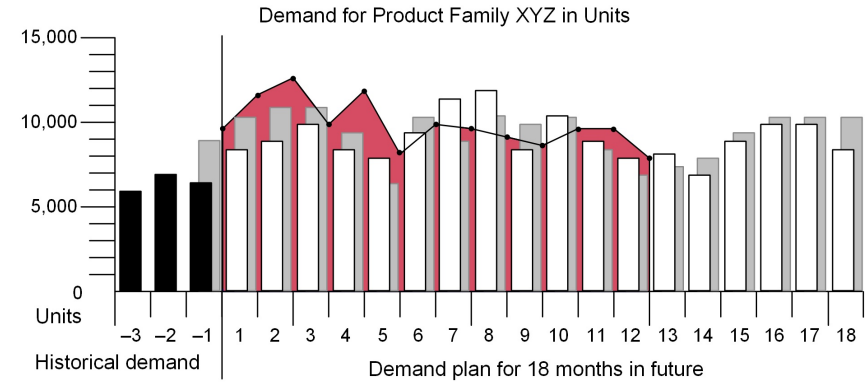
To keep the meeting brief, review is at the product family level; subfamilies are reviewed only on an exception basis. Other methods to promote brevity include reviewing only what has changed since the last meeting, focusing on validating assumptions, and reviewing only significant performance metric results. The rest of the meeting should be spent on what strategies can be employed to close any gaps between the demand plan and business plan revenue goals. The demand manager can facilitate these meetings by preparing demand plan dashboards that consolidate the various departments’ plans, highlighting where significant disagreements exist.

Exhibit 2-35 shows an example of such a dashboard for an 18-month demand plan in units. Note that the dashboard also lists examples of key performance metrics, assumptions, events, opportunities, risks, and decisions. Note also that a separate dashboard in monetary units would be provided to show the results of the unit plan in terms of its impact on organizational revenue.

A key aspect of this and other review meetings is replanning. Since the plan is reviewed each month, replanning promotes consensus building. For example, referring to Exhibit 2-35, if there is significant disagreement over the amount or timing of the demand increase from the Period 6 TV ad buy, the demand-side leaders can agree to a number but also agree to revisit it the next month when new information may be available to help clarify the issue. Participants could be assigned research tasks or be asked to communicate with others during the month so that they have better information for the next meeting. The success of the demand plan depends on the quality of the communication process.

Finally, the demand review meeting is a place to review performance metrics in relation to demand and forecast accuracy. Organizations might set rules for exception review of performance metrics. For example, if the demand plan differs from actual demand for a particular product family for three months running, a detailed strategy review should occur to determine what can be done to improve results. Individual metrics could also be color-coded in the dashboard to show exceptions.

Exhibit 2-35: Example of a Demand Plan Dashboard —Units



Key:
Actual demand
Annual business plan
Prior demand plan
Current demand plan

Product family XYZ:
Lead time = 2 weeks
Inventory turnover = 2 weeks

Metrics (excerpt)		Historical Month		
Goal	Metric	–3	–2	–1
Delivery promises	On time in full	88%	86%	80%
Improve cash flow	Cash-to-cash	16d	13d	14d
Plan accuracy	Plan vs. actual	75%	80%	68%

Key assumptions
- Internal: Period 6 TV ad buy, results seen in Periods 6–8
- External: Competitor X will mimic Product XYZ feature ABC by Period 14 at lower price

Key events
- Internal: Period 1 deliveries delayed due to Machine 123 breakdown, will continue to delay in Period 1.
- External: Economic growth will continue to be flat for next 12 periods.

Risks/Opportunities
- Risk: Customer Z is vulnerable.
- Opportunity: Breakthrough in product development can reduce product replacement time by 3 months.

Decisions
- Rapid development of Product Family XYZ replacement for release in Period 14.

Achieving consensus on what to produce can be contentious even between just the demand-side professionals. Setting the tone that disagreement between plan numbers should be an expected occurrence can keep participants from becoming frustrated with the process. Failure to acknowledge these differences or allowing each department to plan and act using its own set of numbers will generate far more conflict down the line because the supply organization will not know which set of numbers to use. This situation is far from rare, especially in an extended supply chain. According to Oliver Wight colleague Ron Ireland, most supply chains operate with between 14 and 25 individual demand forecasts. Those that do use a single set of demand numbers typically have adopted the S&OP process.

This step in the S&OP process results in product and brand management, marketing, and sales representatives issuing an updated medium-term demand plan for current and new products. The demand plan should be reviewed by a senior sales and marketing executive before being entered in the S&OP files. Sometimes this process is called a marketing/sales handshake, because it requires coming to an agreement on a request for product and coordinated demand-influencing activities. The consensus plan arrived at by the demand-side managers is used as the basis in both the supply planning phase and the financial reviews.

Evaluating supply capability

The supply planning phase includes a supply review meeting, which uses the consensus demand plan to

generate a production plan. The role of the supply management team is to identify any constraints that would prevent operations from being able to satisfy the demand plan. This process is sometimes called the operations handshake, because it requires operations professionals to agree on production plan recommendations that could best fulfill the demand plan while keeping operations profitable. The supply review meeting is used to finalize supply plan recommendations.

During this meeting, the feasibility of meeting the demand plan is discussed related to capacity and profitability constraints. If the demand plan can be met, the production plan will match the demand plan. The supply management team may need to alter the production plan and revise the S&OP data to meet the demand plan as closely as possible. If supply cannot match demand in total units or in product mix, then the meeting involves generating one or more alternative plans that propose solutions to the supply and demand mismatch, such as the following:

- Produce above demand for certain periods to meet later spikes in demand.
- Increase capacity by hiring, adding shifts, planning overtime, leasing new equipment, or outsourcing (or proposing the opposite to reduce capacity).
- Reduce the demand plan (as a last resort).

Supply-side professionals should highlight any significant risks or costs involved with each alternative that is proposed.

Reconciling demand, supply, and financial plans

Financial review meeting

The financial review meeting analyzes the demand plan in dollars as well as any alternative production (supply) plans for their financial impact and feasibility. The key question that financial professionals will ask is to what degree the plan will achieve or fail to achieve the organization's business and financial goals in the business plan. The financial review meeting will also finalize projections on the revenues, profits, cash flow, or need for capital investments for each alternative and provide a recommendation for the plan that best meets financial goals as well as financial constraints such as budgets, cash flow, or capital expenditure limits.

Pre-meeting

The pre-meeting, or pre-S&OP meeting, is a meeting between people from prior steps, at least one person from the finance area, and the S&OP process owner, the demand manager. Other pre-S&OP team members might include a number of key supply chain managers and other area managers, such as the plant manager, the logistics manager, the product and brand manager, the customer service manager, and the accounting manager. The team reviews the data and set the agenda for the S&OP executive meeting. The purpose of the pre-meeting is to identify areas where consensus can be reached without needing executive input and to add the more contentious items to the executive review agenda.

Executive meeting

The monthly S&OP executive meeting involves the chief executive officer (CEO); the demand (sales and marketing), supply (operations), and financial executives; and other direct reports to the CEO. **Executive sales and operations planning** has its own definition in the *APICS Dictionary,* 16th edition:

> The portion of sales and operations planning that defines executive decision-making processes to balance supply and demand at the volume level in families, fully integrates financial planning and operational planning, and that provides a forum for establishing and linking high-level strategic plans with day-to-day operations.

The purpose of this meeting and its related processes is to provide executives with a broad understanding of supply and demand issues and to allow them to exercise control over the organization's direction if it is not in line with business plan goals.

The attendees review the plans from the prior meetings with the goal of arriving at a consensus demand plan that meets organizational revenue goals to the extent possible and that everyone agrees to support. To accomplish this goal, the meeting may involve reviewing performance metrics or scorecards, changes since the last meeting, new risks and opportunities, and other events. Executives will want to know whether plans are staying on budget, on schedule, and on scope; how well product mixes are performing; whether current strategies need modifying; and what decisions will need to be made and when. Decisions that need to be made during the current period are discussed and then finalized, and responsibilities are assigned to ensure execution.

The assembled executives may accept the decisions and the numbers forwarded from the pre-S&OP meeting, or they may take another path. They will make decisions pertaining to each product family, authorize any decisions with significant financial implications, and compare the demand plan to the business plan to see if actions need to be taken to bring them in line with each other (e.g., additional marketing activities).

Communication of the agreed-upon S&OP plan is critical to all internal participants. For instance, it is critical for sales account managers to understand when material they have requested in the demand plan will not be supplied and therefore they should not make commitments to deliver the product to customers. If supply is available to meet demand, the sales account managers still need to be informed that their sales forecast has been accepted and they can sell against it. Remember—the success of the demand plan depends on the quality of the internal communication process.

Implementing S&OP

Like supply chain management, sales and operations planning rests on the assumption that companies wishing to compete in the expanding global marketplace can and must break down the silo walls between functions and break through the barriers separating supply chain partners. In fact, S&OP is intended to be a planning and controlling tool not just for manufacturing but also for the entire enterprise. Breaking down those barriers, however, doesn't always happen quickly and easily.

The most important consideration is the understanding that the plan to generate enough capacity to match supply with aggregate demand must be created, executed, and monitored in collaboration with sales and other functional areas, not in isolation.

We'll look at three aspects of implementing S&OP:

- Getting buy-in on S&OP's coordinating function
- Emphasizing what each party contributes to S&OP

- Building enthusiasm for S&OP among supply chain managers

Getting buy-in on S&OP's coordinating function

Functional areas within a company and supply chain partners on the outside are accustomed to developing their own plans, controlling their own information, and determining their own actions. S&OP can't function if those assumptions, and those barriers, remain in place.

The basic premise of S&OP is that there should be one plan to unite all the major functions—sales, operations, and finance. Further, S&OP assumes that key players, including executives, will agree to the unified plan, carry it out tactically, and continuously monitor and adjust it in monthly S&OP meetings. The key to getting buy-in to S&OP is to emphasize that it is all about improving communications. As S&OP consultant and author Thomas F. Wallace puts it, "S&OP is as much about institutionalizing communications throughout the organization as it is anything else." If, as Wallace states, you "get all the facts on one sheet of paper" reviewed jointly by the key players monthly, communication has to happen, facts have to be recognized, even if they are negative, and decisions have to made, debated, and acted upon—before the next meeting.

S&OP provides the following organizational benefits:

- **Link between business planning and tactics.** S&OP forms a link between the vision in the strategic and business plans on the sales side and the practical details of the tactical plans on the operations side. The executives of the company are responsible to investors and to one another for making the projections in the business plan a reality. S&OP brings the executives directly into the planning process.
- **Opportunities to be proactive rather than reactive.** The monthly meeting is a chance for executives to respond to changes in economic trends and market conditions as they are occurring.
- **Definitive short- to medium-term plan.** The sales and operations plan is the definitive statement of company plans for the near to intermediate term—typically 12 to 18 months or more. It covers enough time to enable planning for resources and to support the annual long-range business planning process.
- **Unified, cross-functional plan and process.** S&OP brings together a planning team that reconciles all of the functional business plans—not just sales plans and marketing plans, but engineering and development, manufacturing, sourcing, and financing plans—into one unified plan and one unified process.
- **Bridge between customer value and supply chain efficiency.** The S&OP process integrates the tactical focus of the operations side with the customer orientation of the marketing and sales side. There is an inherent tension between the needs of the customer and the evolving quality standards of the supply chain. Reducing cycle times, squeezing out unnecessary inventory, paring down the number of partners, practicing lean manufacturing, and focusing relentlessly on quality may result in a swifter, more agile supply chain, but that can come at the expense of the end customer if marketing isn't there to keep a close eye on the final product. In common terms, cheaper and faster are not always better from the customer's perspective. After all, as we learned elsewhere, **quality** is "conformance to requirements or fitness for use" (*APICS Dictionary,* 16th edition). On the other hand, the perfect product is not always affordable from an operational standpoint. S&OP integrates the sales and

marketing perspective with the operational perspective so the inherent tension between the two can become a creative force that drives the business.

- **Incentive to engage in continuous improvement.** Not merely a plan, S&OP's (usually) monthly meetings incorporate replanning from prior months. This continuous review and improvement should incorporate appropriate metrics for evaluating results against plans.

All functional areas involved in the sales and operations planning process should submit annual budgets for review by finance. The final plan should merge and reconcile all functional area plans and be reviewed by senior management. Budgeting is part of the annual update of the business plan.

Emphasizing each party's contributions to S&OP

The specific contributions to S&OP represent the demand side, where sales and marketing take responsibility; the supply side, where operations does the capacity research; and finance, which does the financial goals analysis. The results are merged and reconciled so that aggregate demand and supply are in balance and meet business and financial goals to the extent possible.

Product and brand management, marketing, and sales contributions

The following contributions go into the planning process from the demand organization for review by the full team:

- **Demand forecasts.** S&OP receives time-phased (e.g., demand per month) forecasts of expected demand (customer orders) arranged by product family.

- **Demand plan commitments.** Product and brand management, marketing, and sales are responsible for developing and implementing realistic strategies and tactics to achieve the goals and revenue objectives stated in the business plan—for the near and medium term. For example, product and brand management may plan new product launches and determine the life cycle impact of events. Marketing sets pricing strategies and performs competitive analysis. Sales strategy includes number and type of salespeople, sales territories (by geography, product, customer type, etc.), and sales and marketing approaches.

- **Demand plan numbers and assumptions.** Along with customer order forecasts and commitments to action, the demand organization contributes estimates of the results of their efforts expressed both in the units (e.g., volume, numbers, weights) and the revenue dollar equivalents, along with all underlying assumptions. Exhibit 2-36 shows how various audiences will use one or more of these reports.

Exhibit 2-36: Demand Plan Estimates

Product and brand management	Units
Marketing and sales	Units and dollars
Logistics	Units
Customer service	Units
Finance	Dollars

- **Market analysis.** Marketing contributes research and analysis of market opportunities; selection of target market segments; development of strategies for capturing a share of those markets; and

development, management, execution, and control of marketing plans, programs, and projects.

Operations contributions

The organization's sales and operations plan is implemented on the supply side of the organization through a production plan. The production plan is a high-level view of future production requirements over a planning horizon of 12 to 18 months.

Sales and operations planning approaches tactics at the level of aggregate supply and demand. It deals with overall capacity in the system, gross volumes, and product families. According to the *APICS Dictionary,* 16th edition, a **product family** is

> a group of end items whose similarity of design and manufacture facilitates their being planned in aggregate, whose sales performance is monitored together, and, occasionally, whose cost is aggregated at this level.

Thus this level of planning is at a higher level than individual products and specific work centers. The mission of S&OP is to balance supply with demand, and this balancing act starts at the level of product families.

Operations makes the following contributions to the plan, to be reconciled with the numbers and strategies from the sales and marketing side.

- **Product families.** For purposes of the S&OP, product families need to be established on the basis of similar operations capacity requirements. "Like capacity" items are grouped together so that the resulting production plan can be used directly by operations. While each part of the organization may create its own product families for internal department planning purposes, such as sales creating families based on similar market appeal, the integrated nature of the S&OP process requires that everyone use the same product families.
- **Output and resources.** Specific output targets are identified for each product family during the planning horizon. These targets include
  - Overall level of manufacturing output and other activities to meet planned sales levels (The projections are generally stated as a rate of production, such as units per period of time.)
  - Inventory levels
  - Backlog levels (The *APICS Dictionary,* 16th edition, defines **backlog** as "all the customer orders received but not yet shipped; sometimes referred to as open orders or the order board.")
  - Required plant, equipment, labor, and material resources for each period in the plan.
- **Operations constraints.** Given a request for product in the form of a demand plan, a primary input from operations involves evaluating whether there is sufficient capacity over the planning horizon to meet the plan for each product family. Information on site and work center bottlenecks is provided as needed to support recommendations. Constraints can sometimes be alleviated by operating above or below optimal capacity or by altering operations strategies or supply-demand strategies. Operations and supply-demand strategies are discussed next.
- **Operations strategies.** The level of output for periods in the plan can be determined according to a level production strategy, a chase production method (also called a chase strategy or chase-demand

matching), or a hybrid of the two.

- A **level production strategy** or **method,** or **level strategy,** aims for the same output in each period (e.g., each month). According to the *APICS Dictionary,* 16th edition, a **level production method** is "a production planning method that maintains a stable production rate while varying inventory levels to meet demand." The level amount is based on the average of demand forecasts for each period with some modifications for desired inventory levels. For example, Porta Potty, a portable outhouse manufacturer, has seasonal demand spikes but produces the same number of units all year round. Leveling offers the benefits of simplicity and, from an operations viewpoint, predictability (no last-minute hiring of temps or layoffs). The tradeoff is the potential for inventory to pile up during periods of low demand or for stockouts if demand spikes upward.

- The *APICS Dictionary,* 16th edition, defines a **chase production method** as "a production planning method that maintains a stable inventory level while varying production to meet demand." This results in demand matching, which aims to match production to demand for each period. For example, restaurants often use chase methods by maintaining a part-time workforce that can be scheduled as needed and altering purchases based on projected demand. Manufacturers sometimes pursue this method by producing different goods for different seasons (e.g., K2 produces skis and in-line skates).

  The benefit, if the strategy succeeds in producing only what is demanded, is a reduction of inventory costs. On the negative side, resources must be ramped up during periods when demand is high, with increases in costs for overtime, additional hiring, training, etc. Layoffs may be necessary when demand falls, resulting in loss of competent, trained workers who may not be available for rehiring when demand picks up again. Finally, plant capacity has to be built up to produce at the highest level of demand rather than at an average level.

- A **hybrid strategy** combines elements of level and chase production. The plant runs near full capacity for part of the cycle, allowing inventory to build up, and then slows or shuts down to allow the inventory to shrink as customers buy the product. A large number of organizations use hybrid strategies. For example, Lego manufactures toy building blocks using one shift for the first half of the year and adds another shift in the second half of the year for holiday season demand.

- **Supply-demand strategies.** For each product family there should be an operational approach for determining when to produce the product in relationship to customer orders (that is, before or after the order). Three strategies are make-to-stock, make-to-order, and assemble-to-order:

  - The **make-to-stock** approach is defined by the *APICS Dictionary,* 16th edition, as

    > a production environment where products can be and usually are finished before receipt of a customer order. Customer orders are typically filled from existing stocks, and production orders are used to replenish those stocks.

    The schedule for make-to-stock production is based on finished goods, which will be manufactured and sent to inventory. A make-to-stock product family usually contains a small number of items made from a large number of components. Consumer electronics, such as televisions, radios, and

audio systems, provide examples of this situation. Most make-to-stock environments represent high volume, low variety products.

Make-to-stock is essentially a mass-market strategy that works well when demand is stable and products turn over rapidly. For slower-moving products or products with unstable demand, the risk here is inventory build-up and, in some cases, product obsolescence. In the computer industry, for instance, components age rapidly toward obsolescence.

- The **make-to-order** approach is defined by the *APICS Dictionary,* 16th edition, as

  > [a] production environment where a good or service can be made after receipt of a customer's order. The final product is usually a combination of standard items and items custom-designed to meet the special needs of the customer.

  Make-to-order product families are at the opposite extreme from make-to-stock families, with a very large number of products made from a smaller number of components. Custom clothing provides a common example. In a custom business, each product is unique to the individual who orders it. If delivery lead time is not an issue, the product can be made to the customer's exact specifications. Most make-to-order environments represent low volume, high variety products. It is dependent on the individual company strategy whether raw materials are kept in inventory in anticipation of customer orders.
  A similar approach to make-to-order is **engineer-to-order** (or design-to-order). Engineer-to-order products are defined by the *APICS Dictionary,* 16th edition, as

  > products [that] require unique engineering design, significant customization, or new purchased materials, depending on customer specifications. Each customer order results in a unique set of part numbers, bills of material, and routings.

- **Assemble-to-order** (or finish-to-order) is "a production environment where a good or service can be assembled after receipt of a customer's order" (*APICS Dictionary,* 16th edition). Assemble-to-order products are partially manufactured and inventoried to await orders. This allows mass customization of products without long lead times and works well with products that can be tailored to customer taste by exchanging a limited number of modular components. The focus of master scheduling in assemble-to-order is on scheduling the manufacture of the modules or components and on final assembly.

  Like make-to-order products, assemble-to-order product families include a large number of end items, but in this case the number of components may be limited. Computers can be assembled to order. (Their components may be complex, but the final assembly of the computer itself uses a few basic components—hard drives, RAM chips, audio and video subsystems, case, power supply, etc.) Instead of being finished in all hues for delivery to stock, paint colors are "assembled-to-order" behind the counter at hardware and home stores. The shelves are stocked with tint base, and a limited number of tints are combined by a computerized mixer for an exact match to hundreds of colors. In such cases, the efficient basis for the master production schedule is to schedule the limited number of components.

  One of the challenges of the assemble-to-order approach is the need to have "reasonably skilled"

labor to do the assembly. Distribution centers are not always eager to train or hire workers to do assembly.

A related concept, **package to order,** is “a production environment in which a good or service can be packaged after receipt of a customer order” (*APICS Dictionary,* 16th edition). Package-to-order can be used to accommodate customer language differences and so on.

- **Actual results and other data for performance metrics.** Operations also provides data on actual production amounts per product family and other historical data such as information on actual capacity limits versus planned limits. Operations may provide other data for planning and feedback purposes such as changes to inventory metrics.

Finance contributions

Finance reviews the demand plan and the proposed production plan for financial feasibility and fit with business plan goals (especially financial goals) and may make a recommendation on the plan that makes the most financial sense if competing alternatives exist.

Building enthusiasm for S&OP among supply chain managers

With its focus on breaking through functional barriers, the S&OP approach to aggregate planning integrates perfectly with supply chain management thinking. Instead of the traditional practice of first developing a sales plan and then asking operations to develop tactics to implement it, S&OP brings together sales, marketing, operations, finance, and other key players to produce an integrated plan that incorporates and reconciles the views of all functional areas. For this reason, APICS considers S&OP to be a best practice.

Chapter 5: Master Scheduling

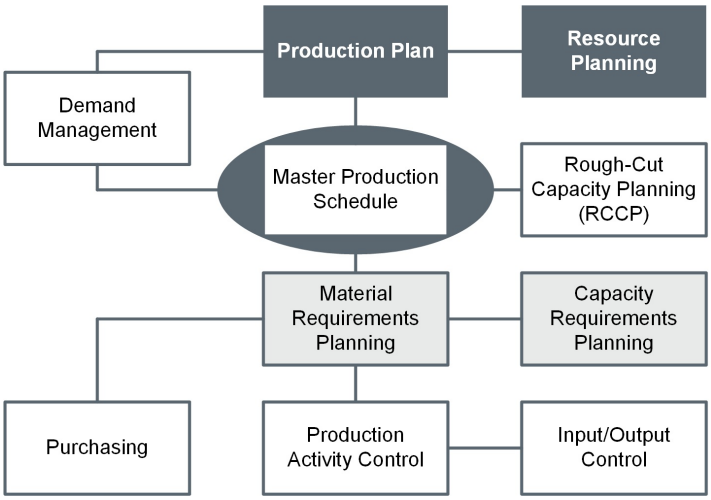
This chapter is designed to

- Identify master scheduling grid components, including the master production schedule
- Describe the steps to follow in creating a master production schedule
- Differentiate independent and dependent demand
- Describe the purposes of bills of material
- Define lead time, exploding, and offsetting
- Define push and pull distribution and distribution requirements planning (DRP) and explain the relative benefits of DRP.

After the collaborative process of sales and operations planning, master scheduling (MS) creates a master production schedule (MPS) that will commit the company to produce specific products on particular dates.

The overall process is shown in Exhibit 2-37.

Exhibit 2-37: Resource Planning, Master Production Schedule, and RCCP



Topic 1: Master Scheduling

The *APICS Dictionary,* 16th edition, defines the **master schedule** as

> a schedule format that includes time periods (dates), the forecast, customer orders, projected available balance, available-to-promise, and the master production schedule. It takes into account the forecast; the production plan; and other important considerations such as backlog, availability of material, availability of capacity, and management policies and goals.

The *Dictionary* defines a **master schedule item** as

> a part number selected to be planned by the master scheduler. The item is deemed critical in its impact on lower level components or resources such as skilled labor, key machines, or dollars. Therefore, the master scheduler, not the computer, maintains the plan for these items. A master schedule item may be an end item, a component, a pseudo number, or a planning bill of material.

S&OP, you recall, works only with aggregate supply and demand, projecting volumes for product families rather than individual products. The master scheduling process, therefore, has to disaggregate the product family data into numbers of individual products based on inventory levels, forecasts, demand plans, order backlogs, and other considerations used to decide what you need to produce and how much of each item to produce. The master scheduling process is typically facilitated by IT such as an ERP system, which creates a master scheduling grid for calculating production based on these data.

Master scheduling grid

As we learned elsewhere, the master scheduling grid calculates a projected available balance and available-to-promise amounts for demand prioritization purposes. It also calculates the master production schedule for operations purposes. See Exhibit 2-38.

Exhibit 2-38: Master Scheduling Grid

Period	1	2	3	4	5	6	7	8	9	10
Forecast	20	22	21	25	24	23	21	21	25	25
Customer orders	19	17	15	11	9	5	2	1	0	0
Project available balance (PAB) 50	31	14	49	24	0	27	6	35	10	35
Available-to-promise (ATP)	14		15			43		49		
Master production schedule (MPS)			50			50		50		50

Demand Time Fence **Planning Time Fence**

Source: APICS Master Planning of Resources, Version 3.1

The line items of the master scheduling grid are defined as follows.

Forecast

The forecast is the per-period demand plan for the individual end item. It is based on the forecast modified by the presumed effect of planned demand-influencing activities.

Customer orders

According to the *APICS Dictionary,* 16th edition, a **customer order** is

> an order from a customer for a particular product or a number of products. It is often referred to as an actual demand to distinguish it from a forecasted demand.

Projected available balance and available-to-promise

The projected available balance (PAB) and available-to-promise (ATP) were covered in elsewhere, including details on how to calculate these items. Note that the time fences in the exhibit were also defined elsewhere.

Master production schedule

The *APICS Dictionary,* 16th edition, defines the **master production schedule (MPS)** as

> a line on the master schedule grid that reflects the anticipated build schedule for those items assigned to the master scheduler. The master scheduler maintains this schedule, and in turn, it becomes a set of planning numbers that drives material requirements planning. It represents what the company plans to produce expressed in specific configurations, quantities, and dates.

MPS also takes into account **interplant demand,** a "plant's need for a part or product that is produced by another plant or division within the same organization" (*APICS Dictionary,* 16th edition).

By providing firm production dates and numbers, the MPS serves as a contract between sales and operations. Putting numbers to the mutual obligations implied by the MPS "contract" offers benefits to both sides:

- For the sales force, the MPS provides assurance that they may make delivery commitments to customers based on the amount of product that will be available week by week.
- For operations, the commitment of the sales force to meet its numbers provides assurance that they can avoid problems resulting from overproduction or an excess of orders. Those problems include layoffs and unused plant capacity in the case of overproduction and the need to expand capacity rapidly and temporarily when orders exceed capacity.
- From the viewpoint of the company and the supply chain, the balance of supply and demand offers several potential benefits:
  - Low holding costs for inventory
  - Fewer stockouts that might back up customer orders, causing frustration and reduced loyalty
  - Efficient use of plant, labor, and equipment

Weekly dates for specific products

Besides disaggregating the product families, master scheduling also determines weekly production dates based on the monthly projections in the production plan. Exhibit 2-39 shows what might happen to monthly S&OP numbers for a family of laser printers when the master scheduler disaggregates the projections into weekly production numbers for specific models.

Note that the exhibit shows production numbers only, not demand projections.

Exhibit 2-39: Disaggregation of Operations Plan Numbers into Weekly MPS

Months	**July**				**August**			
Aggregate production plan (S&OP) (Total production for family of laser printers)	1,000				1,200			
Weeks	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Master production schedule (Shows weekly production numbers for specific models within the product family)								

LX30—30-ppm	50	50	50	75	75	75	50	100
LX21—21-ppm	75	25	100	75	100	100	100	100
LX15—15-ppm	50	150	150	150	75	125	150	150

Stages of verifying capacity

There are three stages in the MPS development process:

1. First draft of the plan
2. Rough-cut capacity planning to verify that the production targets are feasible
3. Revisions to the plan by the master scheduler or revisions to available capacity if capacity isn't sufficient to meet the targets or greatly exceeds expected load

Each planning stage includes a capacity check. These processes are discussed in elsewhere.

Topic 2: Materials and Inventory

Finished goods and raw materials and components are interrelated. Finished goods are needed to satisfy the customer's demand; raw materials and components are needed to produce the finished goods. We have seen that the planning of finished goods is done through the master scheduling process. Raw materials and components are planned using material requirements planning (MRP), and inventory levels at specific locations are planned using distribution requirements planning (DRP). Besides discussing MRP and DRP, this topic explains a number of manufacturing specifics: routing files, lot-for-lot or fixed order quantity replenishment, and offsetting.

Material requirements planning

Material requirements planning is defined in the *APICS Dictionary,* 16th edition, as

> a set of techniques that uses bill of material data, inventory data, and the master production schedule to calculate requirements for materials.

MRP plans dependent demand items—the raw materials and components needed to produce finished goods for consumers. The *APICS Dictionary,* 16th edition, defines **dependent demand** as

> demand that is directly related to or derived from the bill of material structure for other items or end products. Such demands are therefore calculated and need not and should not be forecast.

The *Dictionary* defines **independent demand** as

> the demand for an item that is unrelated to the demand for other items. Demand for finished goods, parts required for destructive testing, and service parts requirements are examples of independent demand.

While independent demand is the subject of demand forecasts, dependent demand is not. Before you can talk about dependent demand for pockets and zippers and bolts of denim, there has to be independent consumer demand for trousers—or at least a demand plan based on the assumption that there will be a demand for those trousers. There can, however, be independent and dependent demand for the same item. For example, an item may be used as a component in finished production but also sold independently as a repair part or upgrade item. Auto parts stores stock a large inventory of replacement parts for independent sales to individuals and repair shops. Shelves in electronics stores contain numerous computer subsystems sold as upgrades. Those items are subject to independent sales and production forecasts. The same items are also ordered by manufacturers who base their orders for components on demand forecasts for the finished computers.

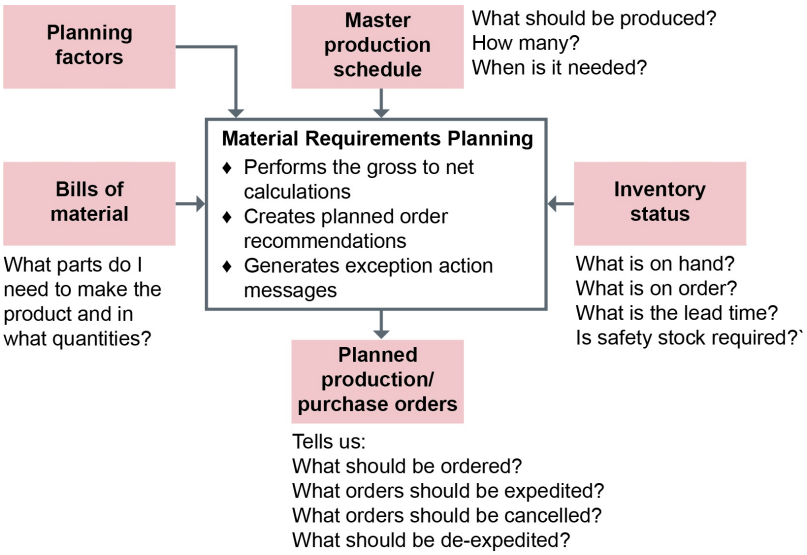
Dependent demand doesn't require estimation, only calculation. A scheduled demand for 1,000 pairs of blue jeans to be delivered in March to a major chain store creates a dependent demand for 1,000 right legs, 1,000 left legs, 2,000 front pockets, 1,000 zippers, 1,000 snaps, several thousand belt loops and rivets, and, further up the supply chain, bolts of denim, tons of cotton, kilograms of metal, and so on.

MRP plans all the orders that will get those meters of cloth and rivets and pockets and belt loops to the right work centers or suppliers at the right times to get those blue jeans put together on the dates specified in the

MPS.

Exhibit 2-40 illustrates the data inputs required for MRP and the resulting outputs.

Exhibit 2-40: Material Requirements Planning



MRP inputs

As you can see from Exhibit 2-40, inputs to MRP include the master production schedule, inventory status, planning factors, and bills of material.

- The **master production schedule** lists planned or scheduled orders for end items—tables, computers, automobiles, finished clothing, etc. The *APICS Dictionary,* 16th edition, defines the following terms related to item orders.
    - **Planned orders** are

        > a suggested order quantity, release date, and due date created by the planning system's logic when it encounters net requirements in processing MRP. In some cases, it can also be created by a master scheduling module. Planned orders are created by the computer, exist only within the computer, and may be changed or deleted by the computer during subsequent processing if conditions change. Planned orders at one level will be exploded into gross requirements for components at the next level. Planned orders, along with released orders, serve as input to capacity requirements planning to show the total capacity requirements by work center in future time periods.

      Note that to be more precise, references to "the computer" in this and the next definition could be replaced by "MRP software."

    - **Firm planned orders (FPOs)** are

        > planned order[s] that can be frozen in quantity and time. The computer is not allowed to change [them] automatically; this is the responsibility of the planner in charge of the item that is being planned. This technique can aid planners working with MRP systems to respond to

material and capacity problems by firming up selected planned orders. In addition, firm planned orders are the normal method of stating the master production schedule.

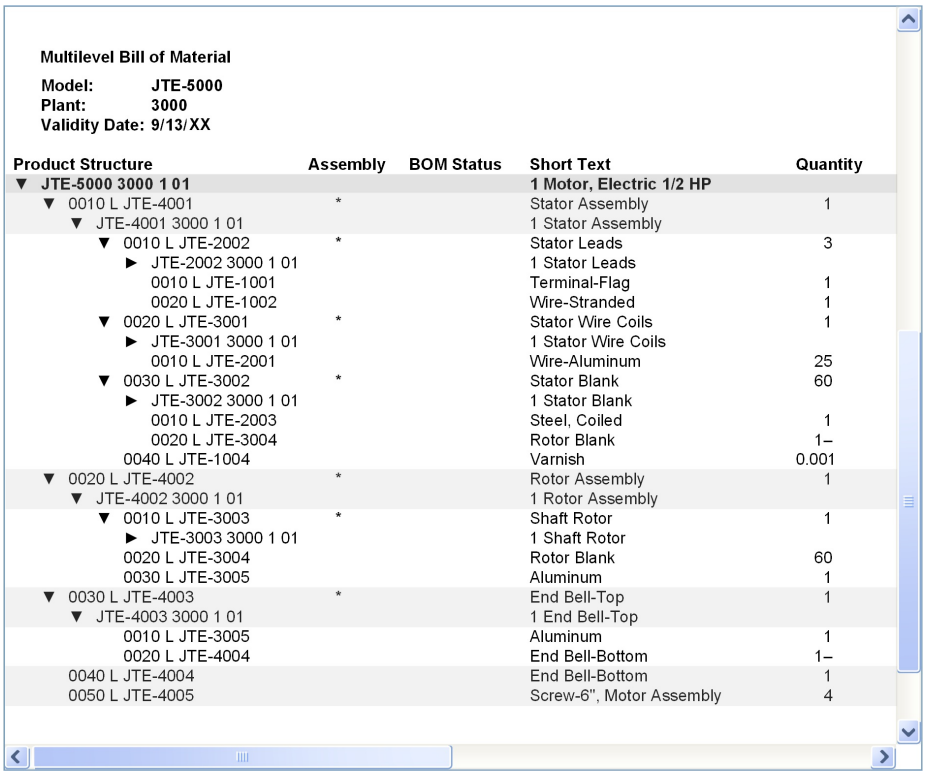
  - An **open order** (released order) is “a released manufacturing order or purchase order.”
  - A **scheduled receipt** is “an open order that has an assigned due date.”

- **Inventory status** is what materials are already available for use in manufacturing the finished goods and what finished goods exist now.
- **Planning factors** include safety stock concerns and lead times (how long it will take to get each component after it has been ordered; this is necessary for proper timing of orders).
- The **bill of material** (BOM) is a complete list of components and the quantities of each needed to make one unit of the end item—the “product tree.” A BOM provides the basis for answering the questions “What do we need?” and “How many of them do we need?” In its simplest configuration, a bill of material is an industrial-strength shopping list, enumerating every component required to manufacture an item. It can also do a great deal more. However, a BOM’s essential contribution is to assist in scheduling all the orders for all the materials needed to manufacture the products in the MPS.

  Bills of material are created in a variety of computer programs, from the simplest table in a word-processing or spreadsheet program, to an illustrated BOM with drawings created in a CAD program, all the way to multipage, interactive, illustrated files in dedicated MRP modules of enterprise software with links to other modules.

  Exhibit 2-41 provides an example of a computer-generated multilevel bill of material for a ½-horsepower electric motor.

Exhibit 2-41: Multilevel BOM for Electric Motor



Multilevel Bill of Material

Model: **JTE-5000**
Plant: **3000**
Validity Date: **9/13/XX**

Product Structure	Assembly	BOM Status	Short Text	Quantity
▼ **JTE-5000 3000 1 01**			**1 Motor, Electric 1/2 HP**	
▼ 0010 L JTE-4001	*		Stator Assembly	1
▼ JTE-4001 3000 1 01			1 Stator Assembly	
▼ 0010 L JTE-2002	*		Stator Leads	3
► JTE-2002 3000 1 01			1 Stator Leads	
0010 L JTE-1001			Terminal-Flag	1
0020 L JTE-1002			Wire-Stranded	1
▼ 0020 L JTE-3001	*		Stator Wire Coils	1
► JTE-3001 3000 1 01			1 Stator Wire Coils	
0010 L JTE-2001			Wire-Aluminum	25
▼ 0030 L JTE-3002	*		Stator Blank	60
► JTE-3002 3000 1 01			1 Stator Blank	
0010 L JTE-2003			Steel, Coiled	1
0020 L JTE-3004			Rotor Blank	1–
0040 L JTE-1004			Varnish	0.001
▼ 0020 L JTE-4002	*		Rotor Assembly	1
▼ JTE-4002 3000 1 01			1 Rotor Assembly	
▼ 0010 L JTE-3003	*		Shaft Rotor	1
► JTE-3003 3000 1 01			1 Shaft Rotor	
0020 L JTE-3004			Rotor Blank	60
0030 L JTE-3005			Aluminum	1
▼ 0030 L JTE-4003	*		End Bell-Top	1
▼ JTE-4003 3000 1 01			1 End Bell-Top	
0010 L JTE-3005			Aluminum	1
0020 L JTE-4004			End Bell-Bottom	1–
0040 L JTE-4004			End Bell-Bottom	1
0050 L JTE-4005			Screw-6", Motor Assembly	4

The *APICS Dictionary,* 16th edition, defines a **multilevel bill of material** as

> a display of all the components directly or indirectly used in a parent, together with the quantity required of each component. If a component is a subassembly, blend, intermediate, etc., all its components and all their components also will be exhibited, down to purchased parts and raw materials.

The *Dictionary* defines a **parent item** as “the item produced from one or more components,” while a **component** is “the raw material, part, or subassembly that goes into a higher level assembly, compound, or other item; this term may also include packaging materials for finished items.”

Exhibit 2-41 shows that the motor parent JTE-5000 3000 1 01 contains the following components, some of which are parents to other components:

- One stator assembly (part number 0010 L JTE-4001)
- One rotor assembly (part number 0020 L JTE-4002)
- One end bell-top (part number 0030 L JTE-4003)
- One end bell-bottom (part number 0040 L JTE-4004)
- Four six-inch screws (part number 0050 L JTE-4005)

The user can click the arrows to the left of the part numbers (far left of the screen) to reveal the parts needed

to assemble those components. In the exhibit, the arrows pointing downward have already been clicked to reveal their components, while the arrows pointing to the right could still be clicked to drill further down into the details for each component. In this way a user can see the steady “explosion” of the parts tree for all the components of the BOM or keep the BOM at a high level as needed.

This provides a hint of how rich a bill of material can become when embedded in sophisticated software.

Another type of BOM is the modular (planning) bill that pertains to the construction of a module that is not a finished product but is a component for use in a product. In a mass customization situation, operations may focus on the creation of a number of modules for later assembly. The MRP in that case schedules orders for the materials used in constructing the modules. Companies can also use a configure-to-order process that presents modular options when the sales order is being entered.

MRP outputs

With the information from the master production schedule and bill of material and on inventory status and planning factors, it is possible to develop a complete schedule for ordering (and delivering) all the components and materials necessary to create the items in the master schedule. The MRP process results in planned orders for making or buying all the components required. It typically includes the following specifications as per the *APICS Dictionary,* 16th edition:

- **Planned order receipts.** A planned order receipt (planned receipt) is “the quantity planned to be received at a future date as a result of a planned order release. Planned order receipts differ from scheduled receipts in that they have not been released.”
- **Planned order releases.** A planned order release is “a row on an MRP table that is derived from planned order receipts by taking the planned receipt quantity and offsetting to the left by the appropriate lead time.” Planned order releases may differ depending on whether the order needs to be manufactured or purchased.
- An **exception report.** This is “a report that lists or flags only those items that deviate from the plan.”

Some explanation of the relationship between these terms and the prior terms related to order types is necessary. When the planning system calculates net requirements in MRP, it generates a set of planned orders, which are subject to change until orders are either made into firm planned orders (FPOs) by the planner or are released to become open orders or scheduled receipts (if assigned a due date). A planned order receipt is the same as a scheduled receipt except that it is used for planned orders (i.e., not yet released) and so there is still some uncertainty whether the order will be released.

Note that when a family of related items is released as if it were one item, it is considered a joint replenishment system. According to the *APICS Dictionary,* 16th edition, **joint replenishment** is a process of

> coordinating the lot sizing and order release decision for related items and treating them as a family of items. The objective is to achieve lower costs because of ordering, setup, shipping, and quantity discount economies. This term applies equally to joint ordering (family contracts) and to composite part (group technology) fabrication scheduling.

Manufacturing specifics

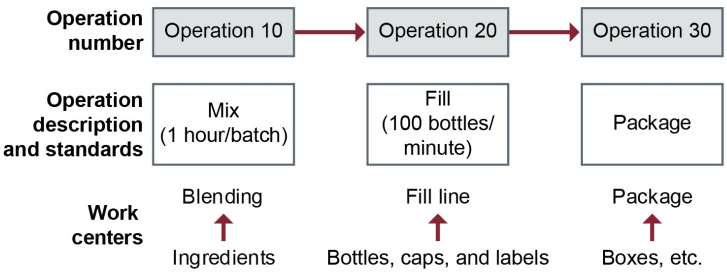
Other aspects of manufacturing related to MRP are the routing file, lot-for-lot or fixed order quantity replenishment, and offsetting.

Routing file

When planning a trip, travelers sketch out a route using a map. In manufacturing, we also look for the route, which is found in a routing file (router file or route sheet). The router maps the journey of a component from work center to work center, specifying all the operations it undergoes on the way to completion. It indicates each of the manufacturing steps required, the sequence of the steps, and the time required. There will be one entry for each operation. This can be a very simple matter if manufacturing takes place in one plant, only a few operations are involved, and the work centers are near one another. However, it can be a very complex map if the component travels around a global supply network with numerous partners. Note that this complexity would still be broken down to be more palatable by having major part numbers each have their own set of routings.

Exhibit 2-42 pictures a simple routing for orange juice.

Exhibit 2-42: Routing for Orange Juice



A **routing** for a product shows how it is manufactured in one or more operations. Each operation is identified by a sequence number and a description. The sequence number places the operations in the proper manufacturing sequence. The operations also identify where that process occurs and the standard setup and run times for the product. Tooling and testing requirements can also be included in the routing definition.

Lot-for-lot or fixed order quantity replenishment

The next section will detail two inventory replenishment methods: lot-for-lot and fixed order quantity (FOQ). While inventory replenishment may include some safety stock as a buffer against demand uncertainty, that sort of variability doesn't affect dependent demand. There's no buffer necessary, so any safety stock would only be a waste of money for storage space, handling, and production capacity. Therefore, a lot-for-lot replenishment technique is often used. In lot-for-lot replenishment, the exact number of components needed for production is the number that should be produced and delivered when needed. Lot-for-lot replenishment can be used whenever excess inventory is undesirable, such as in Just-in-Time systems (which emphasize having the right materials arrive at the right places at the right times) and in the production of expensive, infrequently ordered items.

When operations for filling dependent demand orders allow batch sizes to vary, lot-for-lot is the favored

technique. However, an FOQ technique must be used rather than lot-for-lot for operations that require fixed batch sizes and order quantities (e.g., accommodating a fixed vat size for beer brewing).

Lot-for-lot scheduling depends upon the following essential information:

- Gross delivery required
- Projected amounts on hand for delivery
- Scheduled receipts (more potential deliverables)
- Net requirements (gross minus on-hand items and scheduled receipts)
- Lead time (so operations can be scheduled in time to meet the delivery date)

With that information, you can specify the date to release the order and the date it will be received. The example in Exhibit 2-43 assumes weekly deliveries and a one-week lead time.

Exhibit 2-43: Lot-for-Lot Scheduling

MRP Lot-Sizing Problem: Lot-for-Lot Technique											
Week		1	2	3	4	5	6	7	8	9	10
Gross Requirements		35	30	40		10	40	30		30	55
Scheduled Receipts											
Projected on Hand	35	0	0	0	0	0	0	0	0	0	0
Net Requirements			30	40		10	40	30		30	55
Planned Order Receipts			30	40		10	40	30		30	55
Planned Order Releases		30	40		10	40	30		30	55	

Note in the exhibit that planned order releases (bottom row) are always equal to planned order receipts in the next column to the right and up one row. The orders released always equal the orders to be received—because in this example there is a one-week offset for lead time to produce the order.

In week 1, you will see that there is no net requirement even though the gross requirement is 35 units. That's because the week starts with 35 units projected on hand—enough inventory to fill the order without setting up for production. After that first week, gross and net requirements are equal because there is no more inventory on hand.

Offsetting

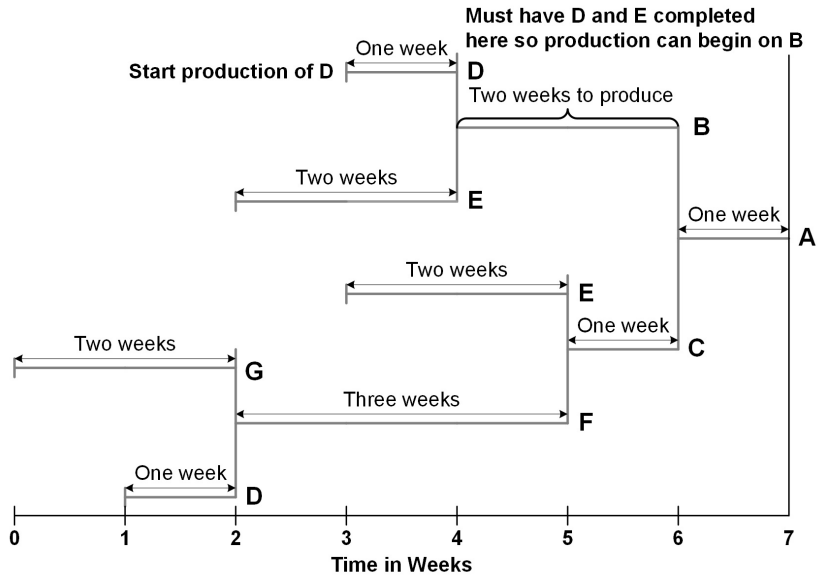
We just looked at a series of orders for one component. Scheduling the orders for all components for a product is more complicated. Why? Because the components are likely to have different lead times, so if you want them all to arrive simultaneously at one work site or work center, you have to schedule different release dates based on the different lead times.

This process of counting backward from a due date to accommodate lead time is called offsetting. If you had a simple product with two components, product A with a lead time of one week and product B with a lead time of two weeks, you would release the order for A one week before the order receipt date, and you would release B one week before that.

Real products can be very complex, of course, with the components themselves having components, and

those components having components, and all of them having different lead times. So let's say product A is constructed from components B and C over a lead time of one week. Assume that component B has a lead time of two weeks and is itself constructed from components D and E, with lead times of one and two weeks respectively. Similarly, component C has a lead time of one week but is also assembled from components E and F with lead times of two and three weeks respectively. Finally, component F has to be constructed of components D and G, with lead times of one and two weeks. This might look as shown in Exhibit 2-44 (with a few extra complications).

Exhibit 2-44: Component Orders Offset by Lead Times for Simultaneous Arrival



Managing MRP

There is a degree of inflexibility built into MRP, because it uses fixed lead times. (A schedule is by its nature inflexible, of course, which can be both a benefit and a limitation.) MRP has ease of replanning among its strong points, especially if you're using software that sorts out the impact that a change in one part of a schedule can have on the other parts. In the net change approach, only those parts of the MRP that require changes have to be altered. Regeneration of the entire plan is the more difficult alternative.

Feedback loops and system nervousness

Good supply chain planning contains numerous feedback loops, so that one level of planning can test the assumptions of the previous level and ask for changes if the plan seems impracticable. Regular S&OP meetings are one place where feedback can be received and processed almost continuously. The MRP is also subject to change when events such as changes in design or the master production schedule make alterations seem necessary. The plan may be revised as often as daily to keep current with changing data.

However, too frequent alteration of the plans can be frustrating for those who have to put them into effect,

such as purchasers; these sometimes frantic adjustments to MRP are known as system nervousness. To avoid this consequence, managers should consider possible problems before incorporating too many changes.

One way to ease the system nervousness is to establish time fences in the master schedule to designate a period of time when automatic rescheduling is not allowed even if changes are made to the MRP—unless an exception order receives specific authorization. Time fences were discussed earlier.

Another way to mitigate excessive nervousness is pegging each component to its parent in the bill of material. The *APICS Dictionary,* 16th edition, defines **pegging** as follows:

> In MRP and MPS, the capability to identify for a given item the sources of its gross requirements and/or allocations. Pegging can be thought of as active where-used information.

When a pegged component is affected by a schedule change, someone can easily check to see what happened to its parent. It may turn out that the schedule change for the component was a mistake. Or, if there is an availability issue with a lower-level item, the planner can quickly check which end items will be affected and take countermeasures to minimize harm to the overall production schedule.

System nervousness is not always a mere annoyance to be suppressed. Nervousness can make an otherwise sound system costly and inefficient. Sometimes it's a symptom of excessive reprioritizing on the shop floor or in purchasing. This can underlie a variety of problems, such as quality issues or other conditions, and root causes should be sought to see if the nervousness is a result of problems in those areas.

Reconciling Just-in-Time or lean with MRP

The fixed lead times in MRP can come into conflict with JIT's or lean's commitment to moving materials as fast as possible to reduce inventory costs. Two ways to reconcile MRP and JIT or lean are the small bucket or bucketless approach and balanced flow:

- **Small bucket or bucketless systems.** MRP typically uses a bucket system of timing orders. For instance, an MRP might schedule all the orders in week-long time buckets: 40 items in week one of the month, 50 in week two, etc. Reducing the bucket size from a week to a day or even less speeds up the flow considerably.

  Some work centers don't use buckets for scheduling at all but attach dates to each item. In bucketless systems, orders can move through the work area on a JIT basis. As soon as an operation is complete, the item moves into inventory, reducing the quantity of scheduled receipts in the MRP system. (You don't have to schedule production of 50 zippers to make 50 pairs of trousers if you already have 10 zippers in inventory ready to be delivered.) Inventory balances are then reduced by backflushing, which means using the bill of material to deduct component quantities from inventory as soon as the unit has been completed.

- **Balanced flow.** Another way of combining JIT and MRP, called balanced flow, is used in repetitive work centers such as assembly lines. MRP takes care of the scheduling and planning for delivery of parts to the line in small lots. JIT pulls the materials through the facility with visual signals such as

kanban cards or empty bins (discussed elsewhere).

Evolution of MRP software

Software to manage MRP has been evolving since the first computerized bills of material, which appeared in the early 1960s. Before MRP software existed, developing material requirements was a time-consuming and arduous task. With the development of the software, planners were freed of the manual drudgery and could dedicate more time to actual planning decisions. Early forays into paperless MRP steadily evolved until MRP II (defined below) crossed the functional borderline out of manufacturing and into other areas. And beyond that, ERP (enterprise resources planning) software, starting basically as an extension of MRP II across all the functions of an enterprise, has now developed modules that link all business functions and even one company to another to facilitate the flow of information among supply chain partners.

Here are the highlights of MRP, closed-loop MRP, and MRP II—steps in the evolution of software from those first bills of material toward resource planning across the supply chain and linking of material planning with actual demand.

MRP software

Material requirements planning software programs take information based on bills of material, component lead times, and incoming orders to schedule manufacturing dates.

One difficulty operations managers have experienced with MRP systems is the software's assumption that all work centers in the chain have infinite capacity. This assumption can result in the generation of impossible schedules. (As you'll see in the upcoming section on capacity management, one of the functions of capacity planning is to check schedule assumptions to make sure that they are consistent with available capacity.)

Setting aside that problem, MRP systems provide very important benefits:

- They can improve on-time delivery percentages, thereby reducing component inventories and holding costs.
- They can free a scheduler to spend less time on scheduling tasks and more time on planning and exception resolution.

Closed-loop MRP

A refinement of basic MRP software is called closed-loop MRP, because it incorporates feedback on available capacity. It calculates the impact of each order on the work center that is scheduled to complete the order, and, if it finds too little capacity at that center, it may change the order date. Other options are to send the order to another work center or site or outsource it.

Closed-loop MRP also leverages feedback from the execution functions to the planning functions to ensure that replanning occurs. Both status information (order status, inventory balances, etc.) and warning signals/exception messages (behind schedule, overloaded, etc.) are passed back to planning. This facilitates the maintenance of valid plans and schedules. As a tradeoff, the increased power of closed-loop MRP increases installation and training costs.

MRP II

MRP II is defined by the *APICS Dictionary,* 16th edition, as

> a method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in dollars, and has a simulation capability to answer what-if questions.

MRP II is the first upgrade of MRP software to step over the boundary separating material requirements planning from other functions such as sales and finance. To recognize this advance in scope and power, it is generally called manufacturing resource planning, a term coined in 1979 by Oliver Wight, instead of material requirements planning. MRP II incorporates the following more-advanced functions not available in previous MRP programs:

- It includes financials—a separate functional area from manufacturing.
- It provides visibility of material and capacity requirements defined in an operations plan.
- It provides detailed activity information and translates activities to financial statements.
- It suggests ways to bring activities back into line with planned priorities.
- It integrates long-term planning (business planning and methodologies that have evolved to become S&OP) with operational planning.

Distribution requirements planning

This second part of the discussion of materials and inventory relates to how inventory is allocated among distributors and others down the supply chain.

Distribution requirements planning (DRP) organizes inventory requirements so the organization has time to plan for when and how many goods will be required; **DRP** is “the function of determining the need to replenish inventory at branch warehouses” (*APICS Dictionary,* 16th edition). (Note that branch warehouses are more commonly called distribution centers.)

Pull versus push distribution

Before we look more closely at DRP, we’ll draw a distinction between systems that pull inventory through the distribution chain toward the retail end and systems that push inventory down the chain. In reality, most distribution chains include elements of both push and pull. The questions for supply chain managers are:

- Which system is best adapted to the needs of the supply chain?
- Where should the line of demarcation between push and pull be located?

Note that manufacturing also uses push and pull to describe whether operations are pulled by actual demand (as in JIT) or pushed by forecast demand, but push versus pull manufacturing strategies are not necessarily related to push versus pull distribution strategies. For example, a JIT environment could operate based on actual demand pull and then perform centralized push distribution to get those orders to the correct customers.

We learned earlier that in terms of distribution, the *APICS Dictionary,* 16th edition, defines a **push system** as “a system for replenishing field warehouse inventories where replenishment decision making is centralized, usually at the manufacturing site or central supply facility.” This traditional approach to distribution replenishment pushes inventory through manufacturing to the company distribution centers. Determination of product requirements is done by a central planning organization and pushed out. Inventory is then in storage until a customer (distributor, wholesaler, retailer) pulls material to meet projected demand.

The *Dictionary* defines a **pull system** as “a system for replenishing field warehouse inventories where replenishment decisions are made at the field warehouse itself, not at the central warehouse or plant.” The benefit of this decentralized inventory planning approach accrues mostly to the entity doing the ordering, because it is able to operate independently to balance its supply and demand requirements as it sees fit. This assumes that the company orders intelligently. At the retail end, for example, the company might be a grocer or hardware franchise with a history in the community and good forecasting instincts.

You might call this a system of serial autonomy, with each partner along the distribution chain making its own ordering decisions. As a system, however, it’s not especially systematic. It doesn’t take advantage of the essential strengths of supply chain management, which are collaboration and mutual decision making.

There are three particular drawbacks to the pull system:

- Orders are likely to increase as they travel up the chain (the bullwhip effect).
- The company doing the ordering knows nothing about the needs and plans of the other chain partners, who may have a greater need for the stock to meet customer service goals.
- The order doesn’t take into account the supplier’s situation.

Push systems solve some of these problems, but with a tradeoff. The downstream partners receive shipments on schedules developed elsewhere in the network rather than when they order it. While this can be beneficial to the supply chain by providing systemwide coordination of inventory management, it is less likely than the pull system to be sensitive to local market conditions.

Hybrid systems are push-pull systems in which push distribution is pursued through centralized planning down to a particular supply chain level or echelon but pull distribution through decentralized planning is used after this point. For example, centralized planning could use information on demand from the retail end of the chain, aggregate this demand at the regional distribution centers (DCs), and push inventory to these DCs. The customers of these DCs, perhaps wholesalers and retailers, then order inventory from these DCs as they see fit. This very common replenishment strategy can increase centralized control by moving the point of push-to-pull down the chain or increase decentralized control by moving the point up the chain. DRP is a type of hybrid system because it contains both push and pull elements.

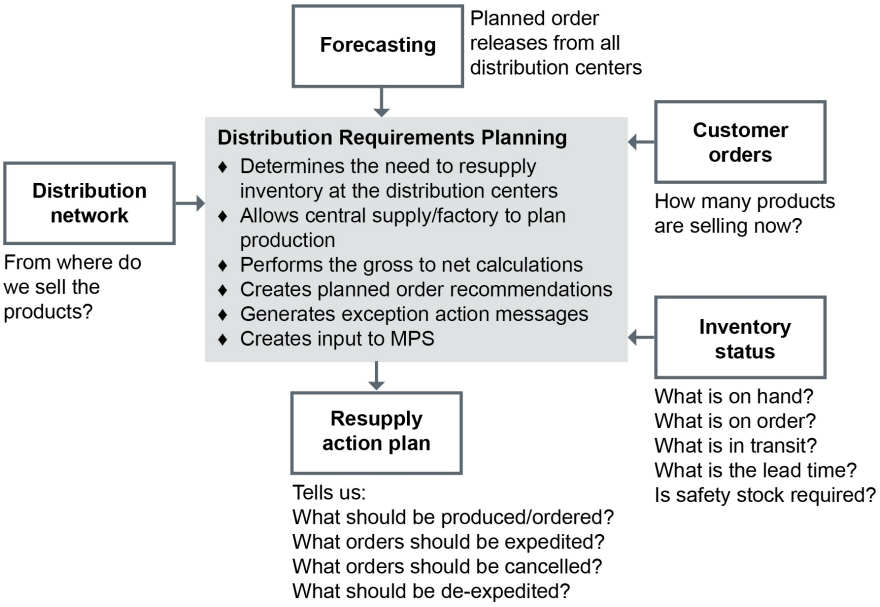
DRP components

Distribution requirements planning combines the following inputs:

- Demand forecasts from distribution centers to determine the gross requirement
- Safety stock for customer service
- Accurate lead time information
- Overall knowledge of the distribution system (a mapping akin to a bill of material that shows how the distribution network is configured)

Exhibit 2-45 shows what goes into and comes out of a DRP system.

Exhibit 2-45: Distribution Requirements Planning Input/Output Diagram

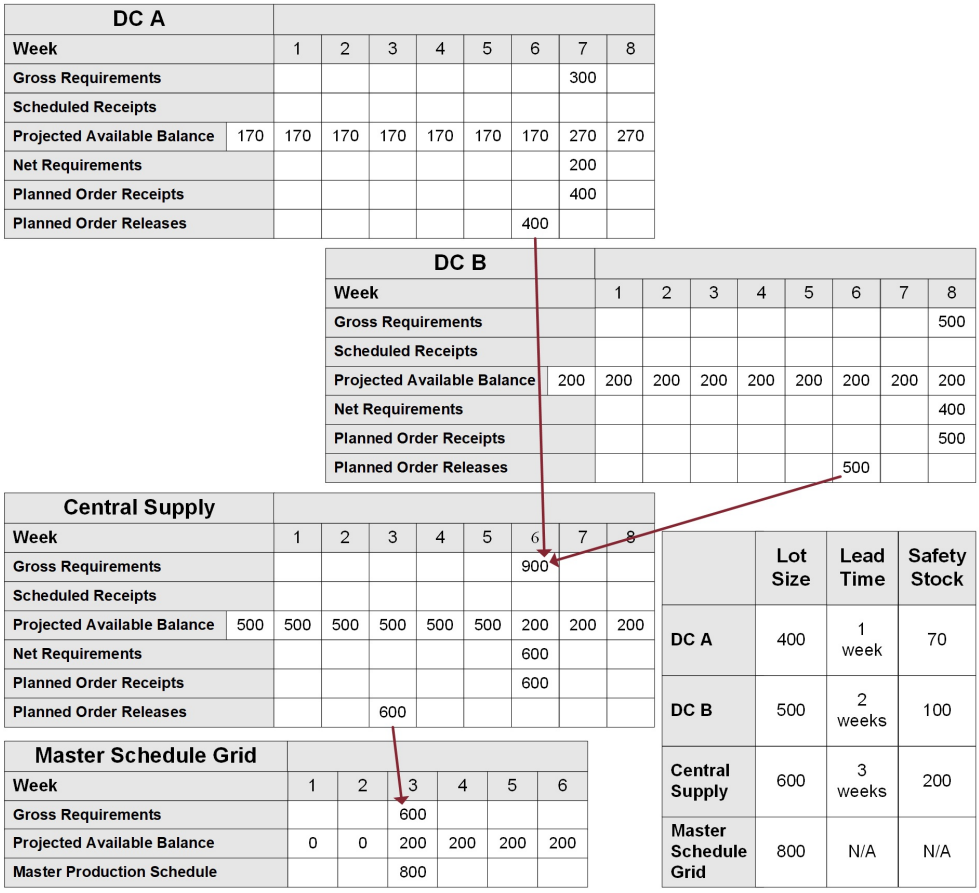


DRP logic

DRP system logic translates DC demand into forecasts for use in factory master scheduling. DRP logic typically uses time-phased netting of requirements (net requirements per period or bucket) rather than a decentralized order point (pull) system.

Exhibit 2-46 illustrates DRP logic using distribution centers A and B, a central supply location, and a master schedule grid for a factory.

Exhibit 2-46: Distribution Requirements Planning



DC A									
Week		1	2	3	4	5	6	7	8
Gross Requirements								300	
Scheduled Receipts									
Projected Available Balance	170	170	170	170	170	170	170	270	270
Net Requirements								200	
Planned Order Receipts								400	
Planned Order Releases							400		

DC B									
Week		1	2	3	4	5	6	7	8
Gross Requirements									500
Scheduled Receipts									
Projected Available Balance	200	200	200	200	200	200	200	200	200
Net Requirements									400
Planned Order Receipts									500
Planned Order Releases							500		

Central Supply									
Week		1	2	3	4	5	6	7	8
Gross Requirements							900		
Scheduled Receipts									
Projected Available Balance	500	500	500	500	500	500	200	200	200
Net Requirements							600		
Planned Order Receipts							600		
Planned Order Releases				600					

Master Schedule Grid						
Week	1	2	3	4	5	6
Gross Requirements			600			
Projected Available Balance	0	0	200	200	200	200
Master Production Schedule			800			

	Lot Size	Lead Time	Safety Stock
DC A	400	1 week	70
DC B	500	2 weeks	100
Central Supply	600	3 weeks	200
Master Schedule Grid	800	N/A	N/A

Source: APICS CPIM Basics of Supply Chain Management

Planned order releases from DCs A and B are released to central supply according to each DC's demand requirements and lead times. In the exhibit, DC A and DC B release planned orders in week 6 for 400 and 500 units respectively. Central supply has a three-week lead time, a projected available balance of 500 units, and a lot size (order quantity) of 600 units. Therefore, to fill the planned order releases of 900 units, central supply releases a planned order for 600 units in week 3 (to account for the three-week lead time and lot size), which will leave a projected available balance of 200 units (equal to its safety stock requirement). Central supply's planned order release of 600 units becomes a gross requirement in the master schedule grid. This allows the distribution centers' time-phased requirements to be factored into the factory's master production schedule.

Push and pull elements in DRP

Distribution requirements planning combines the coordinated planning and control offered by push systems with the responsiveness to local demand that characterizes pull systems.

Although orders originate downstream (that is, toward the retail end), they are evaluated at the supplying locations before being released to determine the actual need at the ordering location and the availability of goods at the sites receiving the order. This helps prevent shortages at supplying sites and overstock at

ordering sites. In this way, DRP keeps inventory in balance around the network.

Because the hybrid DRP system combines information from both supplying and ordering locations, it can, in theory, provide more accurate allocations of stock than either straight pull or push systems, which take into account the needs of only the ordering or the supplying location. Because the DRP system is based on more accurate data and more thorough assessments of need and available supply, it should allow release of smaller, more frequent orders than straight pull or push arrangements. And this in turn provides the supply chain with the benefit of better customer service and lower inventory costs.

Chapter 6: Capacity Management, Planning, and Control

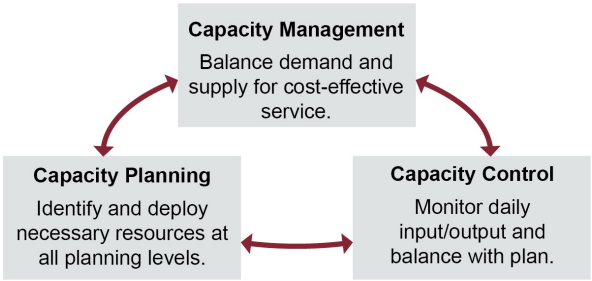
This chapter is designed to

- Define capacity requirements planning (CRP) and enumerate the objectives of CRP
- Explain the purpose of production activity control and describe the activities involved.

Topic 1: Capacity Objectives

In order to execute any new product or service offering, an organization must ensure that it has the capacity to do so. For example, in a manufacturing setting, the organization must have the plants, equipment, production lines, and workers to produce the output dictated by the production plan within the time allowed. Capacity management, along with capacity planning and capacity control, is how an organization ensures that planning and execution of new products and services is possible before dedicating resources to execution. These concepts are shown in Exhibit 2-47.

Exhibit 2-47: Capacity Management, Planning, and Control



- According to the *APICS Dictionary,* 16th edition, **capacity management** is

  > the function of establishing, measuring, monitoring, and adjusting limits or levels of capacity in order to execute all manufacturing schedules (i.e., the production plan, master production schedule, material requirements plan, and dispatch list). Capacity management is executed at four levels:

  - Resource planning,
  - Rough-cut capacity planning,
  - Capacity requirements planning, and
  - Input/output control.

  In order to serve customers in a cost-effective manner, organizations should work to maintain proper capacity levels in the most efficient configuration possible, preventing an imbalance between supply and demand.

- The *Dictionary* defines **capacity planning** as

  > the process of determining the amount of capacity required to produce in the future. This process

> may be performed at an aggregate or product-line level (resource requirements planning), at the master scheduling level (rough-cut capacity planning), and at the material requirements planning level (capacity requirements planning).

Capacity planning involves identifying required resources and selecting the best method available to increase capacity when needed.

- The *Dictionary* defines **capacity control** as

> the process of measuring production output and comparing it with the capacity plan, determining if the variance exceeds pre-established limits, and taking corrective action to get back on plan if the limits are exceeded.

Capacity control takes place at the level of everyday activity, as a form of input/output control. It corrects imbalances that may begin at the single part or hour level before they become a bigger problem.

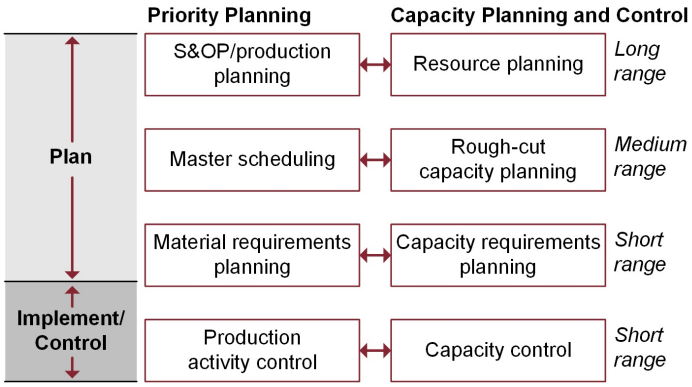
Attempts to balance capacity with load can result in one of three different outcomes: too little capacity, too much capacity, or the correct amount of capacity. Each of these outcomes has different effects in an organization, discussed below:

- **Too little capacity.** If any site or work center in your supply network has too little capacity for the production goals assigned to it, demand at that point in the chain will exceed supply and you will have to either add capacity (if that is possible), shift work elsewhere, or endure stockouts and broken orders.
- **Too much capacity.** If an organization overbuilds at a work center, supply exceeds demand. If full capacity is used anyway, this results in high inventories. If capacity is reduced to actual demand levels, available labor hours, work centers, and warehouse space are wasted. Maintaining overcapacity means that some costs such as salaries, lease or interest payments, and insurance will remain at a high level, reducing profits more than necessary. In other words, when load and capacity are not in balance, the organization is inefficient. For example, in the 1990s and 2000s, companies around the globe ramped up production of fiber optic cables in anticipation of demand that never materialized. The oversupply led to enormous write-downs, plunging stock prices, bankruptcies, and layoffs.
- **The correct amount of capacity.** When organizations get capacity management right, supply and demand stay close to perfect balance, and the organization tends to stay on plan. Deadlines are met, orders are filled on time with quality items, overtime is minimal or nonexistent, and organizations are generally making optimal use of labor, equipment, and space. Continuous improvement practices can continue to improve organizational performance, even as an organization maintains accurate levels of capacity.

Topic 2: Time Horizons of Capacity Management

Capacity planning begins with the S&OP/production planning process and continues through production activity control (PAC). Exhibit 2-48 illustrates the levels of capacity planning as they correspond to the levels of manufacturing planning and control.

Exhibit 2-48: Levels of Planning



Capacity planning starts at a high level, looking at long-range activities. It continues all the way through short-range, daily activities. The following content looks at each of the levels of capacity planning and control in more detail.

Topic 3: Resource Planning

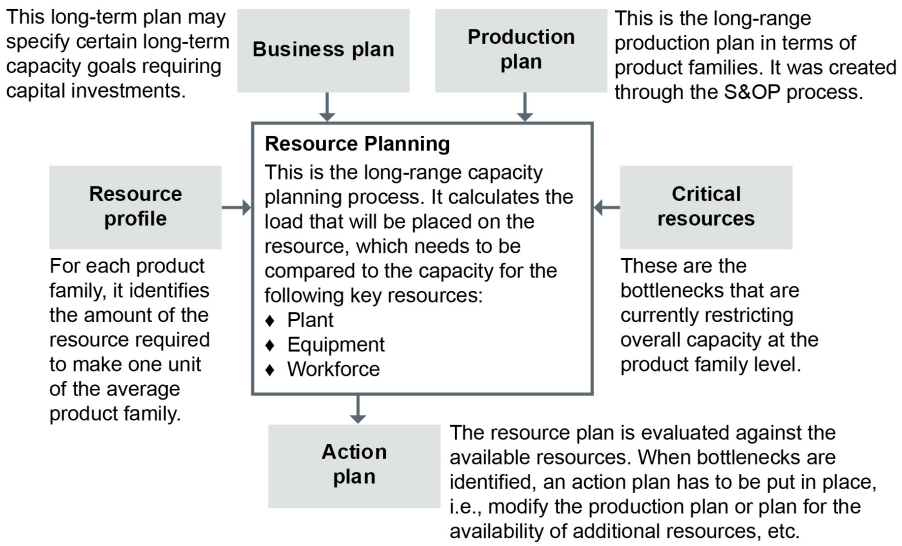
Resource planning (also called resource requirements planning) is capacity planning over the longest time frame. It begins with the production plan, which is an outcome of sales and operations planning, and ends with a resource plan that identifies the resources needed to meet production priorities at a high level. It may also refer to the business plan for longer-term capital investments. Part of the resource plan is a long-range assessment of capacity requirements at an aggregate level. Given long-range demand forecasts, the resources needed—including plant, labor, and equipment—must be identified to create enough supply to match that demand one, two, or even five years into the future.

Resource planning might identify the number of labor hours required quarterly to meet operations goals. If those goals seem impossible to meet with realistic capacity projections, plans may have to be altered. If organizations don't already have the resources in the network to meet demand at this aggregate level, then they must make decisions about modifying capacity, modifying the production plan, or managing demand differently.

For the longer end of long-term capacity requirements, resource planning may involve generating business cases for capital expenditures such as infrastructure improvements, winning approval for them at the executive level, and producing project plans and performing project management to build or acquire the resources needed for long-term strategic business development. It can also involve strategic hiring and workforce training.

Exhibit 2-49 shows the part that capacity planning plays in relationship to resource planning (which interacts with the production plan from S&OP).

Exhibit 2-49: Capacity Planning at the Level of the Resource Plan



The *APICS Dictionary,* 16th edition, defines a **resource profile** as

> the standard hours of load placed on a resource by time period. Production lead-time data are taken into account to provide time-phased projections of the capacity requirements for individual production facilities.

Standard costing was introduced earlier. Rather than standard hours, a resource profile could use measures specific to a given operation such as standard milliliters of a chemical, standard hours of drying time, or standard kilograms of raw material.

For an example of the use of resource planning, assume that manufacturing an average laptop requires 0.75 standard hours of assembly time. If the production plan for the month calls for 100,000 units, then there is a planned load of 75,000 standard hours of assembly time. This amount of time is then compared to the available capacity.

Staging capacity investments

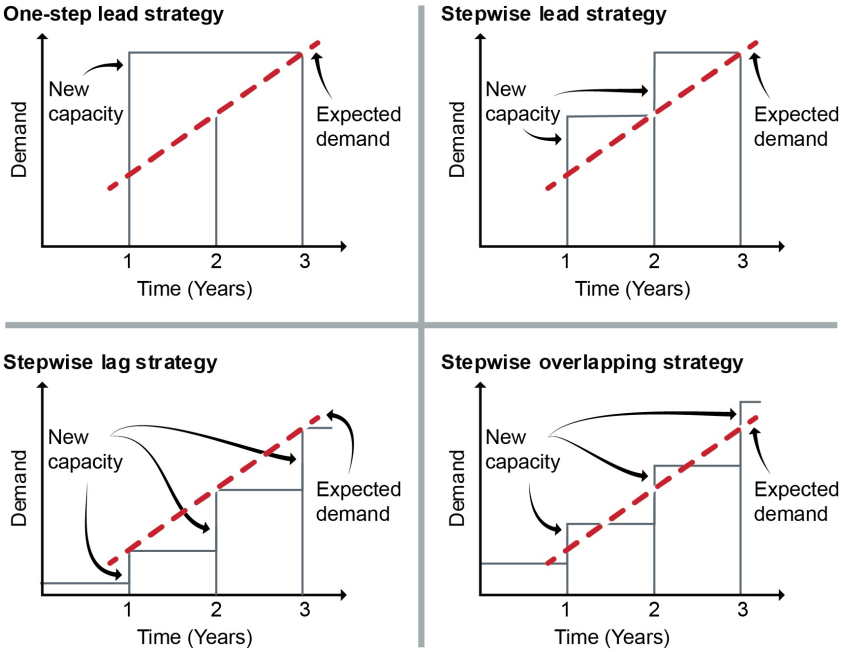
If an organization decides to increase capacity to match expected growth in demand, it can decide how best to stage the investments. For example, it may be necessary to build a new facility to accommodate types of work the organization isn't doing for current projects or to purchase expensive equipment. When the organization does so, it will develop excess capacity, requiring it to wait for demand to catch up.

Organizations might instead decide that they have the basic capacity they need but some upgrades will be required. In that case, they may be able to stage the upgrades to match expected growth in demand, either staying a little ahead (leading), a little behind (lagging), or a little of each (so that demand and supply average out) as capacity is increased in stages to reach a future goal.

Exhibit 2-50 shows four ways to stage growth in capacity:

- One-step lead strategy: expanding all at once ahead of demand
- Stepwise lead strategy: expanding in steps ahead of demand
- Stepwise lag strategy: expanding in steps behind demand (to catch up, in other words)
- Stepwise overlapping strategy: expanding in steps that are sometimes ahead of and sometimes behind forecast demand

Exhibit 2-50: Four Ways to Stage Capacity Growth



No matter which strategy is employed to stage growth in capacity, they will all ultimately involve some form of resource management. The *APICS Dictionary,* 16th edition, defines **resource management** as follows:

> (1) The planning and validation of all organizational resources. (2) The effective identification, planning, scheduling, execution, and control of all organizational resources to produce a good or service that provides customer satisfaction and supports the organization's competitive edge and, ultimately, organizational goals. (3) An emerging field of study emphasizing the systems perspective, encompassing both the product and process life cycles, and focusing on the integration of organizational resources toward the effective realization of organizational goals.

Topic 4: Rough-Cut Capacity Planning

Rough-cut capacity planning (RCCP) is defined by the *APICS Dictionary,* 16th edition, as

> the process of converting the master production schedule into requirements for key resources, often including labor; machinery; warehouse space; suppliers' capabilities; and, in some cases, money. Comparison to available or demonstrated capacity is usually done for each key resource. This comparison assists the master scheduler in establishing a feasible master production schedule.

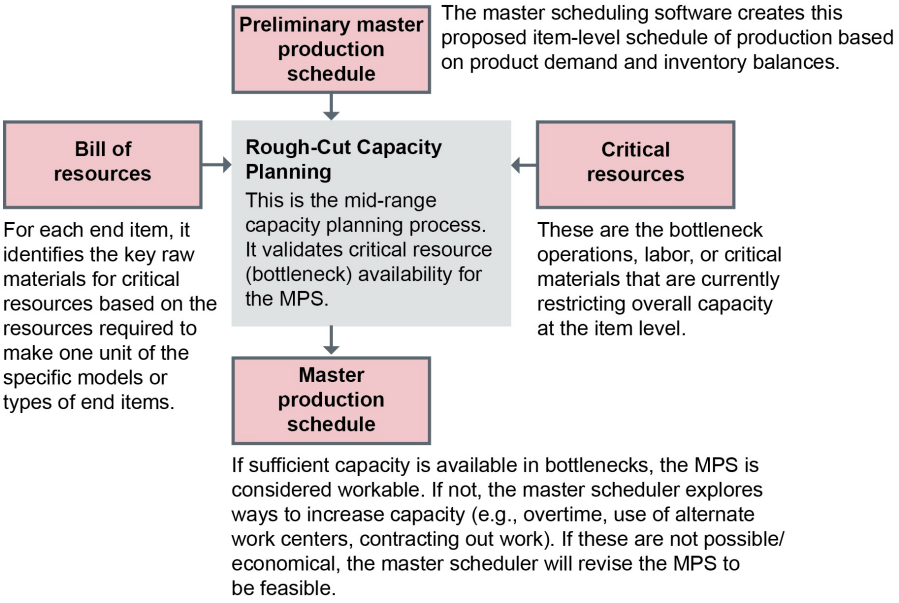
Rough-cut capacity planning takes a more detailed, medium-term look at production priorities as they are described in the MPS and determines whether capacity is available to carry out the scheduled activities. If it does not appear that production targets are realistic within specified tolerances as agreed to by the S&OP policy, the plan goes back to the master scheduler for revision. The master scheduler can alter either the schedule or the capacity. Similarly, if there is too much capacity in the system, adjustments may be needed. The back-and-forth nature of rough-cut capacity planning is often facilitated by supply chain managers, who can represent various parties' interests.

Typically bottlenecks, gateway work centers, and critical suppliers are the only capacity checks that are done at this point. The *APICS Dictionary,* 16th edition, defines a **bottleneck** as "a facility, function, department, or resource whose capacity is less than the demand placed upon it." In other words, at this stage RCCP reviews key resources and bottleneck areas; it is not a review of every component of operational capacity. RCCP examines critical resources in the plants on the premise that if any bottleneck points can generate sufficient capacity (or key materials are sufficiently available), non-bottleneck capacities and materials are normally also sufficient.

An example of a bottleneck work center could include a situation in which an operation's throughput (rate of production) is constrained by a particular component's fixed oven-curing time. Speeding up production before or after this point would only increase work-in-process (WIP) inventory without increasing throughput. A steady supply of components should be ready to be cured (a buffer), but otherwise excess WIP inventory is unnecessary. (These concepts are part of the theory of constraints, discussed elsewhere.) While resource planning could be used to indicate a need for new ovens, the RCCP process works within current capacity limitations. These limits may be flexible, however. For example, the master scheduler could add a second shift to keep the ovens running longer each day. In this way, the rough-cut check is matched against bottleneck capacity and the load specified in the MPS. If there's a gap, the master scheduler must specify what is required to bridge it.

Exhibit 2-51 shows the part RCCP plays in capacity planning.

Exhibit 2-51: Capacity Planning at the Level of Rough-Cut Capacity Planning



Similar to resource planning, RCCP has inputs for critical resources and standard resource capacities (bills of resources versus resource profiles). The difference is that for RCCP these inputs specify individual items rather than product families. According to the *APICS Dictionary,* 16th edition, a **bill of resources (bill of capacity)** is

> a listing of the required capacity and key resources needed to manufacture one unit of a selected item. Rough-cut capacity planning uses these bills to calculate the approximate capacity requirements of the master production schedule. Resource planning may use a form of this bill.

Measuring capacity

Capacity at a work center is measured using the standards that were set for sites and work centers (equipment and workers) to produce a product. Capacity may be measured in a variety of ways besides items per unit of time (widgets per hour). For example, hospital capacity is rated by number of beds. Additionally, some organizations rate a work center's capacity only according to the standard hours of work time available. (100 workers at 40 hours per week is 4,000 hours of work time.) Capacity is never measured is in monetary units—euros, yen, dollars.

Goals of RCCP for master production schedule output

The output of the RCCP process is a workable master production schedule. An MPS is considered workable if the master scheduler has verified that

- Bottleneck capacity per item per time period is sufficient

- The plan makes the best use of resources
- Customer delivery promises can be kept
- The plan is still economical given all excess costs that will be incurred, such as overtime.

Topic 5: Capacity Requirements Planning

Capacity requirements planning (CRP) determines in detail the amount of labor and machinery required to carry out production tasks specified in the MRP, translating MRP orders (measured in units) into hours of work for each work center in each time period. CRP is the most detailed level of capacity planning. At this point in the process, planning looks at orders and work schedules to see specifically how available capacity will, or will not, translate into the production necessary to meet demand.

The amount of work scheduled for a work center is determined by a system that reviews all of the work released to that center by MRP and MPS, adds up the standard hours required for each order, and compares it to capacity.

Another purpose of capacity requirements planning is to assign each facility, work center, and operation a load and perform load leveling. The *APICS Dictionary,* 16th edition, defines load and load leveling as follows.

> **Load:** The amount of planned work scheduled for and actual work released to a facility, work center, or operation for a specific span of time.
>
> **Load leveling:** Spreading orders out in time or rescheduling operations so that the amount of work to be done in sequential time periods tends to be distributed evenly and is achievable. Although both material and labor are ideally level loaded, specific businesses and industries may load to one or the other exclusively (e.g., service industries).

Steps in CRP

Four steps are required to determine the capacity available at a work center: check the open order file, check planned order releases, check the routing file, and check the work center file.

Step 1: Check open order file.

The open order file contains all active shop orders, with quantities, operations, and due dates. The open orders are recognized in the MRP grid on the “Scheduled receipts” line. Taken together, these orders tell you how much capacity is already scheduled at the work center. However, since manufacturing has already begun working on these orders, only the load of the remaining operations needs to be taken into account.

Step 2: Check planned order releases.

The planned orders will be released on the release dates planned by MRP. Since these orders are not yet released, all operations still need to be performed and taken into account.

Step 3: Check the routing file.

The routing file follows each component’s progress through the center or centers. The file may be electronic or a paper copy, and it contains the following for each component:

- Operations to be performed
- Sequence of operations
- Work centers
- Alternate work centers
- Tooling needed for each operation
- Standard times, including setup time for each piece as well as run time

Taken together, the planned order releases plus the routing file provide the information necessary to calculate the amount of time in the schedule for any work center. Recall that the routing file includes information on the operation numbers and sequence, the operation descriptions with timing (e.g., mix: one hour/batch), the work centers, and other requirements. By adding the open orders and the planned order releases, the total commitment of time for the work center can be calculated.

Step 4: Check the work center file.

The work center file provides capacity information about the center, which includes a collection of people or machines (or both) engaged in one type of work. The file contains all the information needed to calculate the amount of manufacturing lead time to complete one order at the work center. At a minimum, the file will contain data on queue time, wait time, and move time.

These times, together with the setup and run times from the routing file, constitute the lead time for the component. Dividing the total time available during a scheduled period at the work center by the run time tells you how many units can be produced at the center in that period.

Lead times can be further broken down. The *APICS Dictionary,* 16th edition, defines **manufacturing lead time** (production lead time) as

> the total time required to manufacture an item, exclusive of lower level purchasing lead time. For make-to-order products, it is the length of time between the release of an order to the production process and shipment to the final customer. For make-to-stock products, it is the length of time between the release of an order to the production process and receipt into inventory. Included here are order preparation time, queue time, setup time, run time, move time, inspection time, and put-away time.

These manufacturing lead time components, along with wait time, can be summarized as follows:

- Order preparation time is the administrative time spent processing an order.
- Queue time is the time spent waiting for an operation to start. (It can be a significant percentage of manufacturing lead time.)
- Setup time is the time spent preparing work centers for different operations.
- Run time is the time spent performing an operation.
- Wait time is the time spent at a work center before going to the next center.
- Move time is the time spent physically moving items among work centers.
- Inspection time is the time spent on quality assurance.
- Put-away time is the time spent moving the item to its storage location. (It is part of move time.)

The work center file also contains data on work center efficiency and utilization.

Topic 6: Production Activity Control

Capacity control takes the form of input-output control and operations sequencing. Capacity control is the level of capacity planning that has the shortest horizon and takes place closest to the daily action of manufacturing. This is where the planned activities get carried out. Production activity control (PAC), of which capacity control is one part, consists of all those activities meant to ensure that everything goes according to plan.

While it isn't the purpose of this course to go into the details of manufacturing activity, it is necessary to cover the basic objectives of PAC and to look at some control strategies that can help keep things running smoothly. If activities at the work center don't run smoothly, missed production schedules will affect the supply chain from one end to the other.

Control objectives

PAC has four main objectives:

- Execute the master production schedule and the material requirements plan.
- Make the best use of resources.
- Minimize work-in-process (WIP).
- Maintain customer service.

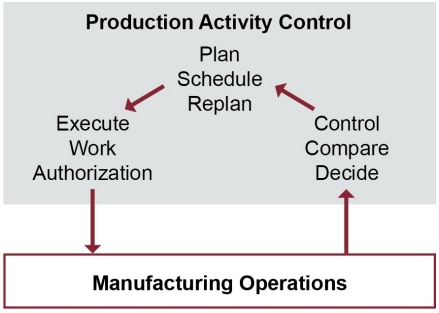
Control functions

Production activity control's functions can be put under three headings, as follows:

- **Plan.** Planning at this level means ensuring that resources are available and scheduling start and completion dates.
- **Execute.** Execution of the plan requires gathering relevant information for the shop order and releasing the orders.
- **Control.** Controlling the workflow requires
  - Establishing and maintaining order priority (first things first)
  - Tracking actual performance (so you know where any problems are)
  - Monitoring and controlling work-in-process, lead times, run times, and queues
  - Reporting work center performance.

These three functions take place in a continuous loop (as shown in Exhibit 2-52), with the data gathering and analysis that takes place in the control function feeding information to the planning function to enable continuous improvement.

Exhibit 2-52: Planning, Executing, and Control



Source: CPIM Workbook

Measuring capacity

If we want to measure available capacity for a given period of time, we need to know three things:

- **Available time.** Available time is a product of hours of operation and numbers of workers or equipment in use during those hours. (For instance, four machines producing eight hours a day, five days per week, yield a weekly available time of 160 hours.)
- **Utilization.** Utilization is the percentage of available time that the work center is actually being used ([hours actually worked/available hours] x 100%). The *APICS Dictionary,* 16th edition, defines **utilization** as "a measure (usually expressed as a percentage) of how intensively a resource is being used to produce a good or service." A work center with an available time of 120 hours per week that operates at 90 hours has a utilization rate of 75 percent [(90/120) x 100].
- **Efficiency.** The *Dictionary* defines **efficiency** as follows:

  > A measurement (usually expressed as a percentage) of the actual output to the standard output expected. Efficiency measures how well something is performing relative to existing standards.

  Efficiency can be calculated as

$$\text{Efficiency} = \frac{\text{Standard Hours of Work}}{\text{Hours Actually Worked}} \times 100\,\%$$

  For example, a work center that produces 110 standard hours of work while operating for only 100 hours has an efficiency rate of 110 percent.

  Recall from the discussion of standard costing in the section on "Develop the Supply Chain Strategy," that standard hours or time refers to the amount of time an average worker or piece of equipment is expected to need, following prescribed methods, to produce one unit of output. Standard time allows for ordinary delays and rest periods.

  Note also that efficiency calculations may be used to determine bonus pay.

This information can then be used to calculate rated capacity and capacity requirements.

Rated capacity

Rated capacity for a work center, therefore, is the available time multiplied by the utilization rate and the efficiency percentage:

$$\text{Rated Capacity} = \text{Available Time} \times \text{Utilization} \times \text{Efficiency}$$

If the work center has 160 hours of available time and its utilization rate is 85 percent with an efficiency rating of 90 percent, the available capacity would be 122.4 standard hours per week (160 x 0.85 x 0.90 = 122.4 standard hours). Note that capacity calculations result in standard hours.

Demonstrated capacity

Another way of measuring capacity available determines the demonstrated capacity; you could consider this the practical counterpart of rated capacity. It is simply the average output measured over a period of time.

$$\text{Demonstrated Capacity} = \frac{\text{Output for n Periods}}{n}$$

For instance, let's say the work center rated above at 122.4 standard hours of available capacity had this performance during six consecutive weeks (n = 6):

Week 1	120.0
Week 2	118.5
Week 3	119.0
Week 4	123.0
Week 5	119.2
Week 6	122.5

Its demonstrated capacity would be the average of the weekly output for those six weeks, or 120.4 standard hours.

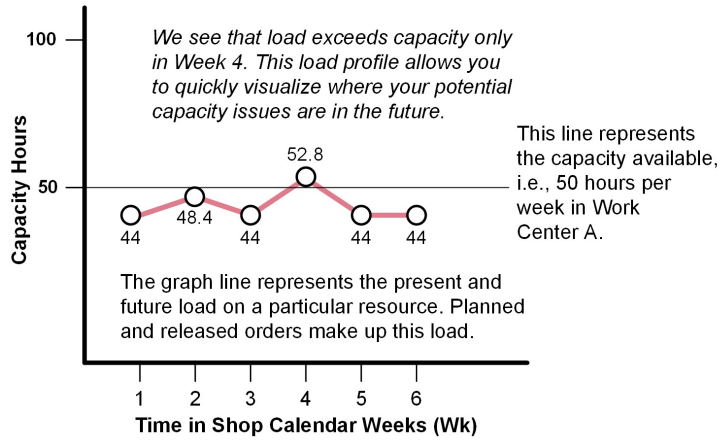
$$\text{Demonstrated Capacity} = \frac{120.0 + 118.5 + 119.0 + 123.0 + 119.2 + 122.5}{6} = \frac{722.2}{6} = 120.4$$

Capacity requirements

Once you know the available capacity at a work center, you can compare it to the load to see if you have a match. If you don't have the capacity at a work center to match or exceed the load, then there is a capacity constraint.

Exhibit 2-53 shows how a constraint might appear on a load profile tracking the capacity hours required in the first six weeks of the upcoming year. Week 4 turns out to be the cruelest period, the week when our earlier question "Can we do that?" gets answered "No, we can't." The planner will have to talk to the work center manager about possible changes in available capacity—adding temporary labor, improving efficiency if possible, or producing extra goods early if the extra demand can be anticipated far enough in advance.

Exhibit 2-53: Capacity Requirements



When load and capacity are out of balance

If you find that there is more load than capacity or more capacity than load, you can choose to either change capacity, change the load, or change a combination of the two.

Change capacity to match the load.

You can select one or a combination of the following means to alter the capacity:

- Add or reduce work hours. Use overtime hours to handle the extra load or undertime hours to reduce the cost of excess capacity.
- Hire or lay off workers. This is an inefficient way to handle a short-term problem (e.g., severance to outgoing employees or training new ones).
- Shift the workforce. If you have work centers that are over capacity and others that are under, you may be able to move workers with compatible skills. Job rotation techniques can prepare the workforce for this.
- Change the routings. Instead of moving workers around, reroute the work to take advantage of overutilized and underutilized stations.
- Subcontract extra work to a third party or hire temporary workers if you have an agency that can provide workers with the requisite skills.

Change the load to match capacity.

It may be possible to reduce (or increase) the load to bridge a gap between load and capacity, but this can be done only if it doesn't complicate matters too much at other work centers. You have two possible tactics:

- Change lot sizes. **Lot size (order quantity)** is "the amount of a particular item that is ordered from the plant or a supplier or issued as a standard quantity to the production process" (*APICS Dictionary,* 16th edition).
- Change the schedule.

Continuous improvement

In addition to carrying out production plans according to schedule, PAC can engage in continuous

improvement by adopting techniques associated with six sigma, kanban, lean manufacturing, and other tried and true systems.

Here are a few strategies employed to speed up manufacturing (and other) processes.

Concentrate on constraints.

According to Goldratt's theory of constraints, a production process is no faster than its slowest function, known as the constraint. Capacity is limited by the constraint the way traffic flow is constrained by traffic jams. Cars headed into the jam can speed up without helping a bit; they just make the traffic queue longer, sooner.

So here are a few principles for handling the constraint in a system:

- Elevate the constraint, which means working to remove the constraint. For example, if you have only one machine to do a constrained task, buy another one. (Need would typically be identified in resource planning.)
- Put some inventory in a queue before the constraint as a time buffer. You want to make sure the constraint always has inventory so it never stops functioning, because that will make the system slow down even more.
- Control the rate of material feeding into the constraint. You want material coming in at the rate required to maintain the time buffer. Anything less depletes the buffer; anything more causes an expensive queue.
- Improve the flow at the constraint in any way possible, for instance, reduce setup time or increase utilization.
- Adjust loads to avoid the constraint when you can. There may be a cost tradeoff, but using more expensive work centers justifies itself if the added expenses buy even more valuable throughput. **Throughput time** is "the length of time from when material enters a production facility until it exits" (*APICS Dictionary,* 16th edition).
- Change the schedule—as a last resort.

Use visual signals.

The kanban system from Japan speeds up operations by pulling inventory through the work center instead of pushing it up to the next workstation where it sits in a queue. As defined in the *APICS Dictionary,* 16th edition, **kanban** is

> a method of Just-in-Time production that uses standard containers or lot sizes with a single card attached to each. It is a pull system in which work centers signal with a card that they wish to withdraw parts from feeding operations or suppliers.

The term **demand pull** is defined in the *Dictionary* as

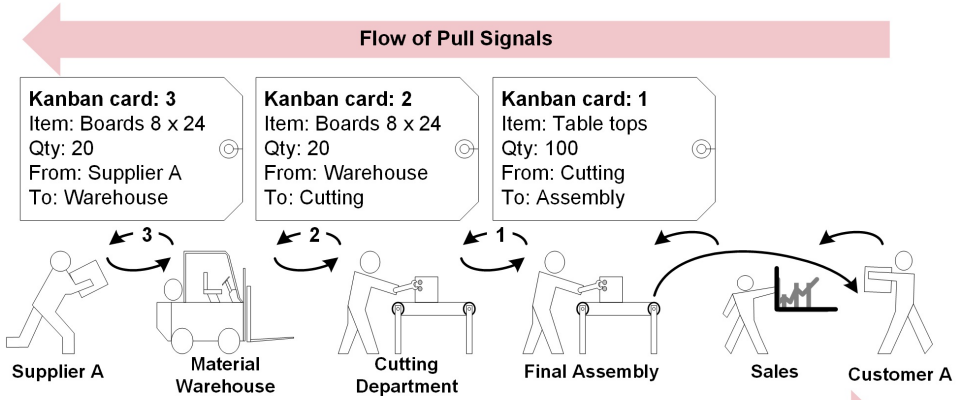
> the triggering of material movement to a work center only when that work center is ready to begin the next job. It in effect eliminates the queue from in front of a work center, but it can cause a queue at the end of a previous work center.

In Japan, kanban systems often use display cards as the visual signal to tell a workstation to begin operations. The idea is to keep the lot sizes as small as possible to optimize use of space and labor.

Many plants have adopted the system and modified it to use a signal other than a card. An empty space can do for a signal to begin operations. In Harley-Davidson's version of kanban, for instance, components are placed in special containers. An empty container signals the need for more parts.

Exhibit 2-54 illustrates a kanban system that pulls inventory all the way through the supply chain, from raw material to finished goods.

Exhibit 2-54: Kanban System with Visual Signals



Process:

1. Customer sends in an order for 100 tables.
2. Order is scheduled in the plant.
3. Assembly sends kanban card 1 to the previous department requesting 100 table tops.
4. Cutting department sends kanban card 2 to the warehouse requesting 20 8 x 24 boards.
5. Planning sends kanban card 3 to the supplier to send more 8 x 24 boards.

Key Points:

1. The kanban system is a pull system. Kanban means "display card" in Japanese.
2. It is a replenishment system that synchronizes the customer's requirements through the plant and to the suppliers.
3. Production should start only when a kanban card has been issued.
4. The movement of kanban cards depends on the number of containers for each component and the timing of when to deliver the card to the upstream facility.

Develop pull partnerships and learn to be lean.

Kanban's visual signals are one example of a pull system of production control. These systems, often part of lean or Just-in-Time systems, depend upon having supply partners who understand the vision and are willing and able to cooperate. Having a supplier who delivers small lots of inventory to your plants on an as-needed basis can help you save space and avoid slowdowns due to material shortages and can save on labor costs at the docks.

Developing lean thinking focuses on taking only the absolute minimum numbers of steps (literally as well as figuratively) and using only the bare minimum of resources. A simple example: Reduce the distance between work centers with the heaviest traffic. Fewer steps taken by many employees can add up to considerable savings of time, energy, and money. (Organizing the entire work site this way is called JIT layout.) Produce only what customer satisfaction requires. Quality is in the eyes of the customer. Reduce waste, reuse, and recycle.

Chapter 7: Inventory

This chapter is designed to

- Define inventory and inventory management
- Identify the main types of inventory
- Describe valid reasons for holding inventory
- Identify key performance indicators relevant to inventory management
- Describe the factors to be weighed when setting inventory policy
- Identify why inventory is managed in aggregate and at the item level
- Explain ABC analysis and how it shapes aggregate levels of inventory
- Differentiate between inventory cost categories
- Describe the effects of inventory on financial statements
- Describe how inventory can be given different values on the balance sheet based on how it is valued by accountants
- Understand the use of inventory turnover as an inventory control tool

Topic 1: Inventory Basics

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

> those stocks or items used to support production (raw materials and work-in-process items), supporting activities (maintenance, repair, and operating supplies), and customer service (finished goods and spare parts).

Organizations that carry inventory do so because it is a necessary cost of doing business. However, since it is a cost, organizations are continually working to find the optimum levels of inventory that can maximize profits, production efficiency, and customer service. Inventory can also be seen as an investment that, if managed correctly, can be a strategic asset to the organization. For example, inventory can decouple demand and supply, so proper management of inventory can provide protection against variability in either.

The management alternatives to inventory include the following:

- Reduced variability in the quality, amount, and timing of supply deliveries
- Shorter production cycle times
- Careful maintenance of production equipment
- Improved demand forecasting and/or use of actual demand orders

Types of inventory

Inventory comes in several different types, classified according to where along the supply chain it is being held. (Note that classification of inventory type depends on the point of reference, meaning that a raw material supplier's finished good becomes a manufacturer's raw material upon transfer.) Each type serves particular functions, all of them adding to the supply chain's flexibility. A basic understanding of inventory depends upon knowing the types of inventory and the functions performed by each type.

- **Raw materials inventory** includes purchased parts, materials, or subassemblies to a production process that have been acquired but have not yet entered production.

- **Work-in-process (WIP) inventory** is defined in the *APICS Dictionary,* 16th edition, as

  > goods in various stages of completion throughout the plant, including all material from raw material that has been released for initial processing up to completely processed material awaiting final inspection and acceptance as finished goods inventory.

  In other words, work-in-process inventory is inventory to which value has been added, but it is not yet a finished good. WIP can also include subassemblies for a BOM that are held in inventory.

- **Finished goods inventory** includes the finished, ready-to-use products waiting to be purchased by the customer.

- **MRO (maintenance/repair/operating supplies) inventory** includes spare parts, lubricants, hand tools, and cleaning supplies that are needed to maintain production but are not in the final product. Because of this, MRO is expensed rather than being an asset on the balance sheet like the other types of inventory. Maintaining reliable production requires keeping an inventory of supplies for both routine maintenance and emergency repairs. Attention to production machinery and MRO forecasting can reduce equipment costs and downtime.

One additional type of inventory that is often overlooked is in-transit inventory.

- **In-transit (distribution or pipeline) inventory** is "inventory in the transportation network and the distribution system, including the flow through intermediate stocking points" (*APICS Dictionary,* 16th edition). Some amount of raw materials, WIP, finished goods, or MRO inventory is in transit at any given time due to the never-ending cycle of production and replenishment; an example is inventory on container ships for international shipments. Counting only the inventory that is currently in stock could be omitting a significant percentage of total inventory. In-transit inventory is measured by the average annual inventory in transit, which is a function of transit time in days and annual demand. Reducing this cost requires finding ways to reduce transit time, because less volume needs to be in transit at a given time.

Functions of inventory

Inventory can be seen as both an asset and a liability. The following functions, or purposes, of inventory answer the question "Why have inventory in the supply chain?"

- **Anticipation inventory** is "additional inventory above basic pipeline stock to cover projected trends of increasing sales, planned sales promotion programs, seasonal fluctuations, plant shutdowns, and vacations" (*APICS Dictionary,* 16th edition). It is intended to cover the demand projected in the organization's demand plan. The demand plan will include anticipation of demand peaks and valleys due to promotions or changes in seasonal demand. In a level production strategy, anticipation inventory may require building additional inventory before it is needed in order to cover the anticipated increased demand later in the year.

- **Safety stock (fluctuation inventory)** is defined in the *APICS Dictionary,* 16th edition, as follows:

  > 1) In general, a quantity of stock planned to be in inventory to protect against fluctuations in demand or supply. 2) In the context of master production scheduling, the additional inventory and capacity planned as protection against forecast errors and short-term changes in the backlog.

> Overplanning can be used to create safety stock.

Safety stock is held as a buffer against miscalculations of timing or quantity. It decouples adjacent manufacturing processes or partners along the supply chain so the problems of the upstream process/partner won't cause difficulties for the downstream process/partner—at least, not right away. If a supplier goes bankrupt suddenly, for instance, safety stock can be used to continue production while looking for a replacement supplier. Safety stock helps meet customer service targets and reduces stockout costs. Use of safety stock to satisfy unplanned demand should be considered normal to a point. Inventory policy can be used to set an acceptable frequency for use of safety stock; increased frequency of use over this target is an exception indicating there may not be enough inventory. Decreased frequency of use under this target may indicate that there may be too much inventory. Infrequent or non-use of safety stock is a red flag that there is too much inventory.

Note: When the delivery times fluctuate, safety stock may be used for A and B items (fast and medium-fast movers) in the ABC inventory method. However, when applied to C items (slow movers), inventory will increase too much. In this case, safety lead time should be used.

- **Lot-size inventory or cycle stock** is the purchase or manufacture of inventory in quantities greater than needed to receive quantity discounts or full truck discounts or to match batch sizes for production. A more general term that encompasses other types of reordering systems other than in full lots is cycle stock. The *APICS Dictionary,* 16th edition, defines **cycle stock** as inventory that "depletes gradually as customer orders are received and is replenished cyclically when supplier orders are received."

- **Hedge inventory.** Hedge inventory is not a commonly used term in organizations, but many organizations do practice hedging when it comes to inventory. Hedging involves managing risk by building, buying, or contractually guaranteeing additional inventory at a set price if supply could be threatened or prices could rise. These decisions involve speculating on events such as the weather, the economy, labor strikes, civil strife, or political actions.

- **Buffer inventory** includes materials maintained to keep production throughput steady at work centers. The *APICS Dictionary,* 16th edition, defines a **buffer** as

  > a quantity of materials awaiting further processing. It can refer to raw materials, semifinished stores or hold points, or a work backlog that is purposely maintained behind a work center.

  The term is also related to the theory of constraints.

- **Decoupling** is defined in the *APICS Dictionary,* 16th edition, as

  > creating independence between supply and use of material. Commonly denotes providing inventory between operations so that fluctuations in the production rate of the supplying operation do not constrain production or use rates of the next operation.

Decoupling allows supply and demand functions to operate at differing, independent rates. Holding a supply of raw materials inventory, for example, decouples the manufacturer from its suppliers. The sawmill operator wants to have a ready supply of trees to turn into dimensional lumber. The furniture manufacturer wants enough dimensional lumber to process.

Since many products are produced in batches when there are competing uses for the same work centers, decoupling also allows scheduling use of a work center so that some production may occur earlier than needed to avoid bottlenecks in overall production. While this adds to inventory build-up because some WIP inventory will be ready for the next work center before it is needed, it is an example of the need to optimize the overall flow of inventory in production. While decoupling is often necessary, supply chain managers look for ways to achieve the same goals without the holding costs by reducing variability in quality, quantity, or delivery time.

Inventory management

The *APICS Dictionary,* 16th edition, defines **inventory management** as "the branch of business management concerned with planning and controlling inventories." Inventory management is required at any organization that carries inventory. This role involves planning and controlling inventory from a supply chain perspective and an internal process perspective.

The supply chain perspective of inventory management is concerned with the inflows and outflows at each stage, from the ordering of raw materials to customer handoff of finished goods. Therefore this area can benefit strongly from inventory visibility and supply chain collaboration. **Inventory visibility** is "the extent to which inventory information is shared within a firm and with supply chain partners" (*APICS Dictionary,* 16th edition).

Inventory management is also integrally connected to production management, so the second perspective of inventory management is an enterprisewide view of inventory processing. Inventory feeds into production and/or is a result of production, so planners, master planners, and production schedulers coordinate with each other at each level of production planning refinement.

Inventory management may be the responsibility or concern of many different competing interests at an organization, as shown in Exhibit 2-55.

Exhibit 2-55: Inventory Management Roles

Purchasing and materials management	Adequate raw materials at low inventory cost
Manufacturing and finance	Efficient and low-cost production balanced against low inventory cost
Sales and marketing	Sufficient inventory to meet customer delivery requests and service levels

Inventory management KPIs

From the supply chain management perspective, there are two key performance indicators (KPIs) for inventory:

- Reduction of inventory costs related to holding, ordering, and transporting materials, supplies, and finished goods at various points along the supply chain
- Achievement of customer service targets related to the quality, availability, and on-time delivery of products and services (which may depend upon availability of supplies)

Since inventory represents such a large investment, improving inventory management promises a significant boost in return on investment. It also means that poor inventory management can lead to very large problems. Keeping too little inventory in the system can result in such dilemmas as frustratingly long lead times or broken orders, which in turn could lead to lost customers and lower market share. On the other hand, too much inventory could have a negative financial impact and greater risk of a reduction in inventory value or write-offs of obsolete inventory. In some businesses, obsolescence sneaks up on a product so fast that excess inventory can actually cause the products to become outmoded before they ever get sold.

The tightrope you walk with inventory management is to reduce the cost of holding and transporting goods while meeting or exceeding customer service goals. Setting and regularly updating an inventory policy is one way organizations perform this balancing act.

Inventory policy

Inventory policy is a way of formalizing the results of strategic inventory decisions so that they can be implemented consistently. Inventory policy codifies both broad and specific inventory management decisions. On a broad level, inventory policy could specify centralized or decentralized inventory planning and/or warehousing, frequency of communications and coordination, or a geographical inventory positioning strategy such as postponement. On a more specific level, inventory policy can specify rules for order quantities, order timing, when to act on exceptions to rules, and amounts of specific items to purchase versus produce.

Organizations weigh a number of factors when setting an inventory policy:

- **Customer demand.** Customer demand is known in advance of production and/or is forecasted. Inventory policy must compensate for variability in demand forecasts.
- **Planning horizon.** The duration of the planning horizon affects necessary inventory levels; long-term plans may provide sufficient time to change system capacity.
- **Replenishment lead time.** The time required to replenish stock at various locations in the supply chain is a key inventory policy input, especially for long or highly variable lead times.
- **Product variety.** Similar products may compete for budget allocations or retail shelf space and thus need interconnected inventory policies. Product families are also planned together.
- **Inventory costs.** Inventory costs include order costs (production and transportation) and inventory carrying costs.
- **Customer service requirements.** Inventory policy specifies a level of safety stock per item and location that balances minimizing failure to fill customer orders within an acceptable time (e.g., stockouts) against increasing inventory costs.

Some of these factors are discussed more elsewhere.

Topic 2: Aggregate and Item Inventory Management

Inventory is managed as an overall strategic concern (in aggregate) and at the individual item level. Each method is necessary. Together these two methods provide inventory managers with sufficient information to meet both strategic and operational requirements.

Aggregate inventory management

Aggregate inventory management is primarily concerned with the financial impact of inventories, which means getting to an optimal level of inventory that can produce the greatest overall profit for the organization and the supply chain. The objectives of aggregate inventory management are shown in Exhibit 2-56.

Exhibit 2-56: Objectives of Aggregate Inventory Management

Inventory is aggregated, or grouped, prior to analysis not only because the large number of individual items in some organizations would be impractical to analyze individually but also because, when forecasting supply and demand patterns, aggregate-level forecasts are more accurate than item-level forecasts (since, as noted in the definition, aggregation reduces the variability in data). Note that aggregation is performed only to the level that the groupings provide effective analysis.

Aggregate inventory management can be used to

- Determine the types of inventory to hold
- Optimize the flow of inventory and provide suitable buffers between stages
- Match supply with demand
- Set inventory objectives and inventory policy
- Calculate inventory costs by category
- Perform sales and operations planning, including demand management and production and resource planning.

Aggregating inventory helps inventory managers determine the costs and benefits of a particular group of inventory. Inventory can be aggregated by

- Demand pattern (e.g., women's running shoes versus men's running shoes)
- Production process (e.g., men's and women's running shoes produced on the same production line)
- Stage of production flow (e.g., raw materials, finished goods)

- Product or SKU (stock keeping unit) family or type (e.g., finished goods with similar functions but variations in models, packaging, colors, or styles)
- Distribution pattern (e.g., products that originate at the same source and/or are to be delivered to the same location or customer zone)
- Relative value to the organization (e.g., ABC inventory analysis).

Let's take a closer look at ABC inventory classification.

ABC inventory classification

ABC classification, also known as ABC analysis, is defined by the *APICS Dictionary,* 16th edition, as follows:

> The classification of a group of items in decreasing order of annual dollar volume (price [more typically standard cost] multiplied by projected volume) or other criteria. This array is then split into three classes, called A, B, and C. The A group usually represents 10% to 20% by number of items and 50% to 70% by projected dollar volume. The next grouping, B, usually represents about 20% of the items and about 20% of the dollar volume. The C class contains 60% to 70% of the items and represents about 10% to 30% of the dollar volume. The ABC principle states that effort and money can be saved through applying looser controls to the low-dollar-volume class items than will be applied to high-dollar-volume class items.

ABC classification is thus based upon the monetary value of inventory, which is usually a standard cost. As you might imagine, the A grouping has the greatest value and qualifies for the most careful treatment and highest level of controls.

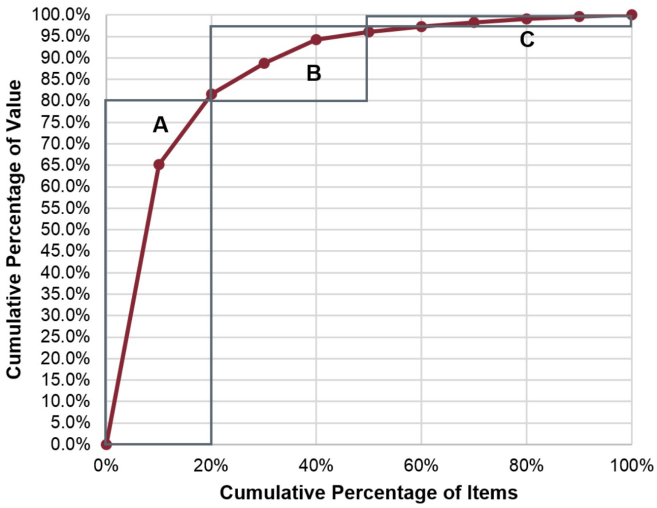
Dividing inventory into A, B, and C groupings is an application of the Pareto principle, which asserts that in any population (customers, inventory items, etc.), a very small percentage will be responsible for a very large portion of the group's impact. It is a general rule, of course, but it often proves to be meaningful enough as an estimate that it is worth applying.

The ABC application of Pareto analysis, or the 80/20 rule, reads this way:

- The **Class A** inventory items are those with the highest value in terms of annualized monetary volume. A classic Pareto analysis would determine that 80 percent of the inventory's monetary value would reside in 20 percent of the part numbers in the inventory.
- The **Class B** inventory items are those with the next highest value in terms of annualized monetary volume. Approximately 15 percent of the inventory's monetary value would reside in 30 percent of the part numbers in the inventory.
- The **Class C** inventory items are those with the lowest value in terms of annualized monetary volume. Approximately 5 percent of the inventory's monetary value would reside in 50 percent of the part numbers in the inventory.

Exhibit 2-57 shows an ABC classification that uses an 80/15/5 split.

Exhibit 2-57: ABC Classification in Inventory Management



Annual monetary volume is just one criterion used to assess value. Class A items could be high profit margin goods or lower margin goods that sell rapidly. Other considerations, such as quality concerns or anticipated upgrades, may suggest altering the classes.

Some organizations further refine this type of classification system. For example, one organization found that one percent of its items accounted for 50 percent of their annual monetary volume, so they made an additional class and called their system an ABCD inventory classification to highlight this inventory's importance.

An ABC inventory classification might be used as a foundation for any of the following policies:

- Putting more time, effort, and money into cultivating relationships with the suppliers of the A items (and none into working with C suppliers)
- Warehousing the A items in the most secure part of the facilities, taking more care in transporting them, providing quick access to fast turnover goods, etc.
- Conducting more rigorous demand forecasts for A items than for other items
- Prioritizing cycle counting activities (discussed later) (Note that ERP systems usually segregate ABC systems for the purpose of counting. Using ABC as an inventory policy may require using a different identification data field.)

There are also various other methods for aggregate inventory classification according to specific criteria, for example, individual cost or utility value.

Item inventory management

Item inventory management is used in short-term operational decision making. Management specifies rules to follow for individual inventory items using inventory policy and/or information technology systems. These rules specify

- When to order inventory

- How to determine order size
- Relative importance of each inventory item
- Inventory control procedures for individual items.

The goal of item inventory management is to enable planners to translate strategic inventory goals into measurable results: proper production and distribution of each product or SKU. While sales and operations planning plans production at the family (aggregate) level, master scheduling plans inventory production at the item level (involving generation of the item-level master production schedule). Item inventory management is also necessary at retail locations, which must anticipate demand for inventory both at the aggregate and item level to ensure that individual items are available for purchase. Item inventory management is implemented through inventory planning, inventory models, and inventory control, which are discussed elsewhere.

Topic 3: Inventory Costs and Accounting

Inventory costs

A number of specific costs are associated with inventory.

Acquisition costs

The *APICS Dictionary,* 16th edition, defines **acquisition cost** as “the cost required to obtain one or more units of an item. It is order quantity times unit cost.” Acquisition cost is also referred to as product cost or purchase price.

Landed costs

According to the *APICS Dictionary,* 16th edition, **landed costs** include “the product cost plus the costs of logistics, such as warehousing, transportation, and handling fees.” Landed costs for purchased inventory are the sum of all direct costs, including the price paid (i.e., acquisition cost), transportation to the site, customs, and insurance. Landed costs for internally sourced inventory include direct labor, direct materials, and factory overhead costs.

Carrying costs

Carrying cost (also called holding cost) is “a percentage of the dollar value of inventory per unit of time (generally one year)” (*APICS Dictionary,* 16th edition). It is a variable cost that increases as the level of inventory increases. Carrying costs may be as high as 40 percent of the value of the inventory and are unlikely to be less than 15 percent. They include all the expenses involved in housing the inventory, such as the following:

- **Storage costs.** Storage costs include allocations for rent, operating cost, taxes, material-handling costs, lease payments for equipment, depreciation, power costs, and operating costs. These material, labor, and overhead costs for storing and transporting inventory are allocated to individual SKUs based on their volume (called cube), weight, or density. Large, dense, or difficult-to-handle goods have higher storage costs.

- **Capital costs.** Inventory requires financing, and capital costs refer to the return expected by creditors and investors because the money could be invested elsewhere (called opportunity cost). Companies get financing from debt or equity sources. Debt sources include borrowing arrangements that charge interest and require repayment; equity sources include money from investors (who get an ownership stake in the organization) plus retained earnings (past profits). The relative proportion or weight of each of these sources is called the weighted average cost of capital (WACC). WACC can be used as a required percentage return on inventory sales that must be exceeded.

- **Risk costs.** Risk is related to the sensitivity of the inventory to loss of value, such as its perishability, speed of obsolescence, or likelihood of theft. Risk costs include the cost of insurance, inventory value reductions, and inventory write-offs. Subjective quantifications of risk can be added to inventory, such as a two percent per day decline in inventory value due to obsolescence. In this example, inventory remaining in stock for more than 50 days is considered valueless.

Ordering costs

The *APICS Dictionary,* 16th edition, defines **ordering costs** as follows:

> Used in calculating order quantities, the costs that increase as the number of orders placed increases. It includes costs related to the clerical work of preparing, releasing, monitoring, and receiving orders, the physical handling of goods, inspections, and setup costs, as applicable.

Ordering costs are all those costs that do not vary due to quantities ordered but vary only by the frequency of ordering.

Ordering costs include costs incurred when ordering inventory and setup costs resulting from the process of preparing to go into production to fill the order. For purchased materials, ordering costs include all the costs associated with the purchasing process. Use of electronic forms and payment transfers can reduce these ordering costs; less frequent ordering can also reduce these costs but at the price of additional inventory holding costs. Setup costs include labor for cleaning machinery and making any necessary adjustments or modifications. This requires shutting down the machines, but it is sometimes possible to reduce the shutdown time by doing some preparation work off the work site while the machines are still processing previous orders.

Backorder, lost sale, and lost customer costs

The cost of backorders, lost sales, and lost customers are costs related to customer service. A **backorder** (also known as a stockout) is "an unfilled customer order or commitment…an immediate (or past due) demand against an item whose inventory is insufficient to satisfy the demand" (*APICS Dictionary,* 16th edition). The cost of backorders, lost sales, and lost customers can be difficult to quantify financially but can be measured using various means such as percentage of orders shipped on schedule, which can help quantify the safety stock investment needed for a particular item at a particular location to keep this risk at acceptable levels.

Capacity variance costs

Capacity variance costs are the costs of changing capacity beyond a "normal" range, including the costs of overtime, additional shifts, layoffs, or plant closings. Capacity variance costs can be minimized by production leveling strategies (producing a consistent amount throughout the year), but this strategy increases inventory holding costs during periods of low demand.

Cost balancing

Inventory managers set order amounts and timing to reduce acquisition, carrying, and ordering costs without sacrificing customer service. (Remember, an order schedule is necessary for all managers all along the supply chain—the retailer and the distributor order more finished goods, the manufacturer orders more components and supplies, the supplier orders its own materials and supplies, and so on.)

Effects of inventory on financial statements

In addition to inventory describing the things the company owns that are available for sale or that are used in the production of things available for sale, inventory can be viewed as all the money currently tied up in the supply chain. What is critical to know is this: As much as 40 to 50 percent of a supply chain's invested

working capital can be tied up in inventory.

While inventory can be seen as the buffer that hides the flaws in the supply chain, it can also be seen as the lubricant that keeps a supply chain flexible. A flexible supply chain is able to respond quickly to internal or external (market) changes, such as fluctuations in demand. Therefore, inventory management is an integral supply chain management role because it strongly affects the company's cash flows and financial position.

In order to keep the cash flow turning over, the goal of the supply chain professional is to efficiently manage the company's inventory level and cost while maintaining and improving customer satisfaction. If a company has fast delivery and strong customer satisfaction because it keeps a large inventory, it can also face financial failure because of all of the capital tied up in inventory. On the other hand, if a company does a great job at reducing its inventory and associated costs down to next to nothing, it may run the risk of being unable to deliver the requested products. This may cause customers to take their business elsewhere. Balancing cost, inventory level, and customer service are vital.

Use of the financial statements for inventory management is an exercise in inventory management at the aggregate level. As noted earlier, aggregate inventory management views inventory in total to determine if the flow of materials through the various inventory classifications is efficient and effective enough to maximize profits. Discussions surrounding the financial impacts of inventory are generally framed around reducing inventory, reducing inventory costs, or increasing the number of times per year that cash is invested into inventory and returned in the form of revenue, called inventory turnover.

The financial statements introduced in an earlier section are revisited here, with an emphasis on inventory.

Balance sheet

Recall that the balance sheet has two major sections that have to be in balance as per the accounting equation:

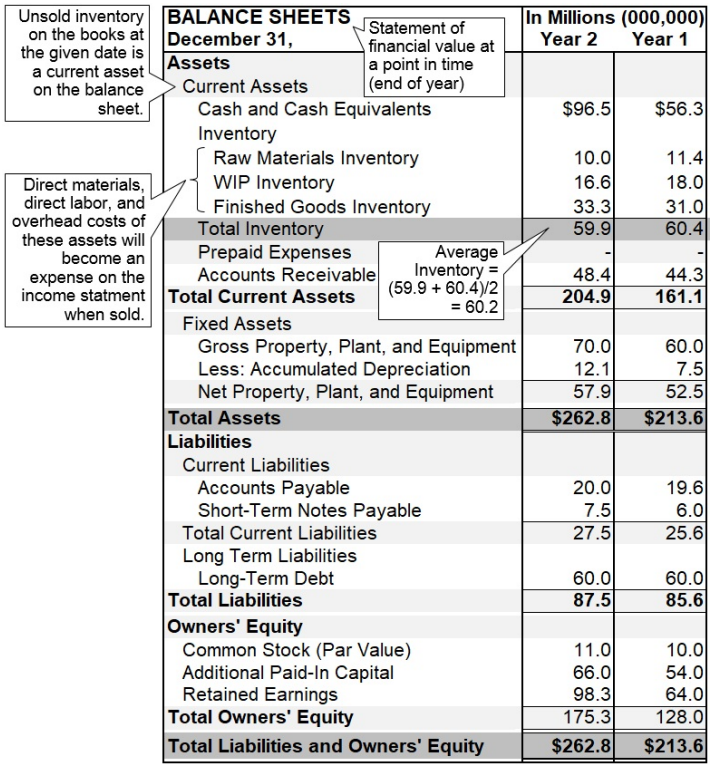
$$\text{Assets} = \text{Liabilities} + \text{Owner's Equity}$$

Exhibit 2-58 displays a version of the balance sheet from an earlier section. Inventory is a current asset that is broken down in this example by raw materials, work-in-process inventory, and finished goods inventory. Note that most externally available balance sheets will list only total inventory, while internal reports made for management purposes often have more details such as these.

Inventory as an asset

Raw materials, WIP, and finished goods are carried as current assets on the balance sheet. MRO inventory is a period expense; it is expensed on the income statement during the period in which it is purchased. The balance sheet items do not impact the income statement until the inventory is sold, reduced to fair market value, or written off (when inventory becomes obsolete).

Exhibit 2-58: Sample Balance Sheet Showing Two Years of Results



BALANCE SHEETS December 31,	In Millions (000,000) Year 2	 Year 1
Assets		
Current Assets		
Cash and Cash Equivalents	$96.5	$56.3
Inventory		
Raw Materials Inventory	10.0	11.4
WIP Inventory	16.6	18.0
Finished Goods Inventory	33.3	31.0
Total Inventory	59.9	60.4
Prepaid Expenses	-	-
Accounts Receivable	48.4	44.3
Total Current Assets	**204.9**	**161.1**
Fixed Assets		
Gross Property, Plant, and Equipment	70.0	60.0
Less: Accumulated Depreciation	12.1	7.5
Net Property, Plant, and Equipment	57.9	52.5
Total Assets	**$262.8**	**$213.6**
Liabilities		
Current Liabilities		
Accounts Payable	20.0	19.6
Short-Term Notes Payable	7.5	6.0
Total Current Liabilities	27.5	25.6
Long Term Liabilities		
Long-Term Debt	60.0	60.0
Total Liabilities	**87.5**	**85.6**
Owners' Equity		
Common Stock (Par Value)	11.0	10.0
Additional Paid-In Capital	66.0	54.0
Retained Earnings	98.3	64.0
Total Owners' Equity	175.3	128.0
Total Liabilities and Owners' Equity	**$262.8**	**$213.6**

While it sounds good that inventory is an asset, what this means to finance is that some amount of the organization's current assets are less liquid than others. (Liquidity is how quickly assets can be converted into cash.) Therefore, optimum inventory holdings are those that equal projected sales in the organization's demand plan (plus an optimal amount of safety stock), because inventory that is projected to be sold soon is considered more liquid, while inventory in excess of the demand plan is less liquid.

Risks of carrying too much inventory

The value of the inventory on the balance sheet includes the costs involved in producing the inventory. However, when the inventory is sold, the portion of inventory value that comprises direct materials (the raw materials), direct labor, and factory overhead will become an expense on the income statement that offsets revenue and reduces cash (an asset). In other words, inventory is an asset on the balance sheet until it is sold, at which point only its profit margin contributes to net income.

Unnecessary inventory can also magnify quality issues. If a defect or other quality issue is discovered, more inventory with the same defect will magnify the quality issue and quality costs for scrap, repair, and/or replacement.

An additional risk of carrying too much inventory is the risk of obsolescence or spoilage. As a general rule, the longer the inventory remains on the books, the more likely it will not be sold and will have to be written

down to fair market value (what the market will currently pay) or written off completely. Inventory that has to be written off requires physical removal of the items and financial recording of the direct materials, direct labor, and factory overhead as an expense without any offsetting revenue. Note that there are strict accounting rules for inventory write-offs that organizations will need to follow (for example, for U.S. GAAP; see the online Resource Center). Accountants will often create an inventory reserve account to reduce the value of inventory in anticipation of write-offs.

Finding average inventory on a balance sheet

A calculation of average inventory for a period of time is frequently used in managing inventory. With today's software systems, average inventory can easily be determined at any time. However, to quickly estimate average inventory levels one can add the inventory value at the start of a period to the value at the end of the period and divide by two.

As an example, using the data in the balance sheet shown in Exhibit 2-58, we can calculate the average inventory for year 2 as follows (amounts in thousands):

$$\text{Average Inventory} = \frac{\text{US\$59.9} + \text{US\$60.4}}{2} = \text{US\$60.2}$$

Average inventory (however your organization calculates it) is used in performance measures and calculations for inventory space requirements.

Accounting value of inventory

How is the value of inventory on the balance sheet calculated? Inventory valuation is a financial accounting process that follows specific rules based on the age distribution of inventory. Various accounting methods can cause the accounting value of inventory over time to be more or less in alignment with its actual market value—first-in, first-out (FIFO); last-in, first-out (LIFO); actual costing; or standard costing. Standard costing applies the standard cost to inventory valuation; any variances from actual costs are adjusted at the period end and would be reflected in the financial statements. These accounting methods were mentioned earlier along with a discussion of how international accounting standards and other countries' accounting standards differ on which methods are and are not allowed.

Other reasons that the reported level of inventory on the balance sheet could differ from the actual market value is that this reported amount may include inventory that is reserved, obsolete, damaged, or otherwise unsalable. Some of this obsolete or damaged inventory will be written off as it becomes clear that it cannot be sold.

Since changes to inventory levels can affect the accounting values of inventory and financing needed to sustain the inventory, supply chain managers should consult with financial managers with enough advance notice so the organization can determine how to change inventory levels while keeping the organization solvent and in good standing with creditors and investors.

Income statement

Recall that the income statement shows the cumulative, dynamic relationship of earnings to expenses over a given period of time. Exhibit 2-59 repeats the income statement from earlier.

Managers, investors, and creditors use the income statement to determine whether the company has made or lost money during some period of time, such as a quarter or a year. An income statement measures profitability in more than one way. Gross profit is determined by subtracting cost of goods sold (COGS) from revenues. COGS includes inventory costs of direct labor, direct materials, and factory overhead for all goods that sold that year. Reducing elements in COGS can therefore directly increase gross profit.

Exhibit 2-59: Sample Income Statement Showing Two Years of Results

INCOME STATEMENTS	In Millions (000,000s) except per share amts.	
For the Years Ending (Profit or loss over a period of time)	Year 2	Year 1
Revenue (Sales)	**$302.6**	**$276.9**
Less: Cost of Goods Sold (COGS)		
Direct Labor	38.3	37.6
Direct Materials	101.5	99.7
Factory Overhead	26.6	26.1
Less: Total Cost of Goods Sold (COGS) (Product expenses: these expenses are booked when the related units of inventory are sold.)	166.4	163.4
Gross Profit	**136.2**	**113.5**
Less: Operating Expenses		
Selling Expenses	30.3	24.9
General and Administrative	27.2	22.2
Lease Expense	12.1	8.3
Less: Total Operating Expenses (Period expenses: these expenses are recorded in the period in which they are incurred.)	69.6	55.4
Less: Depreciation	4.6	4.0
Less: Interest Expense	3.9	3.9
Net Income (Profit) Before Taxes	**58.1**	**50.3**
Less: Income Taxes	16.3	14.1
Net Income (Profit)	**$41.8**	**$36.2**
Net Income (as a Pct. of Revenue)	14%	13%
Net Income Per Share-Basic	**$3.95**	**$3.78**

Reducing these costs is more effective in increasing profits than increasing revenues through an increase in sales volume, because variable costs increase as revenues increase. By reducing costs, you are effectively increasing the profit margin on inventory without having to raise prices.

This shows that increasing sales cannot produce higher profits as quickly as lowering costs. It also shows that lowering variable costs in the supply chain can strongly impact profits.

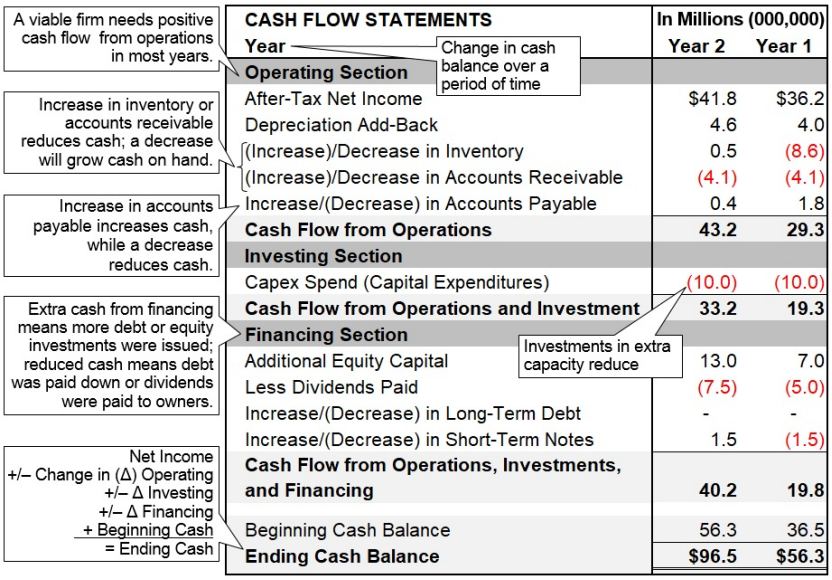
COGS is an expense that is matched to the revenue being generated. Strategies that build inventory far in advance of actual sales can defer accounting for expenses that make up COGS until that inventory is sold. However, supply chain managers should understand that operating expenses (see Exhibit 2-59) are expensed on a periodic basis. These immediately booked expenses could cause problems with maintaining financial ratios at the proper levels. However, the actual cash outflows for both the product (depending on payment terms) and period costs would occur as the inventory is being built up (e.g., salaries, utilities, maintenance), so cash flow could be an issue without proper advance planning for the inventory build-up on the part of finance.

Statement of cash flows

The indirect method for preparing a statement of cash flows, discussed earlier is tied to the accrual accounting method, which measures an organization's performance and position by taking into account economic events regardless of when a cash transaction occurs. The cash accounting method is the opposite of the accrual method; it recognizes transactions only when there is an exchange of cash.

Exhibit 2-60 is the statement of cash flows using the indirect method that was first shown earlier. Remember that a company does not want all of its capital tied up in inventory. Insufficient cash can cause an organization to fail quickly if it cannot raise funds in some other way. Note that an increase in inventory lowers the cash position, while a decrease in inventory increases the cash position. (The parentheses show which actions reduce cash.)

Exhibit 2-60: Sample Statement of Cash Flows Showing Two Years of Results



CASH FLOW STATEMENTS	In Millions (000,000)	
Year	Year 2	Year 1
Operating Section		
After-Tax Net Income	$41.8	$36.2
Depreciation Add-Back	4.6	4.0
(Increase)/Decrease in Inventory	0.5	(8.6)
(Increase)/Decrease in Accounts Receivable	(4.1)	(4.1)
Increase/(Decrease) in Accounts Payable	0.4	1.8
Cash Flow from Operations	**43.2**	**29.3**
Investing Section		
Capex Spend (Capital Expenditures)	(10.0)	(10.0)
Cash Flow from Operations and Investment	**33.2**	**19.3**
Financing Section		
Additional Equity Capital	13.0	7.0
Less Dividends Paid	(7.5)	(5.0)
Increase/(Decrease) in Long-Term Debt	-	-
Increase/(Decrease) in Short-Term Notes	1.5	(1.5)
Cash Flow from Operations, Investments, and Financing	**40.2**	**19.8**
Beginning Cash Balance	56.3	36.5
Ending Cash Balance	**$96.5**	**$56.3**

Changes to inventory affect cash flows

Inventory can strongly affect cash flows, which, in turn, can affect covenants with lenders (contractual agreements that may include lender requirements that the borrower maintain certain financial ratios at certain levels). Even a reduction in inventory can create one-time adjustments for finance that impact reporting. However, once the adjustments are made, the long-term financial impact of inventory reductions is usually positive.

For example, consider a situation in which a supply chain manager discovers that some types of inventory at his organization are not selling and have been held for long periods of time. He suggests that reducing these types of inventory will allow the organization to reduce inventory by €60 million (m). However, the organization's chief financial officer raises a major concern. The organization's bank has a financial covenant

on its loans that requires the organization to maintain a ratio of 2:1 between owners' equity and liabilities (twice as much in equity). If inventory is reduced by €60m, in the best case, cash would increase by a few million euros and, in the worst case, the organization would have to pay to scrap the inventory. Assuming that the transaction could be completed with no net change in income, in order to keep the balance sheet in balance, owners' equity (retained earnings) would be lowered by the same €60m. To maintain the financial covenant, the organization would need to decrease its liabilities by half as much, or €30m. These requirements could put a large burden on cash flow. Failure to maintain the covenant would place the organization in technical default, and its debts could become immediately due and payable. The result is that the organization is unable to perform the change immediately. The supply chain manager learns the value of consulting with finance prior to making suggestions for a major change in inventory so that finance can determine ways to accommodate the change while keeping the company solvent. The financial officer recommends that to prevent such a situation from recurring that the organization should make financial reservations for aging or obsolete stock, which would help the finance department understand how to prepare for the inventory write-off.

Financial ratios for inventory management

Two financial ratios that have relevance for inventory management are the inventory turnover ratio and the cash-to-cash cycle time. These ratios are defined and discussed in another section.

Chapter 8: Inventory Planning

This chapter is designed to

- Define centralized and decentralized inventory planning
- Discuss how locations of inventory can be optimized by echelon, number, and geographic location
- Explain the reason for using, the basic process, and the assumptions underlying fixed order quantity or economic order quantity (EOQ) methods of determining order quantities
- Describe ordering systems, including order point, periodic review, min-max, and time-phased order point
- Describe the functions and drawbacks of using safety stock and safety lead time
- Explain how and why inventory is tracked
- Distinguish between period and cycle counting and explain their benefits and drawbacks.

Topic 1: Inventory Planning Basics

According to the *APICS Dictionary,* 16th edition, **inventory planning** is

> the activities and techniques of determining the desired levels of items, whether raw materials, work in process, or finished products including order quantities and safety stock levels.

Inventory planning can be centralized or decentralized or a hybrid of the two.

- In centralized inventory planning, inventory is pushed out to later stages in the supply chain by the lead organization or channel master. Later stages such as distribution centers have no say in what they receive, but the central system usually attempts to replace inventory that is sold and to plan for seasonal effects or other trends. Centralized planning can minimize overall inventory levels but may respond slowly to local demand.
- Decentralized inventory planning involves each supply chain stage determining its own inventory requirements and placing orders independently, so there is no coordination expense.
- Hybrid systems use centralized planning up to a certain point in the supply chain (such as the distribution centers), followed by decentralized inventory planning at all later points.

Decentralized inventory planning can lead to the bullwhip effect and other problems, especially if actual customer demand isn't available to all stages of the supply chain. Therefore, centralized planning has grown in popularity.

Inventory planning has two major components: where to locate inventory and the desired levels of items at each selected location.

Locations of inventory

Where should inventory be located? Inventory should be located in any place in the distribution network structure where it can serve a valid purpose as a buffer between stages of the supply chain, reduce overall costs, and meet customer service goals.

Warehouses, distribution centers, in transit

Inventory can be stored in warehouses and in retail locations.

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

> facilities used to store inventory. Decisions driving warehouse management include site selection, number of facilities in the system, layout, and methods of receiving, storing, and retrieving goods.

Distribution centers are a type of warehouse. According to the *APICS Dictionary,* 16th edition, a **distribution center** is "a location used to store inventory." Inventory can also be located in transit; in-transit (or distribution or pipeline) inventory was described elsewhere.

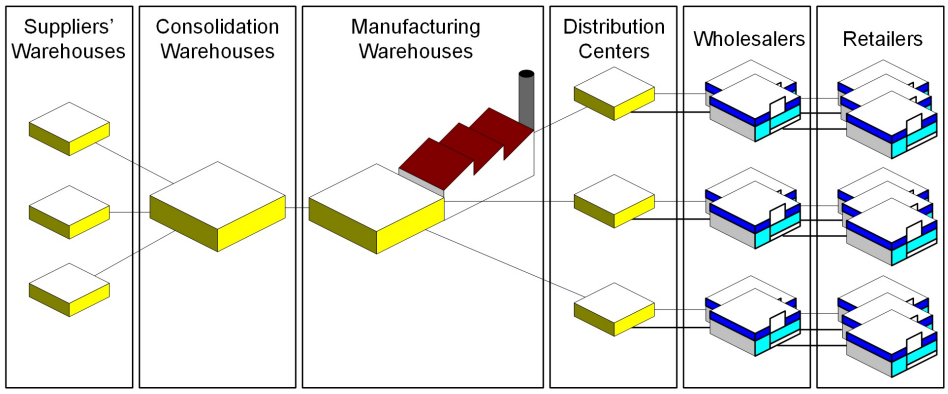
Echelons

How can these inventory locations be optimized to minimize total inventory and maximize customer service? Treating each stage of inventory handling as an echelon is a good way to start understanding how to manage inventory locations. According to the *APICS Dictionary,* 16th edition, an **echelon** is

> a level of supply chain nodes. For example, a supply chain with two independent factory warehouses and nine wholesale warehouses delivering product to 350 retail stores is a supply chain with three echelons between the factory and the end customer. One echelon consists of the two independent factory warehouses, one echelon consists of the nine wholesale warehouses, and one echelon consists of the 350 retail stores. Each echelon adds operating expense, holds inventory, adds to the cycle time, and expects to make a profit.

Exhibit 2-61 illustrates the possible locations of inventory by these supply chain nodes.

Exhibit 2-61: Locations of Inventory by Echelon



Echelons can be helpful in planning the locations of inventory because organizations can decide how many to have. Some organizations will not have as many as others, since each adds to material, labor, overhead, and inventory costs. Consolidation warehouses could be omitted entirely. A direct-to-customer business model would not contain any wholesalers or retailers. The same could be true for any other echelon.

The organization performs strategic network design to determine the optimum number of echelons, followed by analysis of the number and geographic location of specific sites. Usually this analysis makes use of network modeling, operations research, and decision support systems to calculate the lowest total cost of

ownership of all storage locations, handling costs, and transportation costs for a selected level of customer service.

Each echelon can provide particular benefits, such as the following:

- Suppliers' warehouses provide a buffer against manufacturing orders.
- Consolidation warehouses lower transportation costs by grouping shipments from multiple sources into fewer shipments to a manufacturer/assembler.
- Manufacturing warehouses provide a buffer for manufacturing processes as raw materials and WIP and for later echelons as finished goods. That is, the buffer provides decoupling between these supply chain nodes.
- Distribution centers provide a buffer for later echelons. When they serve as break-bulk warehouses, they lower transportation costs by receiving large shipments (economy of scale) while shipping out individual orders. They can also serve as consolidation warehouses by grouping shipments from multiple vendors into fewer shipments to a wholesaler or retailer.
- Wholesalers may provide buffering, consolidation, or break-bulk services.
- Retailers provide immediate access to inventory.

Consolidation and break-bulking not only reduce transportation costs but can reduce inventory, especially slow-moving inventory, since it can be shipped in smaller quantities when consolidated with other inventory.

In addition to buffering, consolidation, and break-bulking, storage locations can provide three other benefits:

- Sorting (cross-docking, assembly, and mixing)
- Seasonal storage (produce inventory year-round; sell in one season)
- Reverse logistics (sites for returns, remanufacturing, repair, remarketing, and disposal or recycling)

(Note that consolidation, break-bulking, cross-docking, and other similar functions are discussed elsewhere.)

Echelons can also be used to aggregate inventory for centralized inventory planning purposes—if inventory planning decisions can be made for the entire supply chain and decision makers have access to visibility of inventory information at each location. Hybrid systems may also be able to use this policy up to the point where centralized planning ends.

Echelon inventory policy considers inventory at a particular point to include all inventory at that echelon and at all later points in the supply chain, including all transit inventory after the given point. The benefit of thinking in this way is that the demand from all lower points can be aggregated for more accurate calculation of order quantities and order levels (discussed in the next topic). At each lower echelon, this process can be repeated and will be more and more detailed.

Levels of inventory

In addition to determining the number and location of warehouses, supply chain managers in manufacturing enterprises must oversee the stocking of warehouses with an optimal level of inventory. And they must establish transportation links that ensure timely arrival at and departure from warehouses.

In the ideal network, raw materials, components, and other 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 supply chain.

One reason this ideal state is difficult, or impossible, to achieve is the fluctuation in demand 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 supply chain is generally necessary. The supply chain manager's challenge in the area of inventory level planning, therefore, involves gauging future demand as accurately as possible and keeping inventory as low as possible without disruptions in delivery to customers.

Inventory level planning requires demand management and forecasting, warehouse management systems, and transportation management systems. These subjects were discussed earlier in these materials. The next topic addresses item inventory management (how much to have, when and how much to reorder, and safety stock and safety lead times). Prior to getting to this level of detail, organizations need to perform aggregate inventory management through setting high-level management policies such as safety stock levels and cycle stock levels (normal operating amounts) of raw materials, work-in-process, and finished goods inventory and by classifying inventory.

Calculation of optimum levels of different types of inventories is beyond the scope of this text.

Topic 2: Inventory Control

The *APICS Dictionary,* 16th edition, defines **inventory control** as “the activities and techniques of maintaining the desired levels of items, whether raw materials, work in process, or finished products.” Inventory control determines two things: how much to order and when (how often) to order.

Note that:

- Inventory control models differ for independent versus dependent demand.
- Inventory management aims to reduce obvious and hidden inventory costs (consistent with service levels).

Inventory control aims to determine order amounts and timing with an objective of reducing carrying, ordering, and setup costs—but without sacrificing customer service goals. Remember, an order schedule is necessary for managers all along the supply chain—the retailer and the distributor order more finished goods, the manufacturer orders more components and supplies, the supplier orders its own materials and supplies, and so on.

The following discussion of item-level inventory control for purposes of ordering inventory begins by looking at three important considerations: determining order quantities, ordering systems, and safety stock and safety lead time. The sum of these considerations allows organizations to calculate order size and frequency for inventory replenishment. Then we’ll cover tracking inventory and assessing inventory accuracy.

Determining order quantities

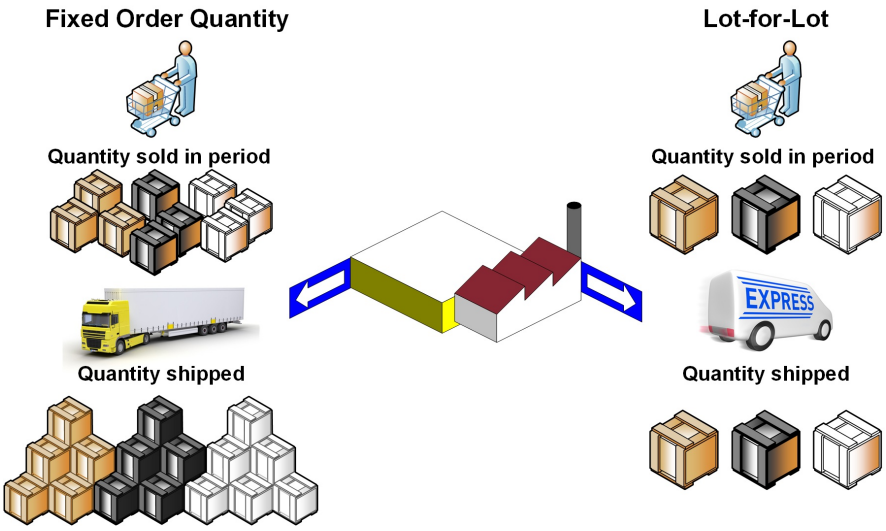
Ordering can be haphazard or disciplined, but it can never be entirely scientific. There are enough unknowns in real life that managers will need to review their ordering model regularly.

What we’re looking for in models is an improvement upon the haphazard ordering method, which goes something like this in a clothing store: “I can’t find any more size 12s back there anywhere; we’d better get purchasing to order some more. How many do you think we’ll need? Should we get some 8s and 10s, too? They’ve been selling pretty well, haven’t they?”

We’ll look first at two models managers can use to determine how much to order and how often, based on demand forecasts: lot-for-lot and fixed order quantity (FOQ). These models are used with independent demand forecasts—that is, they are orders for finished goods ready for sale, not for components. The models were generally designed to be used with decentralized inventory planning, since that was the dominant method in the past, but they can be adapted for use in centralized planning (or another method can be substituted, such as the echelon inventory policies described earlier).

Exhibit 2-62 shows the relationship between these two ordering types.

Exhibit 2-62: Lot-for-Lot versus Fixed Order Quantity (FOQ)



Lot-for-lot

The **lot-for-lot** ordering technique is defined by the *APICS Dictionary,* 16th edition, as

> a lot-sizing technique that generates planned orders in quantities equal to the net requirements in each period.

That is, organizations order no more and no less inventory than is needed. In this ordering system, the quantity ordered will differ in each period depending upon the current requirements.

Common uses for lot-for-lot include Just-in-Time manufacturing environments and ordering A items in the ABC inventory classification system. Lot-for-lot may also occur in some retail environments. For example, at Ace Hardware stores, if a consumer buys an item, the sale automatically triggers an order for one more of the same item to arrive in the next delivery; this is called consumption-driven replacement.

Fixed order quantity

According to the *APICS Dictionary,* 16th edition, **fixed order quantity** is

> a lot-sizing technique in MRP or inventory management that will always cause planned or actual orders to be generated for a predetermined fixed quantity, or multiples thereof, if net requirements for the period exceed the fixed order quantity.

The simplest and cheapest way to introduce discipline into the ordering process is to order the same amount every time. The fixed amount may be determined by the amount in a box or on a pallet or the need to fill shipping containers to achieve full container discounts.

A fixed order quantity can be combined with either a fixed schedule (such as 250 units once a month) or with

a variable schedule determined by inventory levels. (“We’re down to 15 SKUs; get Sam to order 250.”)

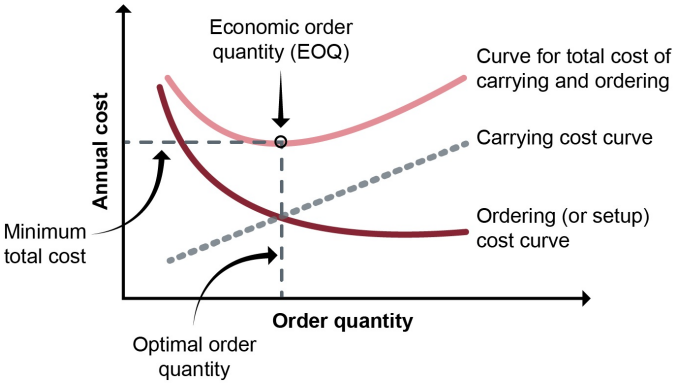
While this method is straightforward, inexpensive, and more disciplined than “We’re out! Get more!” it won’t produce satisfactory results—even if automated—unless customer demand is very stable over the long term. You are not likely to get good results running a volume business in a competitive global marketplace using what amounts to educated guessing.

Economic order quantity (EOQ)

Economic order quantity (EOQ) is a more sophisticated form of FOQ that is widely used. EOQ involves cost calculations—fairly simple arithmetic—to determine the most cost-effective number of items to order when replenishing inventory using a fixed order quantity model. In short, the EOQ is the order size that gives you the lowest total cost for carrying and ordering (or setup) costs. There’s a need to balance those costs, because carrying costs tend to go up with larger order quantities while ordering costs tend to go down, since they respond to economies of scale.

As you can see in Exhibit 2-63, the EOQ is the point on the total cost curve that lies directly above the intersection of the carrying cost and ordering cost curves. These curves are determined mathematically and they always produce the same result, with the minimum total cost lying directly above the intersection of the other two cost curves.

Exhibit 2-63: Determining the Economic Order Quantity



The formula for EOQ is developed by recognizing that the lowest total cost is when the cost of carrying inventory is equal to the cost of ordering inventory:

$$\text{Carrying Costs} = \text{Ordering Costs}$$

$$\frac{Q \times i \times c}{2} = \frac{A \times S}{Q}$$

Solving for Q results:

$$EOQ = \sqrt{\frac{2 \times A \times S}{i \times c}}$$

Where:

Q = Order quantity in units
i = Annual carrying cost rate as percentage
c = Unit cost in dollars
A = Annual usage in units
S = Ordering costs in dollars per order

The first equation above shows the carrying cost formula set as equal to the ordering cost formula, which would be true at the point of intersection in the graph. When the costs are equal, you can solve for Q, which results in the EOQ formula as shown above. You can see two important points about the general quantity-cost relationships from the graph:

- The total costs tend to drop until they reach a minimum, and then they start rising again. So there is an incentive to increase order quantity—but only to a point. And there is a disincentive to order too much, although the more you order, including safety stock, the more assurance you have that you can provide a high level of customer service.
- The minimum total cost occurs where carrying and ordering costs are equal—where the cost lines intersect. After that point of equality, carrying costs tend to rise more rapidly than ordering costs decline. Because of the relationship of the cost curves, you can reduce total costs by reducing ordering costs, which is a goal of lean manufacturing.

Although EOQ is more sophisticated than simpler fixed order models, it is still a fixed order model and so it depends upon the following set of assumptions:

- Demand is constant and known.
- Lead time is constant and known. (The same amount of time always elapses between the time you place the order and the time it arrives.)
- The items ordered arrive all at once, not in stages.
- There are no quantity discounts.
- The variable costs in the calculation model are limited to carrying costs and ordering costs (whereas in reality other variable costs exist).
- There will be no stockouts if you place orders on schedule.

The model's assumptions will no doubt be violated in the real world, but the EOQ model still provides good enough guidance that many companies rely upon it. If, however, these assumptions seem too unrealistic for your particular supply chain, you'll need to add some complexity to the calculation to account for, say, seasonal variations in demand, different lead (and arrival) times for orders from different suppliers, or the availability of significant quantity discounts. The beauty of the EOQ model is that even if there are considerable variations in the cost figures, the economic order quantity tends to vary within a fairly small range.

Ordering systems

Economic order quantity and other methods of determining order quantities do not tell organizations *when* to

place replacement orders for more goods. In addition to picking an order quantity, you have to time your orders. The *APICS Dictionary,* 16th edition, defines **inventory ordering systems** as “inventory models for the replenishment of inventory.” Ordering systems are methods used to answer the question of when orders should be placed.

Ways to determine when to order inventory include the order point, periodic review, min-max, time-phased order point, and demand-driven material requirements planning systems.

Order point system

An order point system determines the inventory level, or point, at which a reorder must be placed. This order point is the point at which we have enough inventory to cover anticipated demand that will be consumed during the replenishment process.

That point is our demand during the lead time plus safety stock:

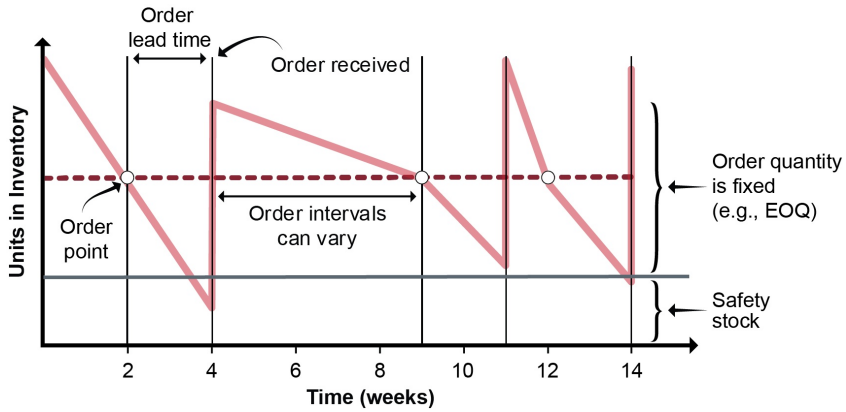
$$\text{Order Point} = \text{Demand During Lead Time} + \text{Safety Stock}$$

For example, if demand during the lead time averages 100 units a week, lead time is two weeks, and safety stock is 50 units, then the order point is when inventory falls to 250 units:

$$\text{Order Point} = (100\ \text{Units per Week} \times 2\ \text{Week}) + 50\ \text{Units} = 250\ \text{Units}$$

The sawtooth diagram in Exhibit 2-64 illustrates the various components of an order point system.

Exhibit 2-64: Inventory Level Fluctuations in an Order Point System



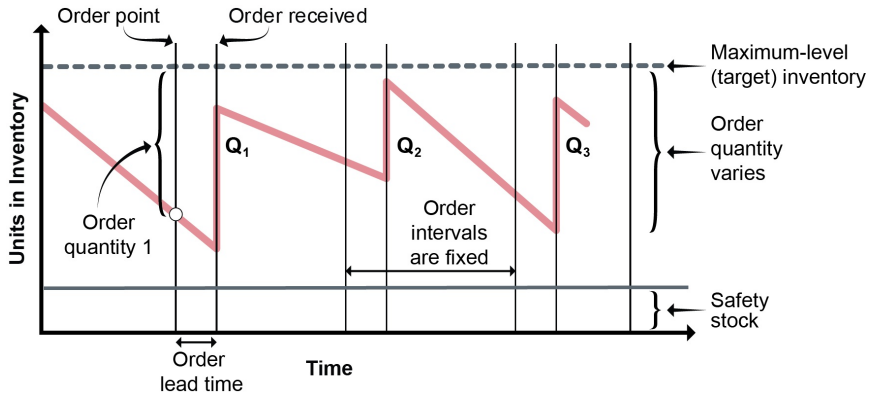
In an order point system, the time between replenishment orders is not fixed but varies based on the actual demand during the reorder cycle. Since the order point is based on the average demand during the lead time, if either the average demand or the lead time changes, the order point should also be changed or the level of safety stock will automatically change. A system based on average demand means that, at maximum demand, stockouts could occur, so some amount of safety stock may be included to reduce the risk of stockouts.

Periodic review system

In a periodic review system, order intervals are fixed, such as each week, month, or quarter, and order quantities (shown as Q1, Q2, and Q3 in Exhibit 2-65) are allowed to vary. The warehouse determines a base stock level, or maximum level of inventory, as shown in the exhibit. The base stock is the inventory target, or "order-up-to" level. This is the level of inventory necessary to maintain effective and continuous operations. The inventory position is reviewed in each period, and the warehouse orders enough to raise the inventory position to the base stock (target) level.

Exhibit 2-65 shows how the sawtooth diagram has fixed-width "teeth" that vary in height according to the amount ordered.

Exhibit 2-65: Inventory Level Fluctuations in a Periodic Review System



The quantity in stock plus the quantity ordered must be enough to prevent stockouts, which means non–safety stock inventory has to last until the next review period plus the lead time required for the next shipment. The quantity ordered is the maximum amount less the quantity of inventory on hand at the order period:

$$\text{Maximum-Level Inventory} = D(T + L) + SS$$

$$\text{Order Quantity} = \text{Maximum-Level Inventory} - \text{Inventory On Hand}$$

Where:

D = Demand per unit of time

T = Time interval between ordering periods

L = Lead time duration

SS = Safety Stock

For example, if average demand is 50 units per week and there are 5 working days, demand per day is 10 units/day. Assume that orders are placed every 10 working days and lead time duration is 3 days. If safety stock should be 4 days' supply, at 10/units per day this would be 40 units. If there are 42 units on hand at the order point, then the maximum-level inventory and order quantity are calculated as follows:

$$\begin{aligned}\text{Maximum-Level Inventory} &= 10\,\text{Units per Day}(10\,\text{Day}+3\,\text{Days}) + 40\,\text{Units}\\ &= 170\,\text{Units}\\ \text{Order Quantity} &= 170\,\text{Units} - 42\,\text{Units} = 128\,\text{Units}\end{aligned}$$

Periodic review systems are useful for supermarkets or retailers with many items to sell because it keeps inventory tracking cost down and helps fill truckload assortments, assuming that the assortments can all be shipped from the same source such as a consolidation warehouse.

Min-max system

With a min-max system, both order timing and order amount are allowed to vary. Orders are submitted after inventory has fallen below the minimum point, but inventory isn't allowed to go over a maximum. If, for example, the minimum is 300 items, the maximum is 1,000 items, and the periodic review reveals that inventory has dropped to 275 items, it would be time to place an order for 725 items. (This assumes that the order would arrive immediately—i.e., no lead time.)

Time-phased order point system

The *APICS Dictionary,* 16th edition, defines a **time-phased order point (TPOP)** system as

> MRP-like time planning logic for independent demand items, where gross requirements come from a forecast, not via explosion. This technique can be used to plan distribution center inventories as well as to plan for service (repair) parts, because MRP logic can readily handle items with dependent demand, independent demand, or a combination of both. Time-phased order point is an approach that uses time periods, thus allowing for lumpy withdrawals instead of average demand. When used in distribution environments, the planned order releases are input to the master schedule dependent demands.

Rather than waiting until inventory drops below the order point, a TPOP system will check whether the item will fall below the order point during the order horizon. When used for a shop floor warehouse, it checks not only available inventory but also planned deliveries during the order horizon and the planned reorder point. If the available inventory plus the planned inventory is below the reorder point, a replenishment order is placed. "Lumpy withdrawals" in the above definition refers to situations such as promotions or export orders that create demand variability that order point systems have trouble adapting to because they are based on average demand.

Time-phased order point systems are useful for parts maintained in low volumes, slow movers, irregular demand items, and large parts that cannot be stored in sufficient quantities. The shop floor warehouse needs visibility to its own inventory levels so it can allocate parts for assembly orders from the warehouse and also backflush these orders against the shop floor warehouse.

Note that when a time-phased order point system is used for independent demand items at distribution centers, it is synonymous with distribution requirements planning.

Demand-driven material requirements planning system

Demand-driven material requirements planning (DDMRP) is a relatively new type of ordering system that can be used for dependent and independent demand items at any point in the supply chain. DDMRP strategically positions inventory to achieve all the benefits of modern supply chain management (reduce inventory, lead times to the customer, and the bullwhip effect and increase customer service and asset usage efficiency) without needing to rely on safety stocks of finished goods or a pure make-to-order environment. Instead,

DDMRP determines how to shrink total lead times by creating buffer inventories of key components that have longer lead times than other components making up a finished good.

DDRMP dynamically determines the best places to position inventory and dynamically adjusts the size of the buffer inventories to minimize total lead time and the total cost of carrying not only finished goods inventory but all component inventories. To do this, it performs daily reviews that account for how long customers will wait for their orders, whether faster lead time would generate new sales, and whether certain inventory positions would leave organizations with more options for dynamic lead time compression. To minimize risk, it also factors in information on the item's supply variability and demand variability and the need to maintain buffer inventories before any bottleneck work centers as per the theory of constraints.

A detailed look at DDMRP methodology can be found in Orlicky's *Materials Requirements Planning,* third edition (2011), and further information can be obtained at www.demanddrivenmrp.com/.

Safety stock and safety lead time

Safety stock, as we've noted in earlier sections, is that little extra inventory each partner along the supply chain keeps as an added measure of security against unpredicted supply and demand fluctuations during lead time. Safety lead time is ordering supplies earlier than needed as a measure of security against unpredicted manufacturing and transportation lead time fluctuations.

Safety stock can also be used to protect against variations in replenishment lead times whenever the annual demand is large enough that the results of using safety stock or safety lead time will have the same effect on inventory levels. For slow-moving items, safety lead times are preferred, because using safety stock will result in a larger overall inventory investment.

Let's take a closer look at these two considerations in inventory control.

Safety stock

The *APICS Dictionary,* 16th edition, defines **safety stock** as follows:

> 1) In general, a quantity of stock planned to be in inventory to protect against fluctuations in demand or supply. 2) In the context of master production scheduling, the additional inventory and capacity planned as protection against forecast errors and short-term changes in the backlog. Overplanning can be used to create safety stock.

Use of safety stock to fill customer orders should be considered normal—to a point. Organizations usually set a target frequency at which safety stock can be accessed, such as once per month. Needing to use safety stock at a given location more or less frequently than this target or never using safety stock at a location would trigger an exception needing review. (Never using safety stock is usually considered a bigger problem than using it more often than planned.)

The amount of necessary safety stock or buffer stock depends upon several variables:

- **Frequency of ordering.** You are most vulnerable to a stockout at the time of replenishment because of the uncertainty of order timing and receipt. If you need to replenish only once a year, you have one point of vulnerability, while replenishing weekly creates 52 potential stockout situations. Therefore,

more frequent ordering typically requires higher levels of safety stock. However, infrequent ordering involves larger orders and average inventory levels, so there is also a cost associated with less frequent ordering.

- **Variability of demand during lead time.** The thought of what opportunities might arise while you're waiting for an order to fill is a reason to keep a little safety stock.
- **Length of lead time.** The longer you have to wait, the more your sales orders or delivery lead times are likely to fluctuate.
- **Accuracy of forecasting.** Higher confidence in the demand forecast reduces the need for safety stock.
- **Organizational, regulatory, or industry requirements.** Some organizations simply have to keep a minimum level of safety stock. For example, medical and pharmaceutical companies often need to keep high levels of some safety stocks to address risk of a pandemic.

There are three basic methods for determining the amount of safety stock to maintain:

- **Fixed amount.** Organizations can use experience or intuition to set safety stock at a location at a fixed level. This method may be acceptable for inventory with stable demand. The level can be periodically reviewed.
- **Coverage.** A coverage method sets safety stock for a given period at the level of inventory requested in the demand plan. If the demand plan forecasts a need for 10 units a day, safety stock for 30 days is 300 units. The advantage of coverage is that the safety stock will adjust itself based on the average (seasonal) demand. For example, ice cream safety stock levels will be higher in the summer.
- **Statistical.** A statistical safety stock calculation involves calculating a normal distribution (bell curve) of the variation in demand with average demand at the center. The standard deviations (sigmas) show analysts how high or low demand can get from the center. To provide protection against peaks in demand, safety stock is set to match the maximum variation in demand at a desired customer service level: it can be based on the most probable scenario or increased for less and less probable scenarios (1 sigma, 2 sigma, etc.).

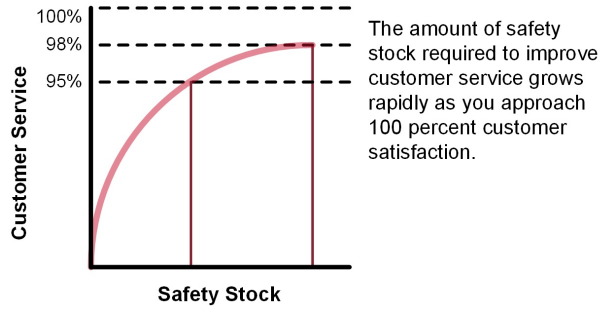
Larger amounts of safety stock can enhance the level of customer service by reducing the stockouts that cause missed or late deliveries. A certain amount of safety stock, therefore, can be considered beneficial to the supply chain. We noted earlier that decoupling is one of the functions of inventory. Holding a supply of products, parts, supplies, or materials gives a supply chain partner at least temporary protection against the effects of a spike in demand on one side or lack of supply on the other.

- If demand shoots up unexpectedly, you have inventory in your warehouse ready to ship to the retailer —or, if you're the retailer, you have those products in the back room or on shelves.
- If supply is suddenly lacking, you have that inventory in the pipeline to keep filling orders until the flow of supply resumes. It's all about being certain you can fill your customers' orders in full and on time with quality goods.

But holding stock costs money, as we have seen, so the prudent manager will look for ways to balance the costs related to holding safety stock on the one hand and expenses related to stockouts on the other—such as rapidly ramping up production, arranging for expensive special deliveries of inventory and customer orders, lost customers, and so forth. Unfortunately, the costs of stockouts are difficult to project accurately, but management should set an acceptable cost level for stockouts as a guide for use in order planning and in selecting methods for dealing with stockouts if and when they occur. The total cost of carrying safety stock plus the cost of stockouts should be tracked and minimized together.

While it may be tempting to shoot for 100 percent order fulfillment, in point of fact it takes a very large increase in safety stock to approach perfection. The graph in Exhibit 2-66 illustrates this point in a general way. It shows that moving from 95 percent order completion to 98 percent requires a very large jump in safety stock, whereas relatively little safety stock was required to achieve 95 percent. (These are typical numbers but they are not the same for all businesses.)

Exhibit 2-66: Safety Stock Increases versus Order Fulfillment



Some companies have found a way to reduce inventory—not just safety stock—almost to zero while actually improving customer service on at least some measures. Dell Computer is a prime example. With their system of taking orders by phone or website, Dell is able to deliver custom computers rapidly. If, like Dell, a business can essentially make or assemble a product to order and deliver it within a reasonable time, it may eliminate its inventory while enhancing its reputation and customer loyalty. (A company may achieve these goals by shifting inventory back up the supply chain to its suppliers, in which case it's possible that nothing has been gained for the supply chain as a whole.)

Safety lead time

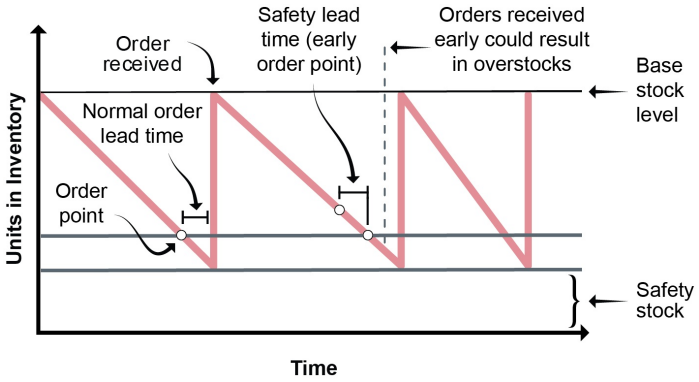
The *APICS Dictionary,* 16th edition, defines **safety lead time** as

> an element of time added to normal lead time to protect against fluctuations in lead time so that an order can be completed before its real need date. When used, the MRP system, in offsetting for lead time, will plan both order release and order completion for earlier dates than it would otherwise.

When order lead times vary significantly or are lengthy, it increases the chances that a stockout could occur while waiting for an order to arrive. Some organizations solve these risks by placing orders early (or late if

orders consistently arrive too early). The safety lead time is the amount of time the order is placed ahead of the normal order point. Exhibit 2-67 shows how safety lead time could be used in an order point system.

Exhibit 2-67: Use of Safety Lead Time in an Order Point System



In order point systems that can vary the timing of orders, the amount of safety lead time used can be very difficult to determine, for example, when studying ordering patterns of retailers. However, reducing unnecessary safety lead time can reduce the bullwhip effect.

Safety lead times also require performing the same balancing act between ordering too soon and having overstocks and ordering too late and risking stockouts. For example, materials shipped overseas often have lead times of 60 days or more. Ordering too soon can result in a serious overstock because orders arrive by the container load. However, delays from weather, labor unrest, or other factors could cause a serious stockout (also due to the large order size). In any case, supply chain managers will—and should—continue looking for ways to achieve the perfect balance between minimal inventory and maximum customer service.

Methods of tracking inventory

Tracking is necessary to keep inventory secure and accounted for. **Inventory shrinkage** is “reductions of actual quantities of items in stock, in process or in transit. The loss may be caused by scrap, theft, deterioration, evaporation, and so forth” (*APICS Dictionary,* 16th edition). Inventory tracking can help minimize the losses from pilferage or misplacement because an organized system makes it difficult for items to be misplaced or stolen. A tracking system can also identify damaged or obsolete goods so that inventory can be properly valued. Finally, tracking inventory is necessary for accounting since inventory is an asset that must be recorded accurately. A proper inventory tracking process assists with keeping accurate counts of inventory.

Most organizations track inventory through the use of a warehouse management system while in storage and a transportation management system while in transit. These systems and the related methodologies are described elsewhere.

Any inventory tracking system will have certain steps:

1. **Identify the item.** Items are identified through the stock keeping unit (SKU). The *APICS Dictionary,* 16th edition, defines a **SKU** as follows:

   > 1) An inventory item. For example, a shirt in six colors and five sizes would represent 30 different SKUs. 2) In a distribution system, an item at a particular geographic location. For example, one product stocked at the plant and at six different distribution centers would represent seven SKUs.

   Items are also identified by association with a purchase order, which indicates expected quantity and location.
2. **Verify the quantity.** Inbound and outbound items must be physically counted and verified against the purchase order.
3. **Get an order to make a move, or request a move and get approval.** A transaction record is initiated when either of these occurs.
4. **Execute the inventory movement.** Inventory is moved between locations.
5. **Create a record of the transaction completion.** The transaction record is finalized after material movement, unless done electronically using tools such as radio frequency identification (RFID) that occur simultaneously with the material movement.

Assessing inventory accuracy

The *APICS Dictionary,* 16th edition, defines **physical inventory** as follows:

> (1) The actual inventory itself. (2) The determination of inventory quantity by actual count. Can be taken on a continuous, periodic, or annual basis.

No amount of forecast accuracy, ABC analysis, secure storage, or automated ordering adds up to successful inventory management without an accurate, current count of the physical inventory on hand. If you don't know how much you have, you don't know how much, or when, you should order.

The *APICS Dictionary,* 16th edition, defines **inventory accuracy** as follows:

> When the on-hand quantity is within an allowed tolerance of the recorded balance. This important metric usually is measured as the percent of items with inventory levels that fall within tolerance. Target values usually are 95 percent to 99 percent, depending on the value of the item. For logistical operations (location management) purposes, it is sometimes measured as the number of storage locations with errors divided by the total number of storage locations.

If inventory is inaccurate, it requires an inventory adjustment. The *Dictionary* defines **inventory adjustment** as

> a change made to an inventory record to correct the balance, to bring it in line with actual physical inventory balances. The adjustment either increases or decreases the item record on-hand balance.

There are two general approaches to keeping accurate inventory records, the results of which are used to make inventory adjustments when errors are found: periodic counts of all items and continuous cycle counts of specific items. Cycle counting is the state of the art, but periodic counting still has its place.

- **Periodic counting.** Periodic counting is the familiar and time-honored way of taking inventory: Shut down the facility once a year and send a large group of employees or temps into the area to count every last item and calculate the dollar value of the items on the shelves. It's disruptive, it's expensive, and it's prone to inaccuracy because of the low expertise of the counters. (They may do it only once a year, after all.) However, for facilities that lack the control and advanced technology found in many up-to-date warehouses, periodic counting may be the only way to get the job done. Retailers and small companies lacking proper technology, for example, still rely on periodic counting.

- **Cycle counting.** Cycle counting is defined in the *APICS Dictionary,* 16th edition, as

> an inventory accuracy audit technique where inventory is counted on a cyclic schedule rather than once a year...The key purpose of cycle counting is to identify items in error, thus triggering research, identification, and elimination of the cause of the errors.

Cycle counting is a more reliable method to determine the value of the items in storage and to facilitate the cost-effective, timely ordering needed for the most reliable customer service.

Here's how it works:

- Some items are counted every day to verify records and record any inaccuracies.
- All items are counted a set number of times per year. A items are counted most frequently—perhaps once a month, while B and C items are counted less often.

Smart rules are used in deciding when to count. Before a replacement order arrives, existing inventory is low and is easy to count. The same is true when inventory is zero. If the system says it is negative, it must be an error.

This continuous, limited counting doesn't require the facility or retail location to shut down for the count, so there is little or no disruption of ordinary business. Unlike the once-a-year count, cycle counting allows timely detection and correction of problems. It is much easier to find inventory error root causes when issues are found in real time. Attempting to problem-solve for transaction errors that occurred months ago is much more difficult. Cycle counting also eliminates the need for annual inventory adjustments.

Exhibit 2-68 provides an example of cycle counting.

Exhibit 2-68: Cycle Counting Example

King Hospital Supplies has an inventory of some 10,000 items, which it has determined to comprise 1,000 A items, 3,500 B items, and 5,500 C items. Cycle counting policy at King Supplies is to count A items once per month (20 working days), B items once per quarter (60 working days), and C items every six months (120 working days). The counts will be distributed evenly over the days.

Item Class	Quantity	Cycle Counting Policy	Number of Items Counted per Day
A	1,000	Each month (20 days)	1,000/20 = 50/day
B	3,500	Each quarter (60 days)	3,500/60 = 58/day
C	5,500	Semiannually (120 days)	5,500/120 = 46/day
			154/day

Though it seems low-tech and old-fashioned, the design and control of the stockroom is the beginning of

accurate record keeping. Here are a few points to consider about keeping a secure storage space that makes tracking and counting inventory easier:

- **Keep it secure.** Employee thefts of small amounts can deplete your inventory before you notice, and, of course, large-scale vandalism or theft can wipe it out overnight. Limit access to the stockroom and keep it under observation. Keep a special high-security area as needed.
- **Keep it neat.** There should be a place for everything, and everything should always be in its place. In a busy retail stockroom, this can be a major challenge, but counting is much easier if areas are consistently used for the same type of items. Random systems can be secure if the record locators are kept accurate.
- **Make labels easily visible and put them on everything.** Labels can be designed for both fast visual identification and for automatic identification, such as using bar codes or RFID.
- **Use bins and space arrangements that make counting easy.** If storage bins and containers are limited to a certain number of items, you can estimate at a glance and count by groups instead of individual items.
- **Treat A, B, and C items appropriately depending on their classification.** A items require tighter control on security and reordering. You don't want to lose them, and you don't want to run out of them.
- **Make technology your friend.** Counting is something machines do better than people. With bar codes/RFID, readers, and instantaneous electronic transmission, you can keep a running tally of what goes into a facility, what goes out, what remains, how much should be on hand, and when you need to submit an order.

Chapter 9: Supply Management

This chapter is designed to

- Define the total cost of ownership
- Indicate how the total cost of ownership can be used to justify investments in the supply chain
- Describe the reasons behind decisions to contract out portions of supply (e.g., outsource and/or offshore)
- Define a make-versus-buy analysis
- Describe the uses and factors involved in a make-versus-buy analysis
- Identify the range of buyer-supplier relationships
- Discuss how each type of buyer-supplier relationship has its uses in a supply chain
- Describe how supply analyses can help in determining, validating, and winning approval for the supply plan.

Organizations settle on one or more supply plan strategies after considering the many factors discussed throughout this and the prior module.

Starting with a goal of aligning the supply plan to the business strategy, supply chain managers determine the total cost of ownership (TCO) of the supply network. Supply plans may lead to contracting out activities (e.g., outsourcing, offshoring). Part of this decision is determining whether to make or buy the necessary capabilities, components, or products. Another aspect is to decide upon the appropriate type of relationship to have with each supplier. The results of these and other strategic supply choices are summarized in the supply plan.

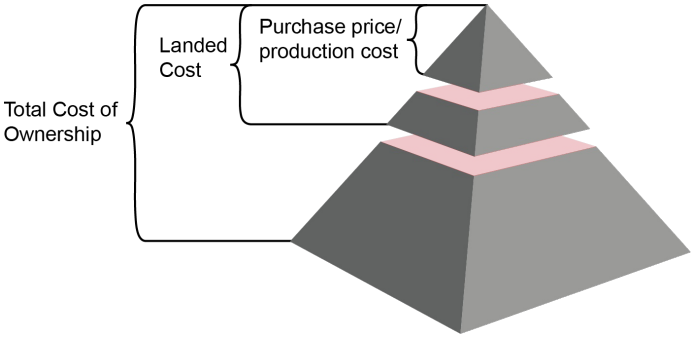
Topic 1: Total Cost of Ownership (TCO)

According to the *APICS Dictionary,* 16th edition, the **total cost of ownership (TCO)** is defined as follows:

> In supply chain management, the total cost of ownership of the supply delivery system is the sum of all the costs associated with every activity of the supply stream. The main insight that TCO offers to the supply chain manager is the understanding that the acquisition cost is often a very small portion of the total cost of ownership.

Two other inventory-related cost category terms are purchase price/production cost and landed cost. Exhibit 2-69 shows how these terms relate to one another.

Exhibit 2-69: Relationship between Cost Terminology



The purchase price or acquisition cost is the price per unit of materials acquired from suppliers. Production cost is the cost per unit of direct materials, direct labor, and factory overhead (cost of goods sold) that is applied to products produced by the organization. According to the *APICS Dictionary,* 16th edition, **landed cost** "includes the product cost plus the costs of logistics, such as warehousing, transportation, and handling fees."

The total cost of ownership includes all of the above costs, plus it considers all other lifetime ownership costs such as durability, ongoing maintenance costs, and responsible disposal.

Use of TCO

The intent of TCO is to get decision makers in the supply chain to see supply chain activities as an investment in capabilities rather than just an expense to be minimized. TCO is primarily a strategic rather than tactical measurement tool, meaning that it is used to select between supply chain strategy options. It is discussed in this section because, once a strategy has been selected, TCO can be used for performance measurement to assess how well the strategy is contributing to organizational strategy and as a high-level control over the end-to-end supply chain process. Note that TCO may change over time and should be periodically reassessed. For example, labor costs in developing countries may increase over time relative to other countries and the lowest cost solution may change accordingly.

TCO compares the differences between incremental (or marginal) costs of alternative supply chain solutions. An incremental cost is the cost associated with producing one additional unit of a product or service. Some costs remain relatively stable until they go above or below a certain level of capacity, at which point they step up or down in incremental cost. Measuring incremental costs considers the effects of system constraints on proposed solutions.

Determining what costs to include in the analysis

A supply chain is a complex system with multiple costs. Effective analysis requires selecting only those costs that help differentiate between alternative strategies. Costs that are the same for each option can be omitted from consideration. Being consistent in the choice of costs to include allows comparison of multiperiod measurements or competing alternatives.

TCO considers both tangible and intangible costs. Tangible costs can be given a value using objective measures such as market value; intangible costs are difficult to measure in financial terms yet may have a real impact, especially in the long term. Examples of intangible costs include customer satisfaction, employee morale, quality, risks (e.g., outsourcing partner failure to meet obligations), or loss of intellectual capital. Such costs may be estimated and included in TCO, but the estimates should be conservative or based on a formula so they are less likely to be rejected by decision makers.

Dividing costs into landed costs, process change costs, and ongoing costs can help determine what costs to include in an analysis and what costs to omit because they are not relevant or would only complicate the analysis.

Landed costs

Landed costs are often the most important costs considered for a TCO study of the supply chain. Some important landed costs that frequently differ between alternatives are

- Purchase price/production cost
- Transportation cost (at each stage), including special packaging costs
- Customs and related costs (tariffs, duties, taxes, fees for various intermediary services)
- Inventory costs (carrying, ordering, and backorder costs)
- Outsourcing cost
- Monitoring and control costs, which are generally higher when outsourcing is used (e.g., sending employees abroad to manage the relationships).

Some landed costs may or may not differ between the alternatives or may be omitted from consideration to simplify analysis. Such costs could include

- Financing and opportunity costs
- Sales and marketing
- Administrative (executive, clerical, including billing/payment, and information system)
- Reverse supply chain (returns)
- Insurance and risk management
- Taxes and foreign exchange (relevant for global sourcing decisions).

Process change costs

Process change costs include the costs of evaluating choices and implementing the changes to the supply chain. These costs are sometimes called pre-transaction costs because they are administrative costs often incurred before landed (transaction) costs are incurred. Such costs may include

- Requirements identification and research
- Product development
- Contract sourcing (search, selection, qualification, and legal review)
- Process change and training of supplier and organization in each other's operations
- Plant openings/closings, hiring/layoffs
- Supplier education and integration (including software systems integration).

Ongoing costs

Ongoing costs (or post-transaction costs) are the costs of ownership that occur throughout the life of the

product or equipment. A durable product will have lower ongoing costs than one that costs less but has lower quality. Examples include

- Life cycle costs (quality, durability, and maintainability versus price)
- Maintenance, repair, and operations and other ongoing service and repair part costs
- Costs of quality (line fallout, defects, in-house or field repairs, rework, returns, warranties)
- Sustainability costs (recycling, recovery of materials, etc.)
- Reputation costs (customer loyalty versus lost customers).

Net costs

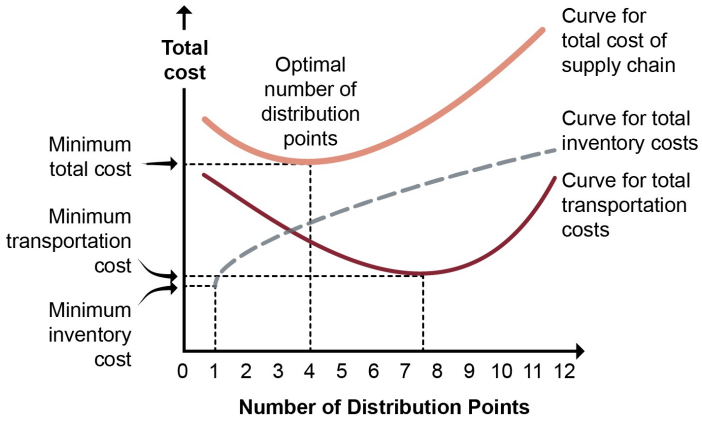
TCO measures the net effect of all cost increases and cost reductions.

Research by Kalakota and Robinson on TCO related to offshore outsourcing reported a reduction in total labor costs of 70 percent, an increase in total transportation costs of 20 percent, and an increase in the organization's monitoring and control costs of 20 percent, for a net reduction in costs of 30 percent. TCO analysis can thus sometimes help make the case for closer sourcing.

Research by Lewis, Culliton, and Steele compared two alternatives for sending electronic parts directly to customers. The first option was to centralize inventory in a single warehouse and make all shipments using rapid air transport services. The second option was to have regional warehouses combined with cheaper transportation options. The first option was found to have the lowest total cost because the higher cost of transportation was offset by the lower total costs for inventory and warehousing. Part of the reason for this is that electrical parts are small and inexpensive to ship via air. Other items and supply chains will have different relative costs.

Exhibit 2-70 shows how a TCO economic tradeoff study can show that the lowest total cost for a supply chain is often at a different point than the lowest total cost for any given system component. The exhibit compares the number of distribution points to total costs. Note that a single distribution point would produce the lowest inventory cost, while seven or eight distribution points would minimize total transportation cost. Four distribution points result in the lowest TCO. Note also that this is just the TCO for distribution. A separate analysis would be needed for supply-side and manufacturing costs.

Exhibit 2-70: Determining the Economic Tradeoffs in Total Cost of Ownership for Distribution



TCO challenges

A key observation to make from Exhibit 2-70 is that total cost analyses grow more and more complex as more costs are considered. The above analysis takes no consideration of transportation lot sizes, the global distances involved, or the amount of safety stock to maintain in the system, to name only a few factors in the total cost of a supply network. Therefore, TCO analysis may require sophisticated analytical tools such as a network model for scenario or simulation use or a decision support system. Either tool can optimize multiple factors such as actual locations of facilities and actual transportation options to generate a globally optimized supply plan.

TCO can be difficult to implement at an organization, much less across a supply chain. Organizations have long-standing department-specific cost reduction policies, management incentives, and accounting practices in place that may penalize individuals for failing to minimize costs in their departments. A TCO strategy therefore requires extensive process changes starting at the executive level, realignment of management incentives toward total cost, and a method of measuring and rewarding success based on achieving least total cost. These change issues are magnified in an extended supply chain.

One way TCO integration can be accomplished is if TCO is incorporated into control and continuous improvement tools such as a scorecard or dashboard. These tools can also ensure that customer service or other objectives are given weight in the analysis. When properly implemented, TCO can help organizations and supply chain partners make and justify wise, cost-effective choices for the long term.

TCO is often involved in decisions regarding contracting.

Topic 2: Make-Versus-Buy Analysis

The *APICS Dictionary,* 16th edition, defines **make-or-buy cost analysis** as follows:

> A comparison of all of the costs associated with making an item versus the cost of buying the item.

An associated definition from the *Dictionary* is for **make-or-buy decision:**

> The act of deciding whether to produce an item internally or buy it from an outside supplier. Factors to consider in the decision include costs, capacity availability, proprietary and/or specialized knowledge, quality considerations, skill requirements, volume, and timing.

Some organizations distinguish between make-versus-buy and outsourcing decisions to show that the process has evolved to become more strategic. This text treats the make-versus-buy analysis as a strategic decision that includes the contracting out of any activity, including products, subassemblies, business processes, or services. Make-versus-buy is strategic because global sourcing of processes or products is a complex and challenging decision that impacts organizational profit and reputation, but it is also tactical because individual decisions can be made on an ongoing basis to address current prices, current capacity, and so on. Therefore, make-versus-buy also has relevance when procuring and delivering goods and services.

Before we take a closer look at contracting, let's consider how to choose activities to be contracted out.

Choosing activities to contract out

Before selecting a partner to provide materials or services, a supply chain company needs to ask and answer a set of questions about the possible consequences of giving the activity in question to another company, including

- Is the activity a core competency?
- What are the consequences of losing related skills or knowledge?
- What is the landed cost (or total cost of ownership)?

Is the activity a core competency?

There is seldom a good reason for outsourcing a core competency. There are very good reasons to contract out tasks an enterprise does only adequately or poorly. A logistics specialist can make its clients look very good by providing customers with same-day or next-day service (plus other options). But if an enterprise has its own fleet and is known around the region for the color of the trucks, the skill of the drivers, and flawless delivery, it should carefully consider the effect on its image before letting a third-party provider take over its delivery functions—even if logistics isn't a core activity.

When considering contracting out components of a product or service, the core competency question revolves around whether the component is integral to the device or if it is modular. An integral component is typically unique to a product, and if it fails the whole product fails. A modular component is interchangeable with other variants on the market, such as a computer component. Integral components are much more risky to outsource.

A detailed process for considering core competencies in the make-or-buy decision is described in *Customer-Centered Supply Chain Management* (Kuglin, 1998). As an example, assume that an enterprise is considering contracting with a supply chain partner, yet to be identified, to provide its customers with overnight order-to-delivery service. Kuglin's process might be adapted as follows.

- **Step 1: Determine whether the enterprise already has overnight order-to-delivery as a core competency.** In making this determination, the enterprise consults both internal and external experts among its clients and providers. If there is a difference of opinion, the enterprise does further research to decide which opinion is correct. It is possible that the enterprise believes overnight delivery is a core competency while clients say otherwise. It is also possible that clients believe the enterprise has overnight delivery as a core competency but the enterprise itself is not fully aware that it has that capability.

  (Kuglin uses the process as part of a complete transformation to a customer-centered supply chain leader. In that effort, the enterprise develops a complete list of all core and non-core competencies as part of a decision of what activities to contract out and which to keep or develop as core competencies.)

- **Step 2: Determine whether there is a need in the marketplace for overnight order-to-delivery service.** While interviewing customers and suppliers about the core competency of the enterprise, the interviewers also question respondents about the need for the capability in the marketplace.

- **Step 3: Determine the relationship between the enterprise's capability to deliver the service and the need for the service in the marketplace.** The preceding steps can produce several outcomes:
  - The marketplace needs overnight delivery and the enterprise already can meet that need as a core competency. In this case, the enterprise might choose to market its capability to raise awareness in the marketplace. (It will "make" rather than "buy" overnight delivery.)
  - The marketplace does not need overnight delivery, in which case the enterprise may not need to maintain, develop, or buy that capability.
  - The marketplace needs overnight delivery, but the enterprise is not able to provide it as a core competency. This situation triggers the final step, which is the make-or-buy decision either to develop the capability or to find a supply chain partner who can do so as a core competency.

- **Step 4: If a need for overnight order-to-delivery service exists in the marketplace and that capability is not a core competency of the enterprise, determine whether to develop the capability as a core competency or to contract with a supply chain partner.**
  - *Develop the core competency to perform the activity.* The company may decide to develop a core competency in providing overnight order-to-delivery service. This may be advisable if doing so is consistent with the company's mission and vision—and if it has the resources to develop that core competency within a time frame acceptable to the market.
  - *Contract out the activity.* Having decided to outsource overnight order-to-delivery service, the enterprise makes a short list of available third-party logistics providers and selects one to develop into a supply chain partner. The selection process may be accomplished by soliciting proposals; Kuglin suggests, instead, developing a business problem and asking potential providers to work with the enterprise to find a solution. This method tests the unique abilities of each company.

What are the consequences of lost skills or knowledge?

When an enterprise contracts out functions to another company, domestic or foreign, it may be divesting itself of valuable expertise. When all the components of a complex electronic system are made offshore, for example, the enterprise no longer maintains the knowledge of those systems in-house. The skill, knowledge, and perhaps the creativity of its former workers in that area are gone and cannot be easily recovered. The costs of those losses may be difficult to measure and balance against the gains, but they are real.

Thus, in some cases, an activity may be only partially outsourced. For example, Toyota

- Allows the electronic systems in its vehicles to be both designed and produced by external suppliers
- Retains the design portion of its vehicle transmissions but outsources much of transmission production
- Both designs and manufactures all of its engines because this is a core competency.

What is the landed cost (or total cost of ownership)?

Once an enterprise has decided to contract out a particular component or service, attention turns to comparisons of quality, cost, and availability. The traditional cost measurement in this case is landed cost. If the goods from domestic and foreign sources are of equal quality and cost becomes the main consideration, landed cost provides a basis for a meaningful comparison. In other cases, such as when quality differences require broader analysis, total cost of ownership may be used to compare costs in a make-or-buy decision.

Components or services delivered by a foreign supplier are often priced far lower than if they were produced domestically. Even assuming that the components or services are of the same quality, however, there are other considerations. Will foreign suppliers be able to provide the components in sufficient quantities to meet production needs? Are there infrastructure constraints that may stall shipments unexpectedly? Will labor, economic, or political problems suddenly cut off supplies? Will shipments be secure against pilferage, damage in transit or handling, tampering, and terrorism? Finally, what other costs are incurred by bringing the components to the manufacturing site from a foreign rather than domestic producer?

Contracting

Contracting out activities to third parties can take many forms, including outsourcing and offshoring or the use of service providers such as third- and fourth-party logistics providers. Outsourcing is a popular term, but it isn't always the correct one. For example, if the organization never did an activity in the first place and then finds a third party to provide that capability, it isn't really outsourcing it but contracting for those services. However, "outsourcing" is commonly used interchangeably with "contracting out," so this topic treats it as a synonym.

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

> the process of having suppliers provide goods and services that were previously provided internally. Outsourcing involves substitution—the replacement of internal capacity and production by that of the supplier.

Outsourcing can be contrasted with **insourcing,** which the *Dictionary* defines as "using the firm's internal resources to provide goods and services." A synonym for outsourcing is **subcontracting,** which involves "sending production work outside to another manufacturer."

Trends in contracting

Anything that can be digitized can be contracted out globally. As a consequence, many corporations have sought out the cheapest labor sources in a wide variety of occupations. This outsourcing takes place in many directions—not only from “developed countries” to “emerging economies.” Developed countries now outsource to one another. Japanese car companies once made inroads into U.S. and European markets with low-priced automobiles. When the competition responded and transportation costs increased, the Japanese car companies began moving production closer to customers in countries such as the U.S. and Canada. Similarly, American car companies are now successfully manufacturing American cars in China for sale to Chinese consumers.

Examples of supply chain contracting

Many of the Fortune 1000 companies contract out multiple business processes, from payroll to manufacturing. The following are some outsourcing examples related to supply chain management.

- **Supplier relationship management (SRM).** SRM organizations with experience in a particular region could assume responsibility for transactional purchasing or supplier sourcing, contract negotiation, two-way communications of expectations, and compliance management. Outsourced SRM can also provide strategic support for alliances such as spend analysis or facilitating design collaboration.
- **Manufacturing.** Manufacturing can be contracted out to organizations that have advantages in labor costs, are located closer to raw materials, or have special expertise in producing products or subassemblies efficiently at expected quality levels.
- **Logistics and logistics management.** Third- and fourth-party logistics providers are ways of contracting out logistics operations or its management.
- **Customer relationship management (CRM).** CRM suppliers may provide call centers or advanced telephony services (like universal queue or voice recognition), database collection and management, and online service agents. The best CRM suppliers train their service representatives in their clients’ products and processes to make performance seamless.
- **Information systems.** Offshore development of custom technology applications can reduce labor costs significantly. Software as a service (SaaS) can be seen as a way to limit investment in software, hardware, and support staff for systems that otherwise become obsolete quickly.

Benefits of contracting

Potential benefits of contracting out activities include the following:

- **Economies of scale.** A third-party provider with core competency in the activity may be able to increase the number of orders efficiently processed from customers, thus expanding market share.
- **Risk reduction.** Contracting transfers risks, such as demand uncertainty, to the third-party provider. The provider may be better equipped to manage demand uncertainty by spreading forecasts over a larger number of customers. (It may handle many more orders than those brought in by any one of its clients, which reduces risks through risk pooling.) The outsourcing provider may also be able to react more rapidly to changes in customer demand.

- **Increased capital available for investment.** Since some of the capital required to engage in the outsourced activity is supplied by the third-party provider, the enterprise has more capital available for research, payment of dividends, debt reduction, etc.
- **Clearer focus.** An enterprise contracts out an activity only if it is not a core competency (in most cases). It does so to increase its ability to focus on its core activities.
- **Access to new technologies.** The third-party provider, because it focuses on the outsourced activity as a core competency, is more likely to have the latest and most effective resources for carrying out that activity. Indeed, if it is to maintain its market share, it must keep up with advances in strategy and technology.
- **Faster development cycle times.** The third-party supplier's technical expertise may enable the enterprise to accelerate development time for new products or services.

Complexities of contracting

Contracting reduces some complexities, since the organization will no longer need to perform or directly administer certain tasks. At the same time, it increases the complexity of other forms of business administration, especially for monitoring and controlling and risk management. Risks include poor quality, intellectual property theft, supplier corruption/fraud, or failure to maintain organizational policy such as for worker protection or environmental sustainability. These all relate to a higher risk of reputation damage, so organizations need well-developed contract clauses, legal review, and audit functions to verify compliance. These subjects are all addressed in more detail elsewhere.

Offshoring

Outsourcing partners may be located near at hand or offshore. **Offshoring** is defined as "outsourcing a business function to another company in a different country than the original company's country" (*APICS Dictionary,* 16th edition). An organization could also offshore without outsourcing by opening a branch in a different country and hiring employees there to staff a business function. Thus, offshoring usually implies locating a business unit or facility in a different country, which could be directly owned or owned by a supply chain partner. Note that in many smaller countries that have numerous neighbors, offshoring could still involve relatively short distances.

Reasons for offshoring

When considering offshoring, the first consideration should be organizational needs, not a search for "today's global sourcing hot spots." Only when an organization has thoroughly assessed its needs for offshoring is there a sound basis for evaluating and selecting specific countries and suppliers. An organization is then ready to consider how potential global suppliers can support the organizational value proposition.

Although cost cutting may be the primary driver for offshoring, it should not be the sole criterion. Another reason for global sourcing is market growth. Sourcing from a particular country may open up new market possibilities. Sourcing relationships allow an organization to learn about conducting business in a potential market. Offshoring may also provide additional sourcing options. Sourcing or procuring products or services from more than one country develops alternate sources and can provide backup for emergencies or other supply chain disruptions.

Offshoring complexity

Offshoring increases the complexity of assessing potential suppliers. Once a supplier is selected, offshoring increases the complexity of developing suppliers to continually improve products and processes. Dealing with foreign-based organizations requires understanding and overcoming complexities such as language differences, culture differences, country-specific processes, and legal, tax, and regulatory differences.

Many suppliers located in countries with lower labor costs also have less-mature organizational levels, less emphasis on total quality initiatives, or less-developed information visibility and technology. Investing in improving these factors adds to the total cost of ownership and may not provide a payback if the relationship must be terminated prematurely.

In addition, some countries with lower labor costs have onerous government regulations and bureaucracy that slow cycle times or permitting unless local expertise in navigating these impediments is obtained. Even with local expertise, organizations could be prohibited by their home country from engaging in certain locally expected activities (e.g., bribery).

Risk management in offshoring

Although many benefits may be achieved by offshoring, organizations must be careful about the risks they assume. Risks include failure to perform or deliver on time, failure of technology systems or electrical grids for unacceptable periods, or theft of intellectual property. Organizations need to exercise great caution in whom they work with and how much to trust these organizations.

One method of mitigating risks when embarking on offshoring is to build sufficient inventory prior to a move to prevent supply interruptions. For example, in the medical device industry, when a product line is offshored, it is not unusual for the organization to build one year of stock to mitigate the risks in the offshore transfer of the production line as well as regulatory risks. However, this is not an option if inventory faces fast obsolescence/perishability. Note also that there is a cost associated with such a build-up and this cost would need to be factored into the original analysis.

Another issue is how the organization will enforce compliance with its business goals and values. For example, many countries have relatively few government regulations related to environmental protection or sustainability. While avoiding onerous regulations could be among the reasons to choose an offshore site, global organizations risk damage to their reputations if problems occur. Take, for example, the lead found in many children's toys and the contaminated foods that have harmed some organizations' reputations and bottom line. Compliance and control costs can increase significantly when using outsourcing or offshoring.

The key point related to risk in any outsourcing arrangement is that the organization remains the responsible party in the eyes of the customer, so it must seek ways to manage its exposure—perhaps through pilot programs, close monitoring for compliance, maintaining backup suppliers, or redundant capacity.

Making the decision

Organizations justify their make-or-buy decision by comparing the advantages to the risks and costs of each alternative. As was implied in the previous discussion of Kuglin's step-by-step process, a primary aspect of this decision is whether an outsourcing partner can provide the organization with new capabilities because

they have complementary core competencies. The organization weighs these potential advantages against the drawbacks of contracting such as potential loss of skills and knowledge and higher-than-expected landed costs. Sometimes the result is that the organization settles on a hybrid approach, retaining some processes and outsourcing others. This possibility is discussed next in relation to manufacturing and assembly processes.

Comparing manufacturing and/or assembly sites

Sometimes organizations contract out manufacturing but continue to perform assembly of the final components, while other organizations choose to outsource both of these activities. Determining the relative costs of manufacturing and/or assembly in different markets is as complex as comparing landed costs for goods.

Exhibit 2-71 summarizes some of the advantages and risks of product manufacturing and/or assembly in another country.

Exhibit 2-71: Advantages and Risks of Overseas Manufacturing and/or Assembly

Advantages	Risks
• Low labor rates (depending on country) • Lower material costs • Lower benefits costs in countries with national health care • Favorable duty rates (especially if materials are domestic) • Lower taxes • Smaller capital investment (if assets are transferred to foreign country)	• Possible costs and disruptions caused by time zone differences (as much as 15 hours between United States and Asia) • Higher transport costs and longer lead times • Higher relationship management costs for communications, travel, etc. • Possible political risks in unstable, unfriendly countries • Costs of hedging currency exchange risks • Costs of maintaining environmentally responsible forward and reverse logistics chains • Environmental costs for mitigating air, water, and noise pollution and preventing spread of invasive species • Higher costs of increased safety stock • Costs of holding inventory in warehouses or in the pipeline • Shrinking inventory due to theft, damage, spoilage, etc. • Increased costs of insurance against damage, theft, spoilage

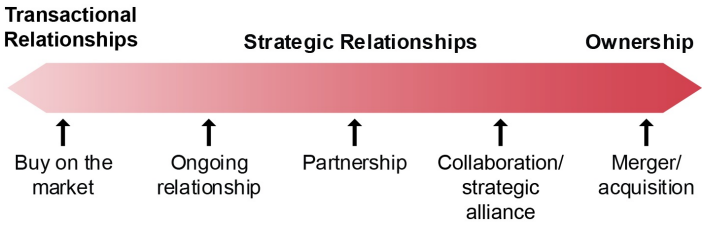
Source: APICS, Advanced Supply Chain Management

So before you expand your network to include low-cost sourcing or assembly, be sure to make thorough comparisons based on all the costs involved in all the possible scenarios.

Topic 3: Range of Buyer-Supplier Relationships

Strategic relationships lie in the middle of a spectrum of buyer-supplier relationships. At one end of the spectrum (shown in Exhibit 2-72) is the traditional transactional purchasing relationship, or “buy on the market.” At the other end is the translation of external supplier relationships into purely internal processes via ownership through mergers and/or acquisition—a relationship with others essentially becomes a relationship with oneself. Between those possibilities are strategic supply relationships differentiated primarily by levels of integration of planning, workflow, and sharing of information.

Exhibit 2-72: Spectrum of Possible Business Relationships



Any of these relationships can be global in nature. In developing supply plans, organizations must decide on the optimal type of relationship for each product or component for which a “buy” decision (or “make” in a merger/acquisition) is made.

Relationship types

Exhibit 2-73 compares supplier relationship types according to five variables:

- Proximity (How long is the relationship? How narrowly defined is it?)
- Visibility (How much information sharing is occurring? What type of information is being shared?)
- Suppliers’ interaction with competitors (Do they work with many competitors as their clients or have some level of exclusivity with you?)
- Communication (At how many points do our organizations touch and communicate with each other? How much trust exists?)
- Culture (Is there any attempt to share cultures or influence the other culture?)

Exhibit 2-73: Characteristics of Different Types of Supplier Relationships

	Characteristics				
Relationship	**Proximity**	**Visibility**	**Interaction with Competitors**	**Communication**	**Culture**
Buy on the market	Arm’s length	Technical requirements of purchase	Significant	Computerized interaction	Not an issue
Ongoing relationship	Medium-term contracts	Some sharing of goals and tactics	Some	Through designated contact points	Awareness of culture

				such as account managers	
Partnership	Longer-term contracts	Full sharing of goals, strategies, and tactics	Limited	Increased interaction between related departments; some degree of trust	Awareness and adaptation to each other's cultures
Collaboration/strategic alliance	Long-term relationship	Full sharing of goals, strategies, and tactics and attempt to reflect partners' plans in their own	Limited or none	Extensive communication; high levels of trust; enforced via contracts and licensing	Merging of cultures
Mergers and acquisitions	Ownership	Full sharing of goals, strategies, and tactics as internal, commonly held information	None	Varies	One culture

Buy on the market

In the "buy on the market" approach to purchasing, organizations buy in response to immediate needs, choosing freely from among all the vendors that can meet those needs. There is sharing of technical purchasing requirements (e.g., specifications and proposal components) rather than strategies or plans.

The relationship is transactional and not ongoing. It is also not exclusive. The purchaser may be buying from competing vendors either simultaneously or sequentially. There may some communication of information electronically (e.g., billing, change orders). These are lower-value relationships, with smaller levels of involvement by both parties.

Ongoing relationship

An ongoing arm's-length relationship with traditional suppliers involves repeated transactions, perhaps regulated through medium-term contracts. The supplier may learn enough about the purchasing organization to suggest opportunities. Communication is funneled through an account manager who adjusts to the customer's culture and way of doing business in all interactions. The company may also define a set of criteria to certify some suppliers.

Partnerships

Partnerships use longer-term contracts. A **supplier partnership** is "the establishment of a working relationship with a supplier organization whereby two organizations act as one" (*APICS Dictionary,* 16th edition). The length of the relationship creates opportunities for increased understanding of each other's organizations and increased efficiencies through greater communication and more value-added services. Business with the competition is minimal.

Collaboration/ strategic alliance

According to the *APICS Dictionary,* 16th edition, a **strategic alliance** is

> a relationship formed by two or more organizations that share information (proprietary), participate in joint investments, and develop linked and common processes to increase the performance of both companies. Many organizations form strategic alliances to increase the performance of their common supply chain.

This alliance is a long-term arrangement that sometimes operates under blanket agreements rather than by individual purchase orders. The alliance may use a **blanket purchase order,** defined in the *APICS Dictionary,* 16th edition, as

> a long-term commitment to a supplier for material against which short-term releases will be generated to satisfy requirements; [it] often cover[s] only one item with predetermined delivery dates.

The blanket purchase order replaces shopping for competitive bids. The suppliers are fully aware of the purchaser's goals and strategies and work with the purchaser to develop and implement complementary tactics. Contact points exist throughout the organizations, and information flows in an unrestricted manner between the two business entities. The trust level is high, and there is a greater level of involvement by both parties. Either to enhance the collaboration or because the two organizations share similar values, the culture of the supplier may evolve toward that of the purchaser.

Mergers and acquisitions

In this type of relationship, suppliers are folded into the purchasing entity. Business goals are shared; business areas participate in setting strategy and planning integration of capabilities, processes, and information. Competition has been eliminated. The level of trust, communication, and shared values will vary, depending on the effectiveness of the merger. Some divisions in merged companies retain separate processes and a separate culture that detract from full communication and trust.

Topic 4: Developing Supply Plans

Developing a supply plan is the strategic design of a supply network based on total cost of ownership, make-versus-buy decisions, and desired levels of buyer-supplier relationships. Supply plans set the organization's design for how it will identify and manage suppliers.

Supply plans answer questions such as

- Are we going to have centralized global sourcing, will each location source independently, or will there be a combination of these methods?
- Will we seek local sources over cheapest sources?
- Will we allow sole suppliers? Single-source suppliers?
- What are our contingency plans for any and all supply risks?
- What are the differences in our supply plans for strategic versus nonstrategic material sourcing?

Plan validation and refinement

The results of the prior analyses may need to be validated and refined at a high level to take into account additional considerations such as the following:

- **Corporate strategy alignment.** The supply planning process starts with corporate strategy as an input, so the proposed supply plan should be built from the perspective of meeting corporate goals for customer service, production capacity, and product quality. Any differences must be resolved at this point, either by providing decision makers with several supply plan options if all of these factors cannot be simultaneously met or by making a case to change corporate strategy if analysis shows that the desired service, capacity, and quality is not feasible or profitable.

- **Corporate mission and culture alignment.** Developing supply plans takes the results of the analyses discussed throughout this and the previous module and determines if the results suggested by computer optimization integrate well with the organization's mission and culture. For example, a corporate social responsibility policy regarding supporting local communities may override a global sourcing decision if the cost difference is considered acceptable given the social and reputation benefits received.

- **Risk assessment.** The risks of a supply plan must be spelled out for decision makers at a high level, including an assessment of the likelihood of each identified risk, its impact if it occurs, and possible means and costs involved in mitigating risks. Process change risks should be called out. Contingency plans should be included.

- **Centralized versus autonomous sourcing.** Centralized control over sourcing decisions to generate the systemic savings may need to be balanced against some amount of autonomy for local sourcing. While centralized sourcing provides the benefit of control, autonomous sourcing provides local expertise and the ability to personalize supplier relationships. However, local management can have a local bias. Centralized control for strategic sourcing with some autonomy for nonstrategic sourcing may generate a good balance if the local areas are guided by central policy and controls.

- **Additional optimization.** Given high-level tentative approval of the supply plan, some additional

strategic refinements can be made to increase customer service, capacity, or quality or reduce costs further without significantly changing the plan. For example, when distribution locations have overlapping territories, the supply plan can specify which of these locations will provide the fastest or least costly delivery to a given area, and that distribution point can be designated as the primary distributor.

- **Planning for future growth.** A supply plan is a long-term plan, so it must incorporate the flexibility to grow to meet continuous improvement goals, additional demand, and/or new products and services. A benefit-cost analysis for each alternative supply plan should consider the plan over a base period plus the costs involved in growing these capabilities over an extended forecast horizon.

One way to measure a plan's flexibility is to measure the baseline level of customer service, output capacity, and quality in the optimized supply chain and then calculate the incremental costs of increasing each factor. A mathematical analysis called a sensitivity analysis can help make this determination. For example, if the supply plan is capable of fulfilling 96 percent of customer orders within 72 hours but long-term strategy calls for increasing these amounts to 98 percent of customer orders or filling them within 48 hours, the costs to make these changes can be quantified by their incremental increase.

The results of these tests could result in plan changes or in contingency plans. For example, a supply plan could include two contingency plans for increasing customer service without significantly changing the supply plan strategy:

- Increase customer service by increasing planned safety stock levels. This strategy increases inventory costs but is a flexible solution.
- Increase customer service by adding more warehouses, which has a high fixed cost and reduces system flexibility.

Plan finalization

Plan finalization involves executives (and possibly a broader range of stakeholders) weighing all factors—such as plan flexibility and ability to accommodate growth, the tradeoff between service levels and total system costs, and alignment with corporate mission and culture—and then selecting a final plan from among the competing options. Supply chain managers should develop and present a small number of supply plan options. The plans should be limited to those that can be sufficiently differentiated based on how they set their priorities. The supply chain manager can present the rationale for each option and then make a recommendation. The key is to make the argument in terms that the audience will understand, avoiding excessive details in favor of graphs or other visual tools to make the key points clear.

Once the supply plan is approved by all decision makers, it is just the beginning of plan refinement. One way that supply plans can be refined and implemented is by using supplier relationship management.

Chapter 10: Logistics

This chapter is designed to

- Define logistics and explain its relationship to supply chain strategy
- Identify the functions within logistics
- Explain the objectives of logistics
- Describe the tactics used to create an effective logistics strategy
- Differentiate between 3PLs and 4PLs and describe their appropriate use
- Understand the options available for expediting and why expediting should be avoided in normal operations as much as possible
- Understand the impact of changing delivery patterns.

The supply chain is about "moving"—or "transforming"—raw materials and ideas into products or services and getting them to customers. Logistics, one of the most critical functions in supply chain management, is about moving materials or goods from one place to another. It is, in that sense, a service provider to design, production, and marketing that can bring added value by being quick and effective.

Topic 1: Introduction to Logistics

Defining logistics

The *APICS Dictionary,* 16th edition, defines **logistics** as follows:

> 1) In a supply chain management context, it is the subset of supply chain management that controls the forward and reverse movement, handling, and storage of goods between origin and distribution points.
> 2) In an industrial context, the art and science of obtaining, producing, and distributing material and product in the proper place and in proper quantities.

Note that the SCOR model refers to the "...obtaining, producing, and distributing material..." as sourcing, making, and delivering.

At a basic level, logistics includes the various tasks required to get the right product to the right customers at the right time. More comprehensively, it also means getting the right quantity of product in the right condition to the right place at the right price.

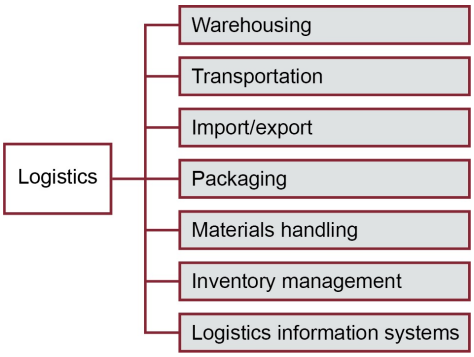
Logistics is part of supply chain management. As Douglas Long writes, "Supply chain management is logistics taken to a higher level of sophistication." Where one ends and the other begins is subject to debate.

In *Supply Chain Logistics Management,* authors Bowersox, Closs, and Cooper include several functions that are treated outside the logistics section of this course, such as forecasting and inventory management. Whether these functions are or are not within the scope of logistics, all agree that inventory and forecasting must be considered when designing and managing an effective, efficient logistics system.

Logistics has a slightly different definition in different regions of the world as well. For example, in Europe, logistics goes from raw materials to the final delivery to the customer, thus including manufacturing, while in the U.S., manufacturing is not usually under the purview of logistics.

Exhibit 2-74 provides an overview of what is often included in logistics.

Exhibit 2-74: Functions of Logistics



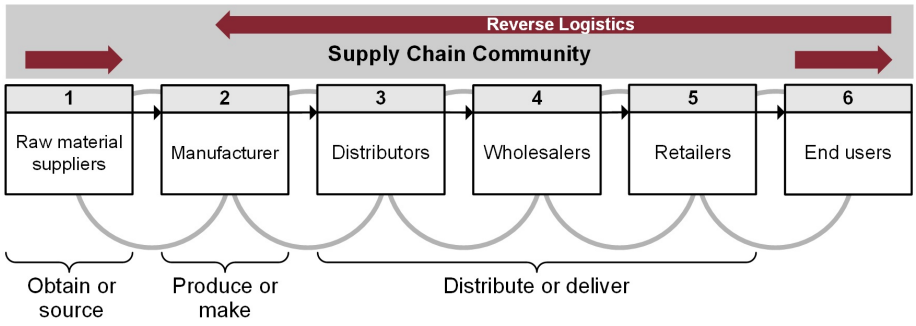
Warehousing and transportation are essential functions of logistics that are inextricably linked—the type and number of warehouses have a large impact on transportation costs. Note that import/export, packaging, inventory management, and logistics information systems (including transportation and warehouse management systems) are addressed elsewhere in these materials. Materials handling is covered in the section on warehousing.

Logistics is the only function in the supply chain that is required to operate 24/7/365—there are no days off. That is why customers often take it for granted; they've come to expect that product delivery will be performed as promised. However, it can be expensive and takes expertise, especially since logistics is now a globally integrated endeavor. For example, during the global financial crisis of 2007 to 2009, the number of containers holding electronics and other goods shipped from the Pacific Rim to the United States decreased. Farmers across the U.S. Northwest had been shipping hay back to Japan and Korea in the empty containers. With fewer containers coming into the U.S., hay farmers had less container capacity for exporting, and their shipping rates increased.

Supply chain partners must efficiently and effectively carry out logistical tasks to achieve competitive advantage. In a global market, this may require mastery of languages, currencies, divergent regulations, and various business climates and customs.

Exhibit 2-75 illustrates the broad scope of logistics.

Exhibit 2-75: Logistics in the Supply Chain



Logistics value proposition

The right configuration of transportation modes, warehouses, and other logistics assets and functions is needed to meet each customer's expectations and requirements. How will you know when you've got the right balance? If you keep in mind that logistics must be managed as an integrated effort to achieve customer satisfaction at the lowest total cost, then it makes sense that cost minimization and service are the key elements in this value proposition.

Service

Logistics customer service implies that the customer order was complete, undamaged, delivered on time, and consistently correct over time. Any level of logistical service can be achieved if a company is willing and able to pay for it. Technology isn't the limiting factor for logistics for most companies—it's the economics. For instance, what does it cost to keep the service level high if a company keeps a fleet of trucks in a constant state of delivery readiness or it keeps dedicated inventory for a high volume customer? How do you decide if it's money well spent? The key is to determine how to outperform competitors in a cost-effective manner.

In most situations, the benefit-cost impact of a logistical failure is directly related to the importance of the service to the customer. When a logistical failure will have a significant impact on a customer's business, error-free logistics service should receive higher priority. For instance, a missing part that causes a plant shutdown might justify flying the parts to the destination, while a late delivery that requires dipping into safety stock will be negligible. The customer that never has expensive delays and very few lost sales will have higher customer satisfaction and loyalty.

Cost minimization

The second element of the value proposition, cost minimization, should be interpreted as the total cost of logistics. The *APICS Dictionary,* 16th edition, describes the **total cost concept** of logistics as

> the idea that all logistical decisions that provide equal service levels should favor the option that minimizes the total of all logistical costs and not be used on cost reductions in one area alone, such as lower transportation charges.

For many decades, the accounting and financial departments in organizations sought the lowest possible

cost for each logistical function, with little or no attention paid to integrated total cost tradeoffs. Instead, today's leading supply chain companies develop functional cost analysis and activity-based costing activities that measure the total cost of logistics. The goal now is for logistics to be cost-effective as determined by a benefit-cost analysis, taking into account how a logistical service failure would impact a customer's business.

Logistics trends

Today the bulk of the logistics budget goes toward transportation costs. According to the 30th annual "State of Logistics Report" by the Council of Supply Chain Management Professionals, United States companies spent US$1.64 trillion performing logistical services in 2018. Of this amount, nearly US$669 billion was for motor carrier transportation and US$368 billion was spent on all other forms of transport, which together constituted over 63 percent of total logistics costs.

According to the "State of Logistics Report," in 2018

- Online purchasing grew by 14.2 percent from the previous year.
- Uncertainty over tariffs resulted in an increase in inventory buffers, as companies sought to mitigate impacts of potential tariff actions.
- Costs for other transportation modes were as follows (in billions):
  - Truck: US$668.8
  - Rail: US$88.4
  - Parcel: US$104.9
  - Water: US$45.7
  - Air: US$76.5
  - Pipeline: US$53.0
- Carrying costs were nearly US$494 billion (US$153 billion of this was for warehousing), shippers' administrative costs were US$52 billion (this includes 3PL costs), and carriers' support activities costs added US$52 billion.

The US$1.64 trillion in total logistics costs was an increase of 11.4 percent over the prior year.

However, the report also discussed some constraints on logistics growth. Warehouse rents continued to increase, as they have for the previous six years, albeit at a slower rate. Trucking resources had a high rate of utilization, resulting in higher rates. In addition to those increases, labor costs associated with both truck drivers and warehouse workers increased as the U.S. labor market remained tight.

Logistics objectives

At the highest level, logistics shares the objective of supply chain management: to meet customer requirements. Other objectives include:

- To respond rapidly to changes in the market or customer orders
- To minimize variances in logistics service
- To minimize inventory to reduce costs
- To consolidate product movement by grouping shipments
- To maintain high quality and engage in continuous improvement

- To support the entire product life cycle, including reverse logistics.

Logistics tactics

An effective logistics strategy depends upon the following tactics:

- Coordinating functions
- Integrating the supply chain
- Substituting information for inventory
- Reducing supply chain partners to an effective minimum number
- Pooling risks

We'll analyze each of these tactics.

Coordinating functions

Logistics has interlocking, interdependent parts. Before the advent of modern logistics management, however, each area had its own separate management and pursued its own strategies and tactics. Rather, a cross-functional approach is needed in logistics, just as in supply chain management. Teams that cross functions are also very likely to cross company boundaries to accommodate international supply chains.

An improvement in one area may very well have negative consequences in another unless decisions are coordinated. For example, locating warehouses in the countryside may save considerable money (Walmart does this), but it makes it harder to provide same-day delivery (which is why Amazon has located its new warehouses in key urban areas). Different packaging will almost certainly affect shipping and storage. You may improve customer service to a level near perfection but be unprofitable.

The overall goal of logistics management is more value in the supply network as measured by customer satisfaction, return to shareholders, etc. There is no point, for instance, in raising the cost of shipping—thus, the price to the customer—to deliver faster than the customer demands. Fast delivery, in other words, is not an end in itself, and the same is true of any aspect of logistics or supply chain management.

Integrating the supply chain

Integrating the supply chain requires taking a series of steps when constructing the logistics network. In a dynamic system, the following steps may be taken out of order and retaken continuously.

1. **Locate in the right countries.**
    - Map all countries in the forward and reverse supply chains.
    - Analyze the forward and reverse chains to see if selecting different geographic locations could make the logistics function more efficient and effective. (Countries differ by infrastructure, labor, stability, regulations, and taxes.)
2. **Develop an effective import-export strategy.**
    - Determine the volume of freight and number of SKUs to move.
    - Decide where to place inventory for strategic advantage. This may involve deciding which borders to cross and which to avoid as well as determining where goods should be stored in relation to

customers. (Some shipping companies now add a “war risk surcharge” if transport is near a nation with civil unrest or war.) Both geographic location and distance from the suppliers and/or customer can affect total costs and delivery lead times.

3. **Select warehouse locations.**
    - Determine the optimal number of warehouses.
    - Calculate the optimal distance from markets.
    - Establish the most effective placement of warehouses globally.
4. **Select transportation modes and carriers.**
    - Determine the mix of transportation modes that will most efficiently connect suppliers, producers, warehouses, distributors, and customers.
    - Select specific carriers.
5. **Select the right number of partners.**

    Select the minimum number of companies—freight forwarders, third- or fourth-party logistics providers—to manage forward and reverse logistics. In selecting logistics partners, also consider their local market and regulatory knowledge.
6. **Develop state-of-the-art information systems.**

    Reduce inventory costs by more accurately and rapidly tracking demand information and the location of goods. Developing state-of-the-art information systems may be difficult in some regions. Such situations make defining the processes and information flows vital.

Information in place of inventory

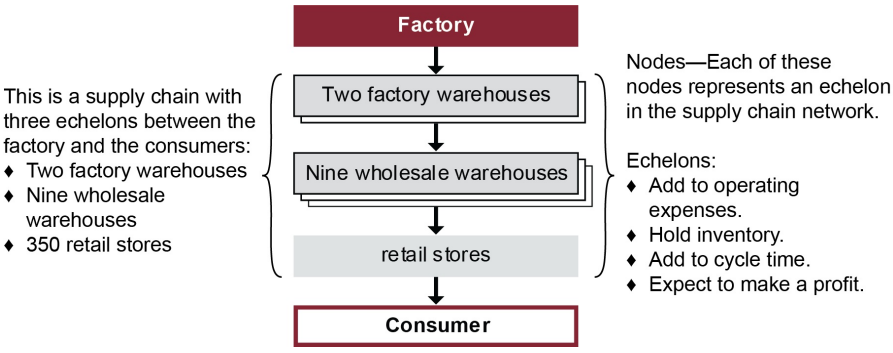
Physical inventory can be replaced by information in the following ways:

- **Improve communications.** Talk with suppliers regularly about plans and trends. Use continuous improvement tools.
- **Collaborate with suppliers.** Use Just-in-Time methods to coordinate deliveries from suppliers. Remove obsolete inventory.
- **Track inventory precisely.** Track the exact location of inventory using bar codes and/or RFID with GPS (the Global Positioning System).
- **Keep inventory in transit.** Keeping inventory in transit can reduce inventory costs. One method of doing this is cross-docking. A payload area can be considered a mobile warehouse. Rolling inventory should be closely tracked by GPS to reduce risk of loss and facilitate rapid adjustments if a customer changes an order at the last minute.
- **Use postponement centers.** Avoid filling warehouses with the wrong mix of finished goods by setting up postponement centers to delay product assembly until an actual order has been received.
- **Mix shipments to match customer needs.** Match deliveries more precisely to customer needs by mixing different SKUs on the same pallet and by mixing pallets from different suppliers.
- **Speed up customs.** Reduce customs time by preclearing freight.

Reducing supply chain partners to an effective minimum number

Having fewer logistics partners generally increases efficiency but could create tradeoffs in other logistics objectives. If possible, look for an entire echelon (tier) you can do without—such as all the wholesale warehouses or factory warehouses. See Exhibit 2-76.

Exhibit 2-76: Costs of Multiple Echelons



The more partners there are in the supply chain, the more difficult and expensive the supply chain is to manage. Handoffs among partners cost money and time. Having many partners means carrying more inventory. Reducing the number of partners can reduce operating costs, cycle time, and inventory holding costs. There is, however, some lower limit below which you create more problems than you solve.

Pooling risks

The *APICS Dictionary,* 16th edition, defines **risk pooling** as

> a method often associated with the management of inventory risk. Manufacturers and retailers that experience high variability in demand for their products can pool together common inventory components associated with a broad family of products to buffer the overall burden of having to deploy inventory for each discrete product.

In regard to inventory management, pooling risks is a method of reducing stockouts by consolidating stock in centralized warehouses. The risk of stockouts increases as supply chains reduce the safety stock or component parts inventories held at each node and move toward Just-in-Time ordering procedures. With every entity attempting to keep inventory costs down in this manner, the risk of stockouts rises.

Statistically speaking, when inventory is placed in a central warehouse instead of in several smaller warehouses, the total inventory necessary to maintain a level of service drops without increasing the risk of stockouts. An unexpectedly large order from any one customer will still be small in relation to the total supply.

There are tradeoffs to consider. Because the central warehouse may be further away from some production facilities than the smaller warehouses would be, lead times and transportation costs are likely to go up. Again, logistics has to be managed from the point of view of improving the value of the overall system, not just one part of it.

Topic 2: Logistics Service Providers

Since the 1980s, there has been a trend toward using outside companies to handle warehousing, shipping, and other logistics responsibilities. This outsourcing of some or all logistics operations is especially common among larger companies, such as 3M, although one might expect such corporate giants to be most capable of handling their own logistics.

The most compelling reason to let another party take over logistics functions is the decision to focus on core competencies.

The two types of outside logistics companies we'll look at here are third-party logistics providers (3PLs) and fourth-party logistics providers (4PLs).

According to the *APICS Dictionary,* 16th edition, **third-party logistics** involves

> a buyer and supplier team with a third party that provides product delivery services. This third party may provide added supply chain expertise.

Fourth-party logistics is described in the *Dictionary* as follows:

> Fourth-party logistics differs from third-party logistics in the following ways: (1) the 4PL organization is often a separate entity formed by a joint venture or other long-term contract between a client and one or more partners; (2) the 4PL organization is an interface between the client and multiple logistics services providers; (3) ideally, all aspects of the client's supply chain are managed by the 4PL organization; and, (4) it is possible for a major 3PL organization to form a 4PL organization within its existing structure. See: third-party logistics.

Early versions of logistics outsourcing involved transactional relationships with third parties offering single services—trucking from Ryder, shipping from the United States Post Office (USPS) or UPS, overnight air from FedEx. (One traditional type of outsourcing has been the use of the government postal services to deliver business mail and small parcels.) The recent trend in 3PL arrangements, however, is toward long-term contractual relationships with providers of integrated services, such as transportation plus storage. The 4PL setup extends that trend by removing all logistics functions from the client company and putting them under integrated management by a general contractor.

How 3PLs and 4PLs are related

References to logistics outsourcing more commonly use the term "3PL" to cover all types. Technically, there is a distinction:

- A 3PL is a buyer and supplier team with a third party that provides product delivery services; this third party may provide added supply chain expertise. In a 3PL arrangement, the third party takes over some or all logistics functions and performs them itself. A 3PL may be a specialized provider that focuses, for instance, on airmail or over-the-road transport or warehousing. It may also be a multipurpose logistics provider capable of taking over the entire logistics function.
- In a 4PL arrangement, a logistics specialist takes over the entire logistics operation and subcontracts some or all specific functions. Playing the role of general contractor, the fourth-party provider hires out

the various logistics services and coordinates the efforts of the subcontractors on the client's behalf. Sometimes this is still called third-party logistics, but the presence of subcontractors makes this in reality a fourth-party setup. Typically, the 4PL charges a fee for its service, not a markup.

Advantages/ disadvantages of 3PLs and 4PLs

Using third-party contractors to carry out some or all logistics functions can provide the following benefits:

- **Improved business focus.** Outsourcing logistics functions allows both the company and its contractor to focus on what they do best, assuming that the client company doesn't have logistics as a core competency.
- **More current logistics technology.** Contract logistics providers are generally able to stay current with technology. Contractors may be quicker to incorporate new software and better able to upgrade to the hardware necessary to run it well. The client company, on the other hand, may have to spread its software and hardware budgets over several functional units in addition to logistics.
- **Greater technological flexibility.** The third-party logistics provider is better positioned to adapt to different technologies used by the company's clients. This potentially expands the company's customer base at a reduced cost.
- **More efficient warehousing for rapid replenishment.** Rapid replenishment may require more warehouses in regions that are closer to clients. Using the 3PL's warehouses is cheaper than building or acquiring the company's own, specifically because in a 3PL warehouse, there is only a cost for the space occupied by your product. The 3PL, if it uses warehouses for multiple clients, can generate economies of scale.
- **Improved service to customers.** Third-party providers may be better able to offer a variety of services to the company's customers.
- **More workforce and resource flexibility.** It's quicker and simpler to hire a contract specialist for a new function—or to drop a contractor when business shifts to a new market—than to hire and lay off workers in response to market changes.

Benefits of the 4PL arrangement include the following:

- **Improved business focus.** Contracting out the entire logistics function frees up the company to focus on its core business.
- **Higher-quality logistics operations (or reduced costs, or both).** The 4PL's special competence in managing logistics should result in lower-cost, higher-quality service with less damage and fewer delays. As a logistics specialist, the 4PL can find the best subcontractors for each function and can design an efficient overall process.
- **Greater business flexibility.** Having a highly competent provider in charge of logistics gives a company the ability to adapt its warehousing, transportation, and packaging needs more rapidly to new market strategies or new products. The provider can renegotiate with current subcontractors or replace them with providers that have the capacities, skills, locations, or other features appropriate for the new venture.

Realizing the benefits of third-party logistics may create some risks:

- **Loss of control.** It may be more difficult to develop a comprehensive logistics strategy when the company has given control of some aspect of the system to a contractor. This can be especially

problematic if the contractor has direct connections with the company's customers.

- **Potential for inefficiency.** If the 3PL takes over logistics functions in which the company was doing a good job, it may actually perform with reduced efficiency in that area.

Turning over logistics to a 4PL involves the following risks:

- **Loss of direct control** over the logistics process and all specific functions
- **Potential for less effective or more costly operations** if the 4PL writes biased contracts rather than seeking out the most efficient suppliers

Logistics outsourcing may put the contractor into direct communication with the company's customers, and that also entails risks. The 3PL employee (or 4PL subcontractor) becomes a representative of the client company, which may be judged by the contractor's behavior. A 3PL may contract with a client's competitors, with the risk that confidential information may pass through the contractor to the competitor.

Outsourcing considerations

Before outsourcing logistics to a third- or fourth-party provider, a company should ask itself the following questions:

- **What are our current costs?** When evaluating bids from potential third- or fourth-party logistics providers, a company needs to know what the functions in question currently cost. It also needs to take into account potential savings in time plus improved quality of service to customers. There's no point in paying more than current costs unless the arrangement will provide other benefits. And there's no point in saving money on logistics if the contractor increases delivery errors or otherwise alienates your customers.

- **What customer skills does the contractor possess?** Has the bidder researched your needs and company culture? If not, how likely is it to do the background work necessary to provide high-quality service to you and to your customers? Is the company reliable? What do its other customers have to say about it? (Be sure to use credible references.)

- **What are the contractor's special strengths?** Many contractors began as providers in one area, such as trucking, mail delivery, or warehousing, and added other logistics competencies as they grew. UPS, for instance, is now a fully integrated transportation company and a logistics consultant, but in the beginning it was a single-purpose company. The shipper needs to evaluate the match between its needs and the contractor's strong suits.

- **Will the contractor hire the most-qualified partners (if necessary)?** Especially when considering a 4PL, a company should evaluate the contractor's ability to subcontract effectively. Some contractors are biased toward their own divisions (or favored subcontractors), even if those divisions or subcontractors aren't the best qualified.

Contract considerations

Once a 3PL or 4PL has been selected, it is important to develop a mutually beneficial contract to ensure that the relationship can be successful. Achieving long-term benefits for both parties requires both parties to

identify what the end result will look like as well as how the parties will get there. Many 3PL or 4PL relationships have poor initial start-up periods that can cause the relationship to fail or falter and thus harm the long-term relationship, so an important contract consideration is to specify what each party will do to ensure that the first six to 12 months of the relationship go smoothly. This difficult period will require commitments of time and energy from both parties as well as formal specification of shared risks and rewards.

On the communications front, contracts can promote regular communications in both directions, for example, forwarding customer feedback to the 3PL. From a monitoring and controlling standpoint, it is important to carefully select the performance metrics to be used to assess the success of the relationship. These metrics need to address strategic priorities such as level of customer service.

Specific rules that should be included in contracts include confidentiality clauses, subcontractor clauses, clauses for remedies, and escape clauses. Since 3PLs or 4PLs are working so closely with your suppliers and customers and likely have direct access to organizational data, confidentiality clauses need to be robust. Subcontractor clauses help set subcontractor quality and other selection criteria, which is especially important when working with 4PLs since you are ceding control. From a remedy standpoint, a specific process for correcting variances from performance targets needs to be laid out in advance and agreed to by both parties. These clauses need to specify the use of arbitration to avoid costly court settlements. Escape clauses provide both parties with the specific allowed reasons for and methods of ending the relationship.

Topic 3: Expediting

To **expedite** is "to rush or chase production or purchase orders that are needed in less than the normal lead time; to take extraordinary action because of an increase in relative priority" (*APICS Dictionary,* 16th edition).

Expediting can be applied to any stage of the supply chain. We'll consider expediting of supply (source and make) and expediting of transportation (deliver).

Expediting of supply

Expediting of supply is something that should be very rare indeed in a well-managed system, because it often reduces profitability and causes other unintended side effects such as harming customer service for customers being bumped. However, expediting is sometimes necessary because not everything goes according to plan or a customer is important enough or willing to pay enough to make it necessary or worthwhile.

What creates the need for expediting (real or apparent)? In many cases expediting is caused by inventory shortages, which are in turn caused by poor demand forecasting. The result is that salespersons start competing against one another to get their customers' needs satisfied at the expense of other salespersons' customers. Salespersons are often willing to spend a great deal of time expediting, by which we mean cajoling various suppliers or internal staff to get more done in less time or shift priorities. When this fails, salespersons may then escalate their expediting to senior salespersons or a vice president based on the importance of the customer. This scenario is an example of what happens when people focus on the short term and ignore long-term improvements. It creates an atmosphere of one emergency after the next. If they were to spend as much time on improving forecasts as they did at expediting, it would likely produce better and longer-lasting results.

Expediting is achieved with suppliers by asking them to prioritize the organization's needs above those of other customers. Depending on how important you are to them, your results may or may not be successful. They may charge the organization a premium for this priority. Expediting is achieved with internal production by making requests to the master scheduler. Policy may dictate that this be a formal request with proper paperwork. The master scheduler will not allow for expediting of production in the frozen zone, so only production in the slushy or liquid zone should be possible candidates for expediting. If expediting is necessary and the slushy zone production will not be ready soon enough, then another option might be to supply it from allocated inventory (e.g., safety stock or convincing another customer to delay receipt of inventory already promised to them).

Expediting of transportation

Expediting of transportation can take the form of the shipper telling the carrier that a particular shipment needs to move to its destination as fast as possible and without any delays. This type of request may involve paying an expediting fee if the goods need to arrive before stipulated in the shipping contract. It may also not be possible to expedite a delivery much if the process is already efficient.

Another way to expedite transportation is to ship via a faster mode of transport if the shipment isn't already in

transit. Just as a commuter may take a cab when a bus will take too long, this may involve using an overnight delivery service if the units are small and light enough for these services to handle, or it could involve upgrading from ground to air transport, again depending on what is being shipped. If expediting is being done at the request of the customer, any extra costs, including administrative costs, would normally be passed on to the customer. If it is being done to fix an error or backlog, the organization will need to assume this expense.

Organizations can measure the amount of expediting that is being done and its costs so they can determine the savings that can be gained if these costs can be avoided.

Topic 4: Delivery Patterns

Delivery patterns, also called shipping patterns, refer to trends in how customers are buying goods and getting them to their place of business or home. This topic addresses some general order fulfillment channels organizations can leverage and then looks at how the direct-to-consumer model has created a radical shift in delivery patterns for many organizations and logistics specialists.

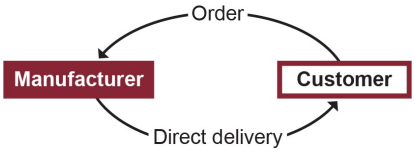
Order fulfillment channels

The type of distribution network a supply chain adopts will have a huge impact on facility location decisions and, for that matter, the number of facilities. Distribution channel strategy is determined during strategy formation; however, some tactical selections can be determined during network design.

There are five types of fulfillment channels, each having different levels of service outputs (break-bulking, spatial convenience, waiting and delivery time, variety and assortment) and channel design intensity (market penetration, distribution-integrative, distribution).

- **Manufacturer storage with direct delivery.** Exhibit 2-77 shows the type of network in which the manufacturer uses direct delivery. The manufacturer takes a customer order through any number of sales channels (direct, catalog, website, etc.) and directly ships the goods to the customer, with no intermediaries other than perhaps a carrier (unless the manufacturer owns a fleet).

  Exhibit 2-77: Manufacturer Storage with Direct Delivery

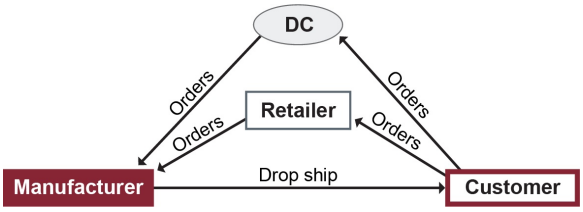
  

  This model is common in business-to-business (B2B) settings but can also be used for business-to consumer (B2C) sales. An example of its appropriate use in the B2B setting is for perishable goods that need to be on retail shelves as quickly as possible to maximize their useful lives. This could also be a supplier that produces large lot-size quantities. The primary benefit to the manufacturer is a direct relationship with its customers so it can directly interact with and market to them in the future. For B2C, it is used primarily for low variety, make-to-order goods that the customer is willing to wait for, since lead times can be long. Since there is only one echelon, the manufacturer has complete control over inventory and has low carrying costs. Shipments are typically in truckload (TL) or container load (CL), but logistics costs can be high and intermediaries may be needed to reduce these costs.

- **Manufacturer storage with drop ship.** Exhibit 2-78 shows the drop ship model, in which a distributor or retailer (or direct sales or online merchant) takes orders from customers and the

customers receive the goods directly from the manufacturer. The distributor or retailer may have a floor model but no inventory. This model would probably use transload and cross-dock facilities. It would be best for high-value, sporadic demand items; these might be make-to-order, customized, or postponed items that can be finished when the order arrives. Shipments may be in small lots, and thus transportation costs can be higher and lead times longer, but the manufacturer can control delivery service reliability.

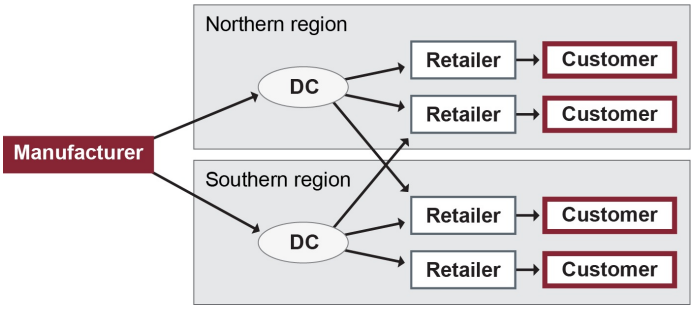
Exhibit 2-78: Manufacturer Storage with Drop Ship



In this model, the manufacturer doesn't have direct contact with the customer, so customer knowledge is less than with the prior model. At the same time, the manufacturer does not need to maintain a sales force or other functions like credit approval.

- **Manufacturer to distribution center to retailer.** Exhibit 2-79 shows the traditional supply chain, a manufacturer working with regional distributors. The distributors supply retail locations in which customers buy goods and handle the local delivery portion with their own vehicles. There can be one or more distribution centers (DCs) in this model, and a wholesaler echelon could also be added. The multiple echelons all need inventory, so this model is inventory-intensive. It is best for mass-produced, inexpensive goods with high competition. It produces strong product availability and high levels of customer service.

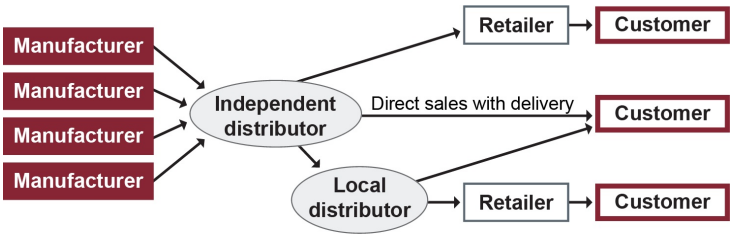
Exhibit 2-79: Manufacturer to Distribution Center to Retailer



The channel intermediaries and retailers are generally independent, but some DCs could be owned if this can be done for less than 3PLs can do it after all facility and inventory carrying costs are accounted for. Distributors provide break-bulk activities and minimize inventory by using fewer, more centralized warehouses. The retailers take over all customer-facing functions and their associated costs. The organization may need to negotiate for preferred shelf space and may not have much control over promotions or access to customer information without forging information-sharing partnerships.

- **Independent distributor with omni-channel network.** Exhibit 2-80 shows a network where an independent distributor is the channel master, buying goods from multiple manufacturers (or other distributors) in bulk and aggregating them for a one-stop shop for retailers, local distributors, wholesalers, or direct customers. Manufacturers gain another sales channel and access to a larger market. Retailers and distributors can often buy assortments in TL or CL shipments and get economies of scale in pricing so they can sell at a competitive price for a profit.

Exhibit 2-80: Independent Distributor with Omni-Channel Network



The distributor needs to develop these local distributor and retail partnerships carefully to ensure that they build and maintain a large enough customer base. This will be accomplished, in part, by holding high inventory levels of fast-moving items. These organizations might negotiate exclusive contracts for markets, but competitors might do the same, and therefore they may not have full market access.

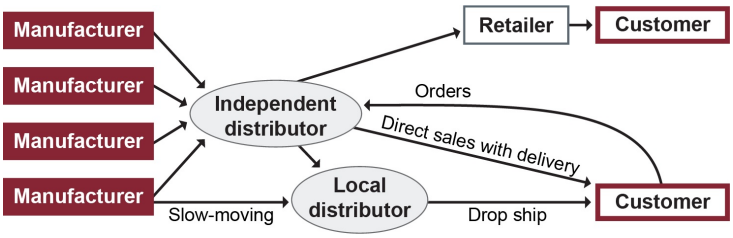
They need a thorough and efficient transportation network of owned or contracted carriers to provide high customer service while controlling relatively high transportation costs. They can provide value-added services like aggregate inventory storage and bulk shipping of assortments. If they want customer information or information on promotions, they will need to form information-sharing partnerships.

They will also have a large number of suppliers they need to coordinate and partner with, when possible, to control prices, lead times, quality, and availability. They might even negotiate cost-sharing contracts.

- **Independent aggregator with e-business network.** The model shown in Exhibit 2-81 is very similar

to the previous model, but it depends more heavily on direct marketing to individuals through its own heavily branded website, which may sell all manner of goods. Alibaba and Amazon are examples. Direct shipment of goods to customers through parcel services is very common, but these organizations may also sell or ship through local distributors (which they may own) and will move slow-moving goods directly from manufacturers through local distributors rather than carry this inventory themselves.

Exhibit 2-81: Independent Aggregator with e-Business Network



Other independent distributors will sell specialty goods to B2B or B2C niche markets using web sales. The independent distributor gains direct access to customers and can manage this customer information and customize the customer's web interactions. They often use loyalty programs that offer free shipping for an annual membership fee. To keep this customer loyalty, they need very high levels of customer service.

The exhibit also shows that some independent distributors in this model still sell goods to local distributors, retailers, or even to other e-businesses. This allows the organization to offer omni-channel fulfillment such as buy online/pick up in store. (Usually the retailer would also be the distributor in this case.) Many retailers are adopting some form of this model, selling both online and in retail stores.

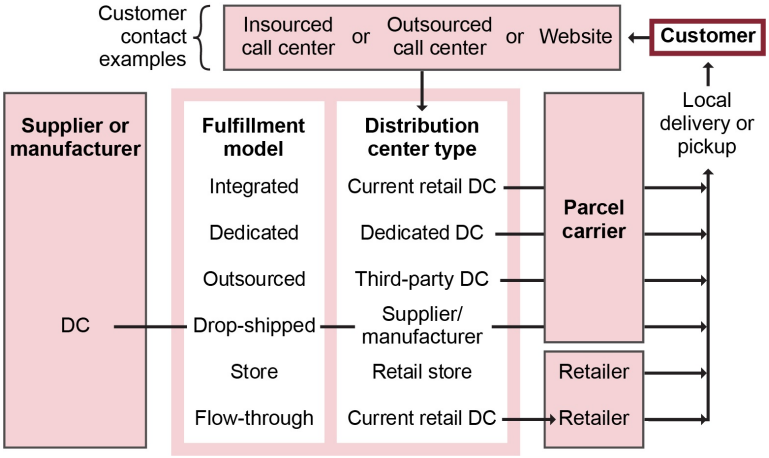
Each type of channel, by virtue of how it's structured, will perform at different levels on the key dimensions that impact customers' satisfaction levels: distribution intensity, customer service level, product assortment, product availability, delivery time, channel complexity, inventory cost, transportation costs, and channel facilities. There are always tradeoffs to be made between channel types and the exact service attributes that make customers happy. What does seem to bring a smile to most customers is having the ability to place orders any time of day or night, anywhere in the world, via the internet. The convenience and variety of the direct-to-consumer model has seen a trend of delivery patterns shifting in this direction, so this model and its implications for logistics are discussed next.

Direct-to-consumer model

Exhibit 2-82 summarizes some of the order fulfillment channels that relate to the direct-to-consumer model

but also shows some other permutations because a variety of tactics can be used to accomplish direct-to-consumer delivery patterns. Other order fulfillment channels can likewise be accomplished in more than one way.

Exhibit 2-82: Direct-to-Consumer Permutations



As online shopping continues to make strong inroads into more and more areas that were traditionally retail purchases, organizations are facing strong changes in delivery patterns. In 2014, John Larkin, managing director and head of transportation capital markets for Stifel, Nicolaus & Co., stated that 9 percent of retail sales were online at that time but that they were growing at 15 percent per year, or five times the rate of brick-and-mortar retail, according to an article on FleetOwner.com by Sean Kilcarr.

The retail delivery pattern involves shipments of goods or components from multiple suppliers, consolidation at distribution centers, and shipment from there to retailers. This pattern emphasizes multimodal transportation for efficiency and economies of scale.

The direct-to-consumer delivery pattern, on the other hand, involves the same first steps of getting goods and consolidating them at distribution centers, but from there it becomes a series of small package deliveries directly to consumers. In some cases, the direct-to-consumer delivery pattern involves forwarding individual packages directly from suppliers to customers with no intermediaries.

Even the direct-to-consumer delivery pattern has been shifting. While there has been a movement toward next-day delivery, for consumers who are working during the day, this has resulted in packages left outside doors or missed deliveries. One innovative solution developed by Wehkamp, a large Dutch mail-order company, was to ask, “When do you want your delivery?” to help make deliveries when customers are actually home. They even developed same-day delivery, in part by reducing their time from customer order to ready to ship to 30 minutes. Other European services have started making deliveries to small village grocery stores or gas stations for customer pickup.

The magnitude of the shift in delivery patterns from large shipments to retailers to individual shipments to consumers is immense for the logistics industry. Third-party logistics providers who specialize in truckload

and less-than-truckload (LTL) delivery networks are under pressure from the reduction in demand for their services. Mergers and acquisitions are already occurring among traditional 3PLs as they seek to scale upward to be large enough to start offering services other than just TL and LTL. If this trend continues, there will be far fewer logistics providers in the market, and those that survive will need to be able to provide their traditional functions plus functions that are currently provided by the likes of UPS, FedEx, and USPS. For example, according to Larkin in the same article quoted above, Amazon.com has a strategy to develop a private fleet to provide same-day deliveries in their top 40 markets, use local delivery services for the next 60 markets, and rely on UPS, FedEx, and USPS only for the remaining markets. Part of its strategy to achieve same-day delivery is to open distribution centers in these urban areas rather than locating them in the countryside as is the case with many retailers, including Walmart.

This substantial capital investment in fulfillment and related technology has been paying off in increased sales for Amazon. A case study of Amazon.com, in the article “Investing in Smart Logistics” on the Fidelity International website, shows how the increase in spending on fulfillment and technology is positively correlated with Amazon’s increase in net sales. For example, in 2012 Amazon invested about US$6 billion in fulfillment and earned about US$55 billion in net sales. In 2013 it increased its investment in fulfillment to about US$8 billion and earned about US$73 billion in net sales. Amazon’s investments in technology have similarly increased each year. Examples of these investments include equipping their new urban distribution centers with floor-to-ceiling racks that substantially increase storage space and purchasing a robotics company to provide robots for picking and put-away.

Chapter 11: Warehouse Management

This chapter is designed to

- Enumerate warehousing objectives
- Identify warehousing considerations of ownership, number, location, configuration, and support systems
- Discuss how storage locations can be organized to maximize velocity and cube utilization
- Describe several stock location methods for grouping inventory in storage locations
- Discuss how to forecast warehouse capacity
- Explain the mechanized and automated systems in warehousing along with their advantages and drawbacks
- Describe materials-handling options in warehouses in terms of space use, labor, equipment, and automation.

Topic 1: Warehouse Objectives and Planning

Warehousing involves “the activities related to receiving, storing, and shipping materials to and from production or distribution locations” (*APICS Dictionary,* 16th edition).

Warehousing objectives

Warehousing can contribute to the broad logistical goals of an organization in a number of ways:

- **Respond rapidly to changes in the market or customer orders.** To enable rapid responses, organizations use demand planning data such as forecasts and market analysis to anticipate changes in the market or customer needs so there will be time to make changes. Changes may include the number and placement of warehouses relative to markets, management of inventory levels, efficient product movement through the facility, and technology to track products. The transportation and warehousing interface is critical.

- **Minimize variances in logistics service.** In today’s times of rapid change, efficient tracking and handling of inventory in the warehouse is critical to achieving predictable service. Loading, unloading, packaging, and order picking each have a role in minimizing variability in service.

- **Minimize inventory to reduce costs.** The more efficiently warehouses are managed and the more strategically they are placed in relationship to markets and transportation, the less inventory will build up in the system.

- **Consolidate product movement by grouping shipments.** The tactic of aggregating smaller shipments into larger ones for more cost-effective transportation depends upon the efficient placement and management of warehouses. Expeditious unloading, tracking, repackaging, and reloading are all crucial to effective consolidation of movement.

- **Maintain high quality and engage in continuous improvement.** Every aspect of warehouse operations should be subject to continuous improvement, with the goal of eliminating errors.

- **Support the entire product life cycle and reverse logistics.** The number, placement, and efficiency

of warehouses must take into account the introduction and growth phases and the end of the product life cycle—returns (repair, replace, or recycle).

Based on these goals, the following considerations must be taken into account regarding warehouses:

- Determining mix of private, public, or contract warehouses
- Determining the optimum number of facilities necessary to aid in reduction of inventory while reducing or eliminating stockouts
- Selecting the right location for each warehouse to ensure cost-efficient access to supply, markets, and transportation
- Designing each facility to be the right size and configuration for its products and processes
- Developing management systems that employ space, labor, equipment, and information technology to minimize delays, product damage, and product loss

Taken together, these factors can increase the overall value of the supply chain and improve its competitive position.

Owned versus leased warehouses

Warehouse ownership takes three forms: private, public, and contract.

Private warehouses

Private warehouses are owned by the company. The benefits of ownership are straightforward.

- **Control.** Private warehouses can be built or, to a lesser extent, remodeled to suit the company's type and size of inventory, its staff, its operations, and its location preferences. Deciding whether to build or remodel can involve some serious calculation and guesswork. Building provides the greatest flexibility to suit the current product mix and operations. Before deciding to build, the company may want to forecast and decide how long the current size and configuration will work before the facility needs renovation. (Warehouse capacity forecasting and planning is covered later.) Remodeling may or may not be less expensive than building.
- **No markup.** A company can avoid paying a markup by owning its own warehouse.
- **Market presence.** A company may be able to reinforce its presence in a local market by placing a warehouse near its customers. Proximity can facilitate faster and more personal service.

The downside of private ownership is a loss of budgetary flexibility. A warehouse is a depreciating asset. The fixed costs of ownership persist even if business turns down and the warehouse isn't used to capacity. Selling a specialized facility—especially in the midst of a general downturn in business—can be time-consuming and hard on the bottom line. Companies have been known to walk away from useless real estate.

Public warehouses

Public warehouses are independent businesses offering various services for a fee. Independently owned warehouses are available in a variety of configurations—refrigerated, bonded, general merchandise, household goods, other specialties, for example. And they may offer benefits that more than compensate for

the loss of control and market presence provided by ownership.

- **Flexibility.** By hiring warehouse services, a company gains the flexibility to increase or decrease its warehousing costs to match market fluctuations.
- **Potential cost reduction.** Despite the markup charged by the owner, a public facility may offer lower overall costs than a private facility by providing economies of scale and lower labor costs. The public warehouse may serve more than one client, thereby making more efficient use of its capacity than is possible in a privately owned, single-use facility.

Contract warehousing

Contract warehousing has evolved from public warehousing, and it offers a combination of the benefits of public and private facilities.

- **Potential cost reductions.** Compared to private warehousing, a contract warehouse may be able to provide equal or better service and do so cost-effectively. When comparing costs, the logistics manager can measure the relative merits of each on performance indicators such as fill rates, units shipped per hour, and rate of on-time deliveries. The contract warehouse may gain a pricing edge on the private warehouse in several ways. First, because the contractor is a specialist, its warehouses may be run more efficiently than warehouses owned and managed by the manufacturer. This may result from the contractor's ability to hold down wages and benefits and to provide economies of scale in transportation. The profit motive prompts a contractor to keep operating costs down to win business.
- **Tailored services.** In return for the stability of a longer-term relationship, the contract warehouse can tailor its services to the needs of a particular client more than a public facility can afford to do.
- **Flexibility.** While a contract locks in the company for a longer time period than a hiring arrangement, it provides more flexibility than private warehousing can offer. Using a short-term contract arrangement, a company can also gain the flexibility of testing new markets without investing capital in new facilities.
- **Expanded geographic market.** A third-party provider may own and operate a widely dispersed network of warehouses that can expand a client company's access to new geographic markets.

Mixing ownership types

Mixing and matching the three ownership types works well for many companies. For instance, a company may use private facilities to handle its year-round business and hire or contract for extra warehouse space during seasonal peaks.

Determining the right number of warehouses

Once, it was easy to decide the number of warehouses: one per market. This was often due to an organization's marketing strategy rather than logistics decisions. Management was mainly concerned with locating distribution centers within easy reach of each market and with storing plenty of inventory in each one to avoid shortages. As logistics matured, however, warehousing became much more strategic.

Once the idea of one warehouse per market went out of favor, deciding on the number of warehouses required systems thinking. Every decision about the structure of a system requires a series of follow-up

decisions to deal with the impact of the first one. Decisions about warehousing, for instance, may affect transportation, lead times coming into and going out of the warehouse, available labor, packaging, locations, taxes, and tariffs (in global supply chains), etc.

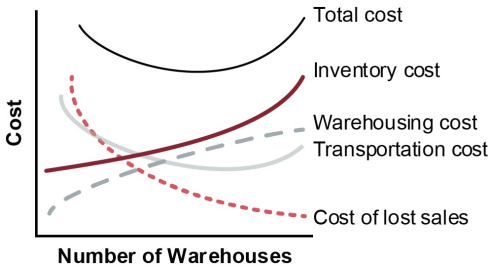
Selecting an appropriate number of warehouses for the logistics system is all about tradeoffs. As you add warehouses to the system, some costs will tend to increase and some will decrease.

An increased number of warehouses in a system can affect the following:

- **Customer service.** The main reason to increase the number of warehouses is to place more goods closer to more customers, thereby improving customer service levels. Today, however, the general trend is to reduce the total number of warehouses. High customer service levels are maintained, despite fewer warehouses, by optimizing logistics operations.
- **Transportation costs.** Adding warehouses can be an effective way to reduce transportation costs by shortening the distances between the warehouses and the points of origin and delivery. There are other considerations, however. A centralized system of warehouses will likely facilitate more rapid inventory turnover. It will also benefit from economies of scale, realized by consolidating outbound shipments into full loads that qualify for lower rates per unit of cargo weight. Transportation costs also reflect the efficiency of service, which may decline with the addition of warehouses. On the other hand, with additional warehouses, inbound transportation costs could increase if there are deliveries by partly full payloads.
- **Inventory.** As you add warehouses, you tend to increase the amount of total floor space in relation to the space available for storage due to redundancies. While more facilities mean less safety stock per site because of shorter lead times, aggregate safety stocks go up.
- **Setup and overhead costs.** More warehouses require more expenditures on construction or renovation, setup, and maintenance. Overhead increases include duplication of equipment (one for each place) and labor. As you increase the total number of warehouses, you also increase the probability of adding relatively inefficient facilities to the system. To reduce the number of warehouses, one can start by eliminating the inefficient locations.

Exhibit 2-83 provides a rough picture of the tradeoffs in costs that occur with the increase in the number of warehouses in a logistics chain.

Exhibit 2-83: Cost Effects of Increasing Number of Warehouses



As the exhibit shows, the overall costs in the system tend to decline as the number of warehouses increases, but only up to a point. After that point, the total cost of warehousing rises corresponding to the number of warehouses. That happens because increasing inventory costs eventually overwhelm savings in other areas. The relative rates of the increases and declines will not be the same in all logistics systems; these are only general trends.

Despite the potential savings resulting from a strategic consolidation of warehousing to serve the same customer base, there are sometimes good reasons to decentralize instead. A logistics chain may benefit from adding warehouses in the following instances:

- Local customers want rapid delivery like that which they get from competitors.
- Transportation can't provide the required service without adding warehouses.
- Small-scale customers require fast, frequent shipments that are better accommodated by a decentralized system of warehouses.

Determining the right locations for warehouses

Deciding upon the location of warehouses is closely linked with decisions about the number of warehouses. Logically, the decision about numbers comes first, because it depends upon the size of the customer base, the volume and timing of demand, and customer service targets. But even after deciding how much storage space is required for meeting these targets, there are choices to be made among possible locations. Some location decisions are independent of desired numbers. If, for example, a supply chain serves markets in several nations, it may be necessary to locate distribution centers in each country, regardless of market size, due to economic considerations and product differences. Availability of transportation also influences choice of location.

Below are the significant factors to be considered when locating warehouses:

- **Available services.** The most important feature of a potential warehouse location is the availability of required services. These may include rail lines or access for trucks, electricity, water, and other municipal services, including adequate police services. Absence of a required service can be a deal breaker.

- **Neighborhood.** Often warehouse locations reflect the historical origins of the city, but warehouses can be located anywhere zoning allows them. Warehouses may also be located in central shopping areas,

such as downtowns; in any commercial zone; or in sparsely settled areas. If the warehouse will be new construction, the area has to meet certain requirements such as available space.

- **Costs.** The costs of procuring and setting up a warehouse are related to available services and to location. Such costs can vary significantly. Insurance costs exist within a wide range depending upon local social and environmental conditions. Cost of land varies with location; in general, the closer to urban centers, the more the land costs. Warehouse design should take into account the efficient use of space, especially on expensive property. There may be a tradeoff in cost of transportation and cost of land, since cheaper land may be more distant from the market to be served.
- **Community inducements.** An area eager to attract business may offer tax incentives that impact the location decision. An available, appropriate workforce is also a requirement, though workers are mobile enough to influence only the general area, not the neighborhood in which the warehouse locates.
- **Regulatory concerns.** Environmental impact statements can slow down construction and run up costs.

The factors influencing warehouse locations are interdependent and impact the rest of the system. Consequently, they require careful analysis. Many of the decisions discussed so far are intensified in a global supply chain, especially decisions related to available services, insurance costs, and the workforce. For example, Toyota decided to locate a plant in Canada rather than in a previously favored region of the southern United States. They based that decision on an assessment of the relative quality of the workforce in each region and the difference in health insurance costs, which are paid for by the employer in the United States and by the government in Canada. Such factors are also of concern in locating storage facilities.

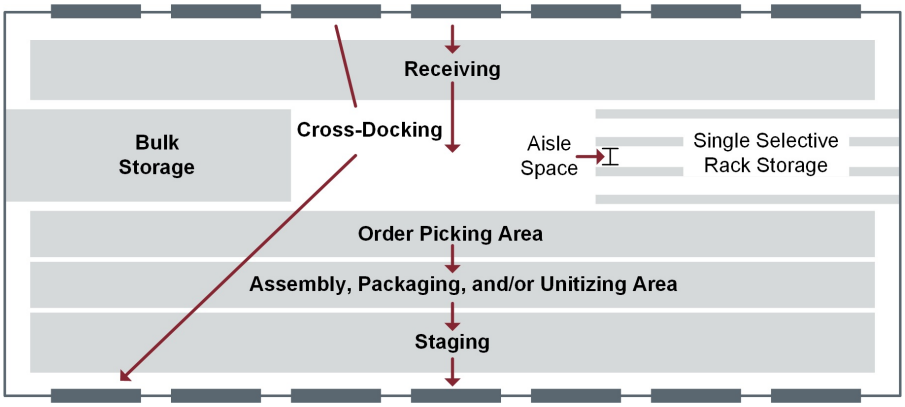
Organization of storage locations

Storage locations are organized to maximize their efficiency and the effective use of space. Warehouse space involves a large capital investment for an organization, so it must be arranged to maximize the amount of storage while leaving sufficient space for equipment movement and other warehouse activities such as receiving, cross-docking, order picking, assembly, packaging, and staging.

Warehouse layout

Exhibit 2-84 shows the basic layout of a warehouse.

Exhibit 2-84: Basic Warehouse Layout



Warehouses are generally designed as one-floor systems so there is no need to move inventory vertically. Rack storage maximizes the cubic space of the warehouse—called cube utilization—by storing items on vertical racks. The maximum height is determined by the equipment used to place and pick pallets or other inventory. Filling an entire warehouse with single selective racks (multi-story racks that are one pallet-width deep on each side of an aisle) might maximize the amount of this type of inventory that can be stored, but the workflow areas will be congested and overall throughput could be abysmal. A velocity analysis can be performed to optimize warehouse flow. The ideal system has 100 percent accessibility, meaning that all inventory can be accessed without having to first move some other inventory.

Once a layout that optimizes velocity and cube utilization is determined, the next concern is to organize stock locations.

Stock location

Stock location involves deciding where to store specific inventory in a warehouse. The idea is to optimize storage based on the organization's prioritization of speed of access or cube utilization.

Here are some stock location methods:

- **Using random-location storage.** As defined in the *APICS Dictionary,* 16th edition, random-location storage is

  > a storage technique in which parts are placed in any space that is empty when they arrive at the storeroom. Although this random method requires the use of a locator file to identify part locations, it often requires less storage space than a fixed-location storage method.

  Random-location storage is also called floating inventory location. This method maximizes cube utilization and can be rapid if the organization uses warehouse automation systems such as directed pick and put-away.

- **Using fixed-location storage.** Fixed-location storage is defined in the *APICS Dictionary,* 16th edition, as

  > a method of storage in which a relatively permanent location is assigned for the storage of each

item in a storeroom or warehouse. Although more space is needed to store parts than in a random-location storage system, fixed locations become familiar, and therefore a locator file may not be needed.

This method may be acceptable for warehouses that do not need dense cube utilization because space is not at a premium, throughput is low, or there are not many SKUs. It is also often used for relatively slow-moving items like spare parts or for situations where order pickers do not get a picking list (e.g., supermarket shoppers expect to find items in a certain place).

- **Using ABC classification.** Inventory can be grouped by its ABC classification and could use secure or fast-moving storage areas.
- **Grouping functionally related items together.** Items can be grouped by their use, for example, all modular components for the same product family, all kitchen appliances, or all hardware. A related storage type is called point-of-use storage, which has special assembly staging areas and nearby inventory storage.
- **Grouping high-velocity items together.** Items that arrive and leave quickly, but not quickly enough for cross-docking, can be placed in locations near the outbound staging area.
- **Grouping items by similar physical characteristics.** Hazardous materials need to be stored in an area with strict security measures. Frozen or refrigerated items are stored together. Bulky or odd-shaped items, such as couches, can also be stored together.
- **Grouping reserve stock separately.** Reserve stock can include bulk storage of items when working stock is considered a partial pallet for picking, or it can refer to defective or obsolete items and returns. Reserve stock can be stored out of the way. The working stock can be replenished from the reserve stock.

Warehouse capacity forecasting and planning

Warehouse capacity forecasting and planning is a must before building or leasing warehouse space, because the warehouse will need sufficient capacity for the next three to five years. Changes to warehouse capacity in a shorter time frame tend not to be cost-effective due to building and/or setup expenses, lease negotiations, and so on.

Capacity forecasting is a function of inventory levels in the aggregate. Individual inventories will vary between a minimum (equal to safety stock) and maximum level. We are looking for the most common inventory level—an average, called the mode. The mode (most common level) will be approximately halfway between the safety stock level and the maximum levels. For the rest of the discussion in this topic, interpret “average” as meaning the mode.

While calculating warehouse size using forecasted average inventory may not seem to leave enough room for maximum inventory, when random-location assignment is used, the inventory that is currently at a maximum level will balance inventory that is currently at a minimum level. If, instead, fixed warehouse locations are assigned to specific items, the size of the warehouse would need to be the sum of all maximum space per item and the warehouse would frequently have a large amount of unused space. Warehouse capacity is therefore typically forecasted as this average inventory level.

A few items need to be considered before calculating the forecasted average inventory level:

- Averages must first be calculated for each type of unit. Various units can be aggregated based on their storage requirements; items of like size can be aggregated because it is the total cubic meters or feet used that needs to be calculated.
- Some average warehouse space requirements may need to be calculated. Often, the number of items that fit on a pallet within a storage bay (including a calculation of how high the pallet can be stacked) could be estimated; the pallet size could be used for its cubic volume requirement. In practice, this analysis is often simplified from cubic meter/feet requirements to the number of pallet storage bays needed to house the forecasted average aggregate inventory. Many organizations and industries standardize their pallet size to allow all pallets to fit in any storage bay. For our calculations, each pallet would then be one unit.
- Some compensation is often added for pallets that are used for individual items rather than shipped as whole pallets. A pallet that can store 18 boxes but holds only one box at present still takes up an entire storage bay.
- Any bulk storage capacity requirements would be calculated separately.
- For each year of the three- to five-year warehouse space requirements, a forecast must be calculated. The year with the highest capacity requirement will indicate the overall warehouse capacity requirement—expressed in cubic meters or feet or in storage bays.

As an example, let's say that the sum of all forecasted average inventories for an organization takes up 18,000 cubic meters (m3) in the highest forecasted year of a five-year plan. All inventory fits on a standard size pallet that, when full, is 1.2 meters deep × 1.0 meters wide × 1.5 meters tall = 1.8 m3. Calculating the need for storage bays divides the space requirement by the standard pallet cubic space: 18,000 m3/1.8 m3 = 10,000 storage bays. The organization multiplies this by a factor of 1.1 to account for partially filled pallets. This factor is based on historical analysis of existing warehouse usage. Then 10,000 × 1.1 = 11,000 storage bays needed.

After determining the requirements for the inventory, the calculation is adjusted to account for other space requirements. When storage bays are used, the process might work as follows:

- **Determine the raw space footprint.** Multiply the number of needed bays by the square meters used per pallet. (Vertical storage and thus cubic space utilization is accounted for in a later step.) This results in a square meter (m2) space requirement for just the inventory. Finding the square meters or feet requirement is useful because real estate is sold or leased using this unit of measure. To continue the prior example, 11,000 storage bays × 1.2 m2 of floor space (1.2 meters deep × 1.0 meters wide) = 13,200 m2 of floor space needed just for inventory.
- **Factor in space for all inventory movements.** Multiply this result by a factor that is greater than one to account for space around inventory in each storage bay, aisle space, handling equipment space, and space for picking, sorting, consolidating, and so on. This is typically at least a multiplier of three. Organizations can analyze existing warehouses that use the same types of warehouse equipment to

determine the right factor to use. In this example, the factor is 3, so the calculation is 13,200 m2 × 3 = 39,600 m2.

- **Account for vertical space utilization.** Determine how many levels of vertical storage will exist for pallet storage bays. For example, if there will be four levels of vertical storage for all bays, then the raw space footprint could be divided by four (e.g., ground storage plus pallet racks that are three levels high). In this example, there are four levels, so the calculation is 39,600 m2/4 = 9,900 m2.
- **Add space for expansion or excess capacity.** Divide by a factor for the target utilization of the warehouse. This is a way of building in excess capacity. For example, if the target utilization rate is 80 percent, then the warehouse floor space would be divided by this percentage to find the total necessary space. In essence, this warehouse would be only 80 percent full under the current forecasts. This utilization rate would be set by organizational policy based on strategic and risk analyses. Since the rate here is 80 percent, the calculation is 9,900 m2/0.8 = 12,375 m2. This much land could be leased or purchased to build a new warehouse, or an existing warehouse of this size (and sufficient vertical height for the racks) could be leased or purchased.

Note that there are many ways of determining warehouse space capacity requirements. Organizations that use fixed-location storage, for example, may use maximum inventory requirements rather than average inventory requirements so as not to run out of space when orders arrive. Additionally, the space requirement could be divided among several distribution centers. If this is the case, the volume of goods to be stored in each warehouse would be divided first, and then the remaining adjustments would proceed separately. This would result in a larger total space requirement, because each warehouse would need its own functional areas for goods handling.

Topic 2: Warehouse Capabilities

Warehouses today offer economic and service benefits that go well beyond simple housing of raw materials, parts, or finished goods. On the economic side, warehouse operations can reduce the overall cost of logistics by their efficiency and effectiveness in receiving goods and packaging or arranging them for reshipping. At the same time, warehouse operations may improve customer service by cutting lead times, packaging goods for easy handling and identification, and arranging shipments to fit the recipient's unique requirements. Warehouses are places of constant activity as workers and machines unload, store, retrieve, repack, arrange, and reload inventory that they may also assemble-to-order.

Let's take a look at some warehouse activities and functions.

Warehouse activities

The following value-added activities may take place in a warehouse:

- **Receiving** is defined in the *APICS Dictionary,* 16th edition, as

  > encompassing the physical receipt of material, the inspection of the shipment for conformance with the purchase order (quantity and damage), the identification and delivery to destination, and the preparation of receiving reports.

- **Prepackaging** refers to when products are received in bulk from a supplier and subsequently packaged in smaller quantities or combined with other products to form kits or assortments.

- **Put-away,** as defined in the *APICS Dictionary,* 16th edition, involves

  > removing the material from the dock (or other location of receipt), transporting the material to a storage area, placing that material in a staging area and then moving it to a specific location, and recording the movement and identification of the location where the material has been placed.

- **Storing** refers to putting items under warehouse control (in a storage point upstream of a work station).

- **Order picking** is defined in the *APICS Dictionary,* 16th edition, as

  > selecting or "picking" the required quantity of specific products for movement to a packaging area (usually in response to one or more shipping orders) and documenting that the material was moved from one location to shipping

  It is also known as order selection.

- **Moving** is "the physical transportation of inventory from one location to another within a facility" (*APICS Dictionary,* 16th edition).

- **Shipping** is defined in the *Dictionary* as

  > the function that performs tasks for the outgoing shipment of parts, components, and products. It includes packaging, marking, weighing, and loading for shipment.

Packaging and **packing and marking** are related to this definition.

Packaging is

> the materials surrounding an item to protect it from damage during transportation; the type of packaging influences the danger of such damage.

Packing and marking includes all

> the activities of packing for safe shipping and unitizing one or more items of an order, placing them into an appropriate container, and marking and labeling the container with the customer shipping destination data as well as other information that may be required.

Warehouse functions

Functions that add supply chain economic or service value include

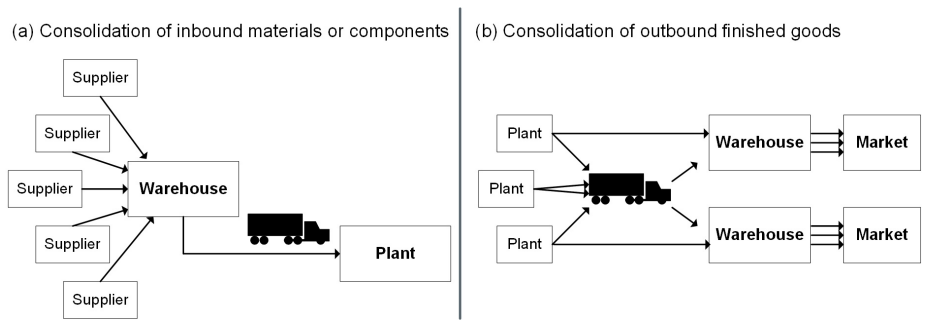
- Consolidation of materials for shipping
- Break-bulk and cross-dock facilities
- Postponement
- Stockpiling seasonal inventory
- Spot-stocking advance shipments
- Assortment (similar to spot-stocking)
- Mixing (similar to break-bulk).

Consolidation

Consolidation occurs when a warehouse receives materials from more than one plant and combines them into outgoing CL or TL shipments to a specific customer. It reduces logistics costs through economies of scale, because the consolidated shipments more easily qualify for CL and TL discounts. It also reduces congestion at the customer's dock. However, the warehouse may have to add sorting and perhaps assembly capability. There will be training and possibly hiring costs—plus costs for remodeling if more space is required.

Exhibit 2-85 provides a graphic view of consolidation as it functions for inbound shipments (a) and outbound traffic (b).

Exhibit 2-85:
Consolidation



Break-bulk and cross-dock facilities

Operations at break-bulk and cross-dock facilities are similar except for the way orders come into the warehouse.

The *APICS Dictionary,* 16th edition, defines **break-bulk** as

> (1) Dividing truckloads, railcars, or containers of homogeneous items into smaller, more appropriate quantities for use. (2) A distribution center that specializes in break-bulk activities.

A break-bulk facility can build new truckloads of assortments of goods all destined for a given location.

The *Dictionary* defines **cross-docking** as

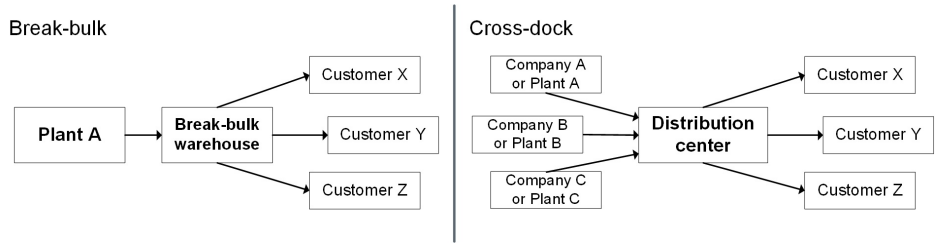
> the concept of packing products on the incoming shipments so they can be easily sorted at intermediate warehouses or for outgoing shipments based on final destination. The items are carried from the incoming vehicle docking point to the outgoing vehicle docking point without being stored in inventory at the warehouse. Cross-docking reduces inventory investment and storage space requirements.

An example of a break-bulk operation is food retailers. They receive full truckloads (26 pallets) of combined customer orders from manufacturers. The break-bulk warehouse sorts or splits individual orders and ships them to the retail customers. Because the long distance transportation movement is a large shipment, transport costs are lower and there is less difficulty in tracking. Walmart provides an example of cross-docking. Walmart's customers are its retail stores. If a supplier sends 1,000 camping cots, the right number gets put in each truck bound for a different retail location as part of the assortment of goods for that store.

Break-bulk and cross-dock facilities provide the benefits of consolidated, full-trailer shipment into the facility, out of the facility, or both. They also reduce handling costs because put-away and picking are avoided.

Exhibit 2-86 depicts break-bulk and cross-dock operations.

Exhibit 2-86: Break-Bulk and Cross-Dock Operations



Postponement

Goods enter a postponement center in component form for later final assembly. Final configuration of the finished product is postponed until an order arrives, allowing parts to be assembled to fit the specific order. For example, since Europe uses four different plugs for electricity, generic printers arrive at a European distribution center and, once orders are received, workers add the correct cable along with written materials and labels in the correct language.

Components can generally be stored more efficiently than finished products. Also, forecasting is easier for the group of products that can be assembled from the parts than it would be for the separate end products. If the warehouse contained finished products, it would require safety stock for each item. There will, however, be costs for training or hiring staff with final production skills. Processing at the warehouse may be more expensive than finishing the product at the plant would have been.

Anticipation (stockpiling inventories)

Anticipation inventory, such as seasonal clothing, lawn furniture, or agricultural products, is stored at the warehouse in anticipation of future demand.

Stockpiling enables more efficient use of production capacity by reducing the need to increase capacity for the seasonal demand. In the case of agricultural products, it's the "production" that is seasonal rather than the demand. So the product is stored in larger amounts as it becomes available and then distributed as demand comes in. A disadvantage of stockpiling is that more warehouse capacity is required than would be necessary for a Just-in-Time delivery system.

Spot-stocking

Spot-stocking is focused on strategic markets. It is allocating inventory in advance of heavy demand in strategic markets rather than the inventory being stocked year-round or shipped as it's being produced.

Advance shipments from a plant are sent to key markets to be sure they are close to customers in season. Agricultural products are spot-stocked during the harvest season to put them close to key markets and then are warehoused centrally for the rest of the year.

Customers and producers benefit from spot-stocking of items in key markets to minimize the chance of a shortage during peak demand.

Assortment warehousing

Assortment warehousing is a technique that stores the goods close to the customer to ensure short customer lead times.

Assortment benefits the customer by reducing the number of suppliers it has to deal with to acquire the assorted goods. It also reduces transport costs by allowing larger shipment quantities.

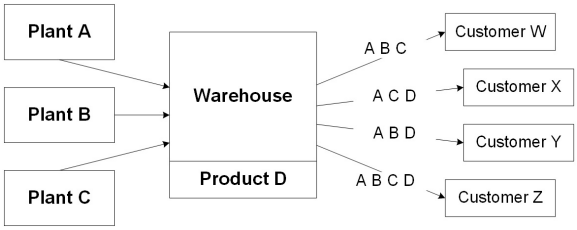
Mixing

Mixing resembles break-bulk but involves shipments from more than one manufacturer. In a typical mixing setup, the warehouse receives full-vehicle shipments of different products from manufacturers in diverse locations, with each shipment receiving the full-load discount. (A full-load discount is a quantity rate discount offered for a full cargo container, carload, or truckload, e.g., usually set at 10,000 pounds (4,536 kilograms) for a truckload. A full load may occur when the cubic volume is full or when the weight limit is reached, whichever comes first.)

At the warehouse, shipments are broken down and assembled into the product mix desired by each customer or market. A particular outgoing shipment may contain goods that just arrived (as in break-bulk or cross-dock facilities), or it may combine the current shipment with products from storage.

Mixing avoids multiple smaller shipments from each manufacturer along with the required separate handling, storage, and display. It also makes more efficient use of storage space in the warehouse. Exhibit 2-87 illustrates the process of mixing shipments.

Exhibit 2-87: Mixing



Topic 3: Materials Handling

The goal of warehousing is to contribute the maximum possible value to the supply chain by making the most effective use of warehouse space, human labor, equipment, and software, automation, and information technology. When all of these considerations are combined effectively, they provide the most efficient movement of goods, the easiest location of stock, the least time spent in stock location and order picking, and the most effective use of available space for storage and all activities.

While all warehouse tasks used to be accomplished by manual labor, mechanical or automated assistance can make most tasks easier, faster, and more efficient. When selecting the best combination of equipment and human labor for the products, space, and type of operations, the logistics manager will most likely need the assistance of warehouse equipment experts who have access to optimization software.

As always, there will be tradeoffs. Equipment or automation may add to expense without increasing value if it can't be used effectively in the available space; conversely, it may be justified by future cost savings.

In this section we will explore mechanized and automated systems as well as warehouse management systems and related information technology.

Mechanized systems

Mechanized systems include a wide range of types of materials-handling equipment, including forklift trucks, conveyors, towlines, tow tractors with trailers, bridge and wagon cranes, and carousels.

Forklift trucks

The first task in materials handling is to unload the vehicle—boat, plane, train, truck. The vehicle of choice is the forklift truck.

Type of fuel, amount of lifting power, size and shape (some models are adapted especially to narrow aisles), and other features can be mixed and matched. Forklifts allow pallets to be raised to the tops of high stacks (and lifted back down) to take advantage of tall warehouse spaces. Some models are adapted to lifting slipsheets used, for instance, by Home Depot instead of pallets. (A slipsheet is a thin, pallet-sized sheet of plastic, laminated paperboard, or corrugated fiberboard that slides underneath a load.) Automation is making some inroads even in forklifts; the familiar forklift is available in a computer-controlled, driverless model.

Conveyors

Conveyors, as seen in Exhibit 2-88, move goods into or out of some types of vehicles and storage spaces. The basic decision when selecting a conveyor is whether or not to have a motor. The roller conveyor relies on gravity to move goods slowly down the line; the belt conveyor (or conveyor belt) is motorized to provide more speed or move goods uphill. Conveyors can be equipped with scanners to read bar codes on items traveling along them, thus speeding up inventory and reducing error rates.

Exhibit 2-88: Conveyor

Source: Photograph used with permission from Metzgar Conveyors, © 2011.

Conveyors offer several advantages:

- Inexpensive operating costs (especially with the roller type)
- Reduced labor costs (including costs for injuries and accidents)
- Efficient use of space (They fit into narrow aisles.)
- Ability of scanners to read bar codes or RFID
- Movement of far more inventory than trucks could move at far less cost (for example, moving coal from a mining area to a storage area)

The tradeoff is that using conveyors can potentially block access to the area where loading takes place.

Towlines

The towline, shown in Exhibit 2-89 and also called a towline conveyor, uses a four-wheeled container that is towed by a dragline, which can be mounted overhead or in the floor. Overhead lines are easier to install and move than in-floor lines. Some automated models can be uncoupled from one line and attached to another, giving them access to more than one dock. Overhead lines with automated decoupling provide more flexibility than standard belt or roller conveyors, but, on the whole, they are much less flexible than forklifts.

Exhibit 2-89: Towlines

Source: Photograph used with permission from Rhodes Systems International, Inc., © 2011.

Towlines may also be equipped with scanners to identify the goods being conveyed. Automated systems can be complex and very expensive.

Towlines provide several advantages:

- Efficient use of space (They fit into narrow aisles.)
- Potential to improve inventory identification and accuracy

Tradeoffs include the following:

- Requirement of heavy capital investment when automated
- Need to invest significant time and money to design complex systems
- Relatively rapid obsolescence, especially in elaborate systems

Tow tractors with trailers

Tow tractors can pull several trailers conveying pallets. They are generally used, like towline conveyors, in order selection. Tow tractors are not automated, and, because they require a driver, they are more expensive to operate than towlines. However, they are also more flexible.

Bridge and wagon cranes

For heavy lifting, warehouse managers may turn to cranes. The two basic types are bridge cranes and wagon cranes.

The “bridge” part of a bridge crane, shown in Exhibit 2-90, is a horizontal girder, or pair of girders, that rests at each end on a truck.

Exhibit 2-90: Bridge Crane

The trucks run along tracks, giving the crane the ability to move objects horizontally in the direction of the runway. They can also move objects perpendicular to the track, along the direction of the girder that runs between the tracks.

Because they are suspended, bridge cranes leave the floor space below them free for other activities and allow aisles to remain narrow to free up storage space. Bridge cranes are best used in low- to medium-volume activities that require moving items that are large, heavy, or awkward to maneuver.

Wagon cranes, also called crane trucks or stacker cranes, offer the mobility that is provided by forklifts and is absent from conveyor systems. They can negotiate narrow aisles and use all three dimensions of warehouse space—height included. They are available in fully automated models that can lift objects in and out of storage without the assistance of a human operator.

Though these cranes are generally used to lift and swing objects that are too heavy or oddly shaped to be moved by other types of equipment, they can also be used to move objects horizontally for short distances.

Advantages of cranes include

- Easy access to most areas within the lifting bay (bridge crane)
- Extension to areas outside the building (bridge crane)
- Ability to lift heavy objects that can't be handled with forklifts or conveyors (especially the bridge crane)
- Ability to negotiate narrow aisles and to use all dimensions of a warehouse, including its height (wagon crane)
- Overhead suspension that leaves all floor space free for other uses (bridge crane)
- Available with radio control for remote operation (bridge crane) or fully automated for driverless picking and storing of items.

The main drawback of either type of crane is capital expense. The logistics manager may have to justify the expense by documenting the crane's appropriateness to the functions and space requirements of the

warehouse.

Carousels

A carousel consists of a series of bins mounted on an oval track with the option of multiple track levels. The entire carousel rotates, moving inventory to a stationary order selector rather than requiring that person to go to the inventory storage location.

The advantages of using a carousel include the following:

- It reduces labor required for order selection by reducing walking length and time.
- It can significantly reduce storage requirements, especially when stackable or multitiered carousels are used.
- Paperwork can be eliminated when the system uses computer-generated pick lists and carousel rotation.

A pick-to-light system uses a series of lights that indicate the right pick location and the number of items to remove from that bin in the carousel. In some pick-to-light systems, a computer generates the pick lists and operates the carousel.

Advantages include

- Efficient use of floor space
- Reduction of time and labor required to pick items from storage
- Available automation to further enhance productivity.

Automated systems

Mechanized handling methods are often supplemented by automated systems, which can include automated guided vehicle systems, automated sorting systems, robotics, live racks, and automated storage and retrieval systems.

Automated guided vehicle systems

Automated guided vehicle systems (AGVS) perform much the same type of work as pallet trucks or tow tractors with trailers, and they operate without a rider. Instead of running on tracks, they move along optical tape or a magnetic wire in the floor, and they can be programmed to stop at various stations along their paths. Models are available with tines for lifting pallets or with platforms; some models are specially designed to move materials into high storage areas along narrow aisles.

Advantages include

- Programmability to increase flexible use without the expense of a human operator
- Ability to maximize use of warehouse space by operating in narrow aisles and providing access to high shelves.

The primary drawback is the high cost of acquisition.

Automated sorting (sortation) systems

Generally used with conveyors, automated sorting systems direct items on a conveyor into their proper locations in a shipment. The system receives the required sorting information from a code on the master

cartons of the items to be shipped. Most automated sorters can be programmed to work at different speeds to fit the requirements of particular shipments.

Advantages include

- Reduced labor costs
- Increased speed (up to one package per second).

Robotics

Robotics in warehousing is used to build and break down unit loads. To break down a load, the robot is programmed to recognize product stacking patterns and place products in a predetermined position on the conveyor belt. To build unit loads, that process is reversed.

The following are advantages of using robotics:

- It can be used in situations that are difficult or dangerous for humans, such as high noise areas or areas with extreme temperatures (such as food freezers) or in working with hazardous materials.
- It has the capacity to integrate program logic and increase speed, dependability, and accuracy.

The drawback of robotics can be the cost. For example, Amazon paid US$775 million to purchase warehouse robotics system manufacturer Kiva in 2012 to control the cost of these devices, which is still US$15 to US$20 million per warehouse after the purchase, according to an article by Ananya Bhattacharaya. Amazon also restricted these systems to its exclusive use. Since there were no similar competitors, it took the industry four years to develop viable alternatives, according to an article in Bloomberg News by Kim Bhasin and Patrick Clark. By 2014, Amazon had 30,000 robots operating in 13 of their 110 warehouses. These robots pick up storage racks and move them to where they are needed, and since the robots require less space to operate, the warehouses that use them can hold 50 percent more inventory per square foot, cutting operating costs by 20 percent, or close to US$22 million, per warehouse. They also reduce the “click-to-ship” cycle to 15 minutes from 60 to 75 minutes. If implemented in all warehouses, Deutsche Bank estimates this would be a one-time savings for Amazon of US$800 million net of robot installation costs.

Live racks

The live rack contains roller conveyors and is designed to be loaded from the rear where it is elevated, thereby using gravity to move product to the front. When an item or carton is removed from the front, the items behind it slide forward.

Using live racks provides these advantages:

- It reduces the need for lift trucks to transfer unit loads.
- It offers automatic rotation of product—the first product on the conveyor will be the first out (first-in, first-out, or FIFO).

A drawback of using live racks is that access to the stock in the middle can be hampered.

Automated storage and retrieval systems

The most advanced automated systems are called automated storage and retrieval systems (AS/RS). In addition to automating both storage and retrieval, these systems feature very high storage racks that multiply

the capacity of the warehouse.

The storage and retrieval functions are handled by a programmable AS/RS machine that moves both horizontally and vertically. The storage racks themselves may rise 100 feet or more, towering over standard warehouse racks. Because of the design of the storage and retrieval machine, the racks can be arranged along very narrow aisles.

The AS/RS machine is programmed at pickup and discharge stations located at the ends of aisles. Another handling device, such as a towline, conveys incoming items to the AS/RS, which is programmed with instructions for delivering the items to specific bins in a specific sequence.

When an AS/RS is being sent into the racks to retrieve items for an outgoing shipment, software helps it find the required items in the most efficient way. The AS/RS machine moves through the racks at high speeds—300 to 400 feet per minute horizontally and 100 feet per minute vertically. Computers may be dedicated to the AS/RS station.

The advantages of AS/RS systems include

- Maximum storage density per square meter or foot of floor space
- Tight control of storage and retrieval for high speed and freedom from error and pilferage
- Reduction of labor costs (and human error).

The obvious drawback is cost. AS/RS systems are complex, large, and very expensive. Other disadvantages may include added labor required to properly put away materials, dedicated space, loss of flexibility (it's not easy to move such a system), and equipment failures.

Comparison summary

A summary of the mechanized and automated materials-handling options is provided in Exhibit 2-91.

Exhibit 2-91: Materials-Handling Options

Type	Features and Uses	Benefits	Limitations
Mechanized Systems			
Forklift trucks	• Load and unload vehicles • Lift pallets or slipsheets • Available in numerous configurations and automated	• Flexible delivery in all directions • Can lift and retrieve in high shelf areas • Automation becoming available	• Expense to buy, train, and maintain • Inventory damage • OSHA requirements
Conveyors	• Store and retrieve goods • Load, unload some types of vehicles • Motorized/ nonmotorized • Scanners for fast, accurate information	• Inexpensive operation • Reduced labor costs • Efficient use of space	• May block access to aisles and/or shelves
Towlines	• Four-wheeled container towed by dragline (floor or overhead mount) • Used in order selection • Automated models can	• Efficient use of space • Can improve inventory identification and accuracy	• Expensive to automate, use in complex systems • Rapid obsolescence

	switch lines • Scanners available		
Tow tractors with trailers	• Like towlines, used mainly for order selection • Can tow multiple trailers • Driver required	• More flexible than towlines	• More expensive than towlines (driver)
Bridge and wagon cranes	• For heavy lifting • Bridge cranes: overhead on movable girder • Wagon cranes: on floor (like forklifts)	• Can lift heavier objects than forklift or conveyor • Efficient use of space • Automation, remote operation available (bridge)	• Very expensive • Single bay linear travel only
Carousels	• Series of multilevel bins on oval track • Rotates • Moves inventory to a stationary order selector	• Reduces order selection labor • Reduces storage requirements • Eliminates paperwork given computer-generated pick lists and rotation	• Item size • Item weight

Type	Features and Uses	Benefits	Limitations
Automated Systems			
Automated guided vehicle systems	• Move on floor on tape or wire • Similar in use to forklift and tow tractors • Riderless with programmed stops • Can have tines or platforms	• Programmable for flexibility without need for operator • Maximum use of space; fit in narrow aisles, reach high shelves	• High acquisition cost
Automated sorting systems	• Usually used with conveyors • Automate direction of items into shipments • Most devices programmable for different speeds to fit shipment specifications	• Reduced human time and labor for retrieval and storage • Speeds of up to one package per second	• High acquisition cost
Robotics	• Used to build and break down unit loads • Programmed to recognize product stacking patterns and place products in a predetermined position on the conveyor belt	• Used in difficult or dangerous environments • Can integrate program logic • Increases speed, dependability, and accuracy	• High cost
Live racks	• Contains roller conveyors • Designed to be loaded from the rear, where it is elevated, using gravity to move product to the front of the rack	• Reduces the need for lift trucks to transfer unit loads • Offers the potential for automatic rotation of product	• Little access to the stock in the middle
Automated	• Automate storage and	• Maximum storage	• High cost

storage and retrieval systems	retrieval • Use very high storage racks • Machine moves both horizontally and vertically • Programmed at end-of-aisle station	allowed per square foot of floor • High storage and retrieval speed with few errors • Reduced labor cost and human errors	

Warehouse management systems

The term “warehouse management system” (WMS) can refer to any set of procedures for the efficient operation of a warehouse, but it typically refers to a software system. The general goal of WMS is to improve the quality of all aspects of warehousing beyond what would be possible without the software. As software sophistication has increased, warehouse management systems have become more tightly integrated with enterprisewide programs that manage overall supply chain operations.

The specific features and benefits of WMS software were covered elsewhere.

Information technology

To perform the inbound receiving process, warehouse personnel need to know what the inventory is and where best to take it (rack storage, bulk storage, outgoing dock, break-bulk, sorting, packaging, and so forth), even if the organization has millions of SKUs, as is the case for many large businesses. For the order picking and filling process, warehouse personnel need to know exactly where the required items are stored and in which order to pick the items. The fastest-moving products or parts should be the most easily accessible, while the slow movers can be parked out of the way. Advances in information technology such as the following have made intelligent, efficient storage and retrieval much easier over the past 30 years, and there is promise of even greater advances in the future.

Electronic data interchange

Electronic data interchange (EDI) makes it possible to direct information around the entire supply chain (not just the warehouse) by helping computers “understand” the format of the information. For instance, purchase orders can be transmitted electronically.

Bar coding

Bar coding enables a warehouse worker to use a scanner to send encoded data directly to a database. The savings in time and supplies, and the reduction of errors, have made the bar code phenomenally successful.

Radio frequency identification

RFID relies upon digitized information contained in a tag placed on the product. When the tagged object comes within range of the reader, the antenna picks up the pulse and sends its coded information to the reader. The readers can be handheld or attached to devices such as conveyors and forklifts. RFID can link the data on the tag’s chips to networks and the internet. This means that all supply chain partners can receive the same information at about the same time.

Automatic identification technologies

“Automatic identification technologies” or “automatic identification and data capture (AIDC)” are umbrella terms used to refer generally to bar codes, RFID, voice recognition, smart cards, optical scans—any technology that offers automated scanning of information from a product. These technologies may also refer to advanced uses of RFID and the internet, a conjunction sometimes called “an internet of things.”

AIDC devices 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 AIDC system are faster information visibility and increased transaction accuracy and processing speed. In a world of networked supply chains, automatic identification promises enormous benefits, including more efficient warehousing and much more.

As the price of RFID technology drops and as supply chains synchronize networkwide enterprise resource planning software and powerful hardware, benefits such as the following will become commonplace:

- Automation will allow supply chain partners to check the items in a shipment without unbundling a pallet.
- Inventory tracking will be continuous, automated, and always current.
- Tracking of individual items electronically will reduce—if not eliminate—theft by signaling when items are moved inappropriately.
- Counterfeiting will be reduced when each item has a unique identifier.
- The supply chain manager will be able to select from the gathered data just the key information needed to run the operation better.

EDI, bar coding, RFID, and AIDC are also discussed elsewhere.

Chapter 12: Transportation

This chapter is designed to

- Describe the dual objectives of transportation
- Discuss how to forecast transportation capacity
- Discuss how to assess capacity constraint factors when evaluating bids from carriers
- Enumerate advantages and disadvantages of transportation modes
- Enumerate hybrid modes of transportation
- Discuss selection of the appropriate mode of transportation given various factors
- Describe the value density versus packaging density relationship.

Transportation, like warehousing, is a key logistics function. A balance must be achieved when weighing the costs of warehousing to reduce lead times against the costs of transportation. The revolution in transportation has created the majority of the possibilities and challenges of modern business logistics. Deregulated transportation gives logistics managers the power and responsibility to refine their supply chain's transportation tactics and provide tangible benefits to the organization's bottom line.

Topic 1: Transportation Objectives and Constraints

We'll begin our consideration of transportation by looking at two of its objectives: product movement and temporary storage. Next we'll examine capacity constraints and capacity forecasting and planning.

Transportation objectives

The primary objective of transportation is product movement: carrying goods and materials between supply chain partners and customers. A secondary objective is providing temporary storage for in-transit inventory.

Product movement

Since the movement of materials around the supply network is both necessary and expensive, keeping down the costs in time, money, and environmental impact is of strategic importance.

Efficient use of time

Efficient use of time is a factor in developing a successful transportation strategy because inventory in transit isn't available for use in production or for sale to customers. This puts a premium on moving materials and goods as infrequently and as rapidly as possible. But the premium isn't absolute. There are tradeoffs to consider, since faster transport modes are expensive.

Transportation costs also trade off against inventory costs. Tactics such as Just-in-Time delivery emphasize reduction of inventory costs, and one method of keeping down inventory is to ship more frequently—thus possibly raising transportation costs.

Efficient use of money

Efficient use of money provides a complex set of challenges to the transportation planner, since transportation drains the logistics budget in a variety of ways. As always, it is advisable to consider all the factors that contribute to total cost. You want to become more cost-efficient in one area without raising costs by a greater amount in another area. **Line haul costs** need to be determined. These are defined in the

APICS Dictionary, 16th edition, as

> basic costs of carrier operation to move a container of freight, including driver's wages and usage depreciation. These vary with the cost per mile, the distance shipped, and the weight moved.

Line haul costs include the following:

- **Vehicle costs.** A supply chain partner can choose between controlling its own fleet of vehicles, hiring transportation as needed, or contracting with a carrier for a longer term. With a company fleet, the company incurs internal costs for financing, leasing, and depreciation; with commercial or public transportation, the company incurs external costs. (We'll cover other variables affecting transportation selection later.) Certainly, in a global supply chain, there are additional challenges that can make it extremely difficult to control your fleet worldwide.
- **Driver/operator costs.** Unless the mode of transport is a pipeline, transportation includes the cost of labor required to operate the vehicle—drivers for trucks; pilots, copilots, and crew for air transport; engineers for rail; and so forth. Driver shortages can drive up costs due to higher market wages, difficulties with certification, lack of investment capital, and expanded regulation.
- **Vehicle operating costs.** Operating and maintaining a fleet of owned or leased vehicles requires expenditures for repairs, cleaning, parking, etc. As fuel prices rise, operating expenses increase for road, air, rail, and water transportation. One way in which steamship companies are minimizing their costs is by running their ships more slowly to consume less fuel, which increases delivery time. For example, Wärtsilä, a ship engine producer, has calculated that reducing cargo ship speed from 27 to 18 knots results in a 59 percent fuel savings at a cost of one extra week in transit between the far East and Europe, or fuel savings of more than US$2 million for a one-way trip. Other companies use semi trucks without sleeping cabs or extra wheels to reduce the overall weight.
- **General and administrative costs.** Funds must be allocated to management of the transportation function.
- **Insurance and security costs.** With a private fleet, a company pays insurance costs to cover a variety of security concerns. Products may be damaged, lost, or stolen in transit. Transporting hazardous materials requires extra expense for insurance coverage, for security, and to comply with regulations. Air, rail, and water transport must provide protection against terrorism as well as vandalism and theft.

Minimal harm to the environment

Finally, transportation of all types makes demands on the environment, some of which show up as costs of doing business. Transportation constitutes a large portion of domestic petroleum consumption in the United States and a rapidly growing amount in other areas of the world, especially in emerging economies such as China and south Asia.

As supply chains extend over increasing distances, fuel for commercial transport and the pollution that goes with it are bound to become increasingly problematic. The costs of fuel and the associated pollution add to the reasons for managing transportation and information efficiently.

However, some progress is being made on this issue both in the U.S. and the European Union.

For the neighboring ports of Los Angeles and Long Beach, California, the Clean Truck Program was signed into law in 2008, requiring diesel-powered, short-haul drayage trucks to meet new environmental standards that will reduce their air pollution by 80 percent. (Drayage trucks transport shipping containers from docks to off-site warehouses.) These diesel trucks were to be retrofitted or replaced in order to meet the new emission standards enacted in 2012. Trucks that do not meet the standards currently pay a fine but will eventually be banned from Los Angeles and Long Beach. Since these ports handle nearly 45 percent of container goods entering the U.S. and container volume is expected to triple by 2020, this is a significant step in reducing harmful pollutants in these areas.

The U.S. EPA's Clean Air Nonroad Diesel Rule (also known as Tier 4), affecting industrial equipment, generators, and transportation infrastructure such as heavy forklifts and airport service equipment, was fully implemented in 2015, reducing allowed particulate matter and nitrogen oxides. Ultra-low-sulfur diesel was also fully implemented in 2014 for nonroad, locomotive, and marine engines. (It was fully phased in for trucks in 2011.)

The European Union has established low emission zones (LEZs) in which high-polluting trucks are prohibited. Specifically, regulations prohibit higher-emission heavy-duty diesel trucks from entering certain EU cities. Vehicle emissions are classified into Euro standards for the vehicles they apply to; trucks are rated Euro VI, Euro V, Euro IV, etc., with the lower numbers having more restrictions due to their higher emissions or lack of particulate filter or catalytic converter. Before a truck enters into an LEZ, the driver must know the emissions standard for that particular vehicle. (For more information on emission standards, see the links in the online Resource Center.)

Note that transportation also affects the environment through water and noise pollution.

Adopting fuel-efficient vehicles and developing new fuels that aren't petroleum-based may slow the growth trend, but any declines resulting from fuel efficiency will be balanced against greater consumption of other resources as markets continue to develop around the world. Not all of these effects are reflected in the costs of doing business.

Temporary storage

Transportation vehicles are not designed for long-term storage and are generally not used for that purpose. Nevertheless, it can sometimes be more economical to "warehouse" inventory in a vehicle than to unload, store, and reload the carrier. However, that necessitates space to park the vehicle, and fees are charged for temporary parking of a trailer. Carrier charges and fees are also added when land or water vehicles are retained beyond a specified loading or unloading time. Those charges are called demurrage fees if they involve rail freight cars or ships and detention fees if they pertain to truck trailers. If the goods to be stored need to be kept at a certain temperature, refrigerated trailers may be utilized and kept running as long as temporary storage is needed, but this can be quite costly.

Three situations provide the most frequent examples of the use of vehicles for temporary storage:

- **Short-term storage.** Trailers and railcars sometimes park at a facility without being unloaded if the

contents need to be stored but are scheduled to move again in a few days. In the global arena, logistics parks (designated areas for storage and distribution built to complement industrial zones) are a growing option for efficient short-term storage. Some trucking companies have their trucks set up with two trailers so the driver can park one temporarily outside an urban area. After the first delivery, the driver retrieves the second trailer and delivers those goods. Logistics warehouses in China are classified as either bonded or nonbonded. Bonded logistics parks (BLPs) are often located near ports and serve as cost-effective holding areas where shipping orders can be consolidated from various locations before being exported. Nonbonded logistics parks, which have cheaper rental rates than BLPS, are increasingly being developed on the expanding road network (such as that connecting Shanghai to other cities in the Yangtze River delta).

- **Crowded facility.** If a warehouse is too full to accept the contents of an arriving truck or railcar, some of the contents of the warehouse may be loaded into another vehicle. That vehicle then takes a slower and often cost-equivalent or cheaper route to its destination. In other cases, the limited shipping dock capacity at the outgoing facility may be the reason to ship something early but by a slower method. In some cases, the cost-equivalent but slower method will be intermodal. The tradeoff in extra transportation time and costs must be balanced against the enhanced storage capacity.

- **Changed destination.** With global positioning to track in-transit inventory, while one generally needs to select a destination to release an order, the destination could be changed mid route. Reasons to divert a shipment of goods while in transit include to make the best use of available warehouse space or to accommodate changes in customer orders, such as last-minute cancellations or new orders. In the case of crude oil, in many cases the oil is traded on the market as soon as the tanker is under way toward a general destination like the U.S. West Coast, and the delivery time frame continually grows shorter as trading continues. The final owner chooses the specific destination based on the best available deal.

Transportation capacity forecasting and planning

As with warehouse capacity, transportation capacity needs to be forecasted and planned in advance. Transportation capacity is easier to scale up quickly than warehouse capacity, since there are numerous options for increasing carrier capacity. Doing so efficiently and economically is the challenge.

A number of constraints on transportation capacity need to be considered when forecasting and planning, so these are discussed first.

Capacity constraints

When evaluating bids from carriers or forecasting transportation requirements, a logistics manager should understand the capacity constraints with which he or she is operating, including distance, volume, density, stowability, handling, liability, and conflicts of interest. The following discussion analyzes the impact of these factors.

Economies of distance and scale

Constraints in these categories include distance, volume, and density.

- **Distance.** The farther your shipment travels, the more it will cost you. It consumes more fuel, requires

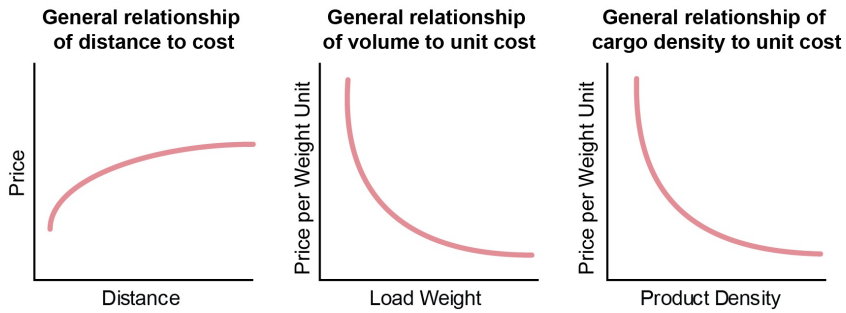
more labor, causes more wear and tear, and, in general, increases variable costs. However, the principle of economies of distance—similar to economies of scale—decreases the impact of that upward trend. The reason is that all miles are not equally costly, and longer trips usually include a greater percentage of the less-expensive miles. Exhibit 2-92 graphs the relationship in a general way.) For one thing, starting and stopping use more fuel and cause more stress on vehicles than cruising. Line hauls especially benefit from this phenomenon, because they generally include a large proportion of highway miles.

- **Volume.** As you pile more weight into a vehicle payload, economies of scale reduce the cost per pound or kilogram, as pictured in Exhibit 2-92. Why? Because you're spreading fixed costs over a larger number of units. Thus, a full load is more cost-effective to transport than a partial load, so consolidate your small loads into larger ones whenever possible. If you don't do so, the carrier may do it for you by adding stops to take on cargo to fill the empty spaces. Someone has to pay for those side trips.

- **Density.** In shipping, low-density goods will cost much more per pound or kilogram to transport than denser goods like coal, the reason being that a truck filled with feathers is carrying far less weight than a truckload of highly dense coal. The variable costs for labor and fuel aren't much affected by the weight of the load, and the fixed costs are spread over the greater number of pounds or kilograms. Density can be increased by packaging as well. For example, motorcycles can be more densely packed for shipping as parts than as fully assembled, operable vehicles.

There is a limit to the positive effects of high-density shipping, however, because there is a cap on the amount of weight a truck can carry—legally or practically. Dense liquids, such as laundry detergent, will reach the weight limit long before filling up the volume of a truck. Setting aside that limiting case, Exhibit 2-92 graphs the general relationship of increasing density to decreasing cost per pound or kilogram of cargo.

Exhibit 2-92: Economies of Distance and Scale in Transportation



Stowability

Items with odd shapes that prevent them from efficiently sharing cargo space cost more to ship than items of similar density and weight that stow more efficiently. Redesigning awkwardly shaped products for efficient storage can greatly reduce the costs of transport and warehousing. For example, items shipped in bales are given a less expensive freight rate by shippers than the same items shipped in individual sale units, to

account for the lower total number of items that can fit in a vehicle payload.

Handling

Challenges involved in handling the cargo during the loading and unloading of vehicles affect pricing. Some questions to consider include

- Is special equipment required to move the cargo?
- Are physical dangers involved?
- Have the materials been properly grouped and packaged for ease of handling and storage all along the logistics supply chain?

How the freight is packaged and grouped before and during loading makes a considerable difference in ease of handling at all subsequent stages of the process. Consequently, packaging has significant cost implications. Different supply chain partners, with different concerns, will be affected by packaging and grouping—the shipper, the carrier, and the recipient (or recipients) who warehouse, distribute, and, finally, unpack the goods for display and sale. At the end of the forward logistics supply chain, someone has to dispose of the packing materials—the pallets, boxes, wrappings, etc.—by reusing, returning, or recycling them.

Consider, for example, automobiles. From the perspective of easy handling, both the shipper and the consignee—such as a car dealer—might be happiest to ship assembled vehicles that could be driven up and down ramps into and out of the shipping vehicle. To improve logistics, however, both foreign and domestic manufacturers now often ship parts and assemble the vehicles in plants near markets. Handling is far more efficient for containers of parts. (This can also improve postponement, since parts can be assembled into different models to fit market segments.)

Packaging also needs to take into account marketing without hindering logistics priorities of safe and efficient handling during shipping. The most productive, cost-effective packaging meets the following criteria:

- Efficiency of handling during loading, unloading, and storage
- Protection against damage to the cargo
- Communication (that is, packages should be labeled for ease of identification, tracking, customs, and handling)
- Low environmental impact

Liability

The cost of transport is affected by the need to protect the cargo against various dangers. If carriers are required to insure the cargo or cover any claims on their own, they will pass along the costs. Examples of major liability concerns include the following:

- **Susceptibility to damage.** Televisions, for instance, are more of a liability issue than paper products.
- **Perishability.** Fresh fish pose a series of problems. Any delays in shipment or refrigeration failures can be ruinous.
- **Value per pound.** Shipping precious metals or antiques exposes the carrier to liability risk.
- **Susceptibility to theft.** Some goods are more valuable than others to thieves and smugglers. The likelihood of theft is also increased if the cargo will sit for part of the trip or will change hands frequently. Shipments awaiting customs clearance are especially susceptible.

Conflicts of interest

Each party in the supply chain has different needs and goals. Suppliers typically idealize flexible delivery times, large yet stable volume demands, and consistent material mixes. Manufacturing organizations strive for high production output and low production costs. Logistics and warehousing management seek to minimize transportation costs by using quantity discounts and minimizing inventory levels. Finance wants to minimize order changes, inventory, and product variety. Retailers need short order lead times and quick delivery. Customers demand variety and low prices.

Historically, for one group's goals to be achieved, the goals of the others may be forfeited. In short, conflicts of interest seem to be built into the supply chain. Because of the advances in technology, supply chain managers now have the information resources to make strategic decisions for optimal impact throughout the supply chain. While tradeoffs had to be made in the past, it may now be possible to come close to meeting the goals of all participants in the supply chain. Here are some key examples.

- **Lot size versus inventory.** Manufacturers often prefer large lot sizes because they improve process control and reduce per-unit setup costs. However, this creates high inventory and storage expenses.

  Recent manufacturing processes seek to reduce inventories and improve system responsiveness. These processes make it possible to meet the needs of retailers and customers by enabling the manufacturer to respond more quickly to customer demand while retaining the process control cost efficiencies the manufacturer wants.

  Information technology can reduce the lead times required by manufacturers to react to the needs of supply chain partners. Technology also allows retailers and distributors to track the status of inventory throughout the process, enabling them to better manage customer expectations. The improved information flow also gives retailers and distributors a better idea of the process flow and the capabilities of manufacturers. The increased confidence level allows retailers and distributors to reduce the inventory held in anticipation of manufacturing problems. The result is better coordination of supply with demand.

- **Inventory versus transportation costs.** When a payload is full, the operating costs are distributed among more items, thereby reducing the per-item delivery cost. When payloads are only partially full, transportation costs are higher, as more deliveries—as well as more gas, salaries, and maintenance—are needed for the same amount of goods. However, when units are delivered by full loads, it takes longer for stock to be depleted, increasing storage costs.

  Information technology can minimize this conflict. Distribution control systems combine forecasting and delivery schedule information to allow a materials manager to transport goods from various warehouses together, minimizing deliveries and transportation costs. Retailers may also choose to combine shipments from different manufacturers by break-bulking. Decision support systems enable the supply chain to find a suitable balance between transportation and delivery costs.

- **Lead time versus transportation costs.** Lead time consists of time committed to processing orders, procuring and manufacturing items, and transporting items. While transportation costs are lowest when high quantities are transported together, lead times are reduced when goods are transported as they

are manufactured. So there is a tradeoff between holding items until there is enough build-up to reduce shipping costs and transporting them early to reduce lead time.

Information can be used to reduce the impact of this tradeoff. Consolidating into full shipments may reduce transportation costs, or other components of lead time may be reduced by using forecasting and information systems to anticipate demand.

- **Product variety versus inventory.** Organizations producing a variety of products incur higher manufacturing costs while their manufacturing efficiency decreases. In order to maintain lead times competitive with those of a manufacturer of fewer types of products, smaller amounts must be transported. The more different products a warehouse stores, the less space there is for any single product's inventory. An additional challenge is forecasting the demand for each product since each of the products is competing for the same customer. As a result, higher total inventory levels must be maintained to ensure the same level of service. Product variety, therefore, increases both transportation and warehousing costs.

  One solution is delayed differentiation, which involves shipping generic products as far out as possible, allowing the variations or customization to be added later. An example would be from a clothing manufacturer, whose main challenge is to predict which styles will have the most demand, since production begins months before the selling season. A shipment of blue jeans can have specific pant lengths be quickly finished at a distribution center before shipment. Delayed differentiation aggregates customer demand across all products. This produces a more accurate demand forecast with less variability, allowing reduced safety stocks and better matching of supply with demand.

Forecasting

With an understanding of the constraints on transportation and the tradeoffs that are needed for the organization's products, supply chain managers can forecast their transportation capacity requirements and thus develop plans for purchasing the right size and type of fleet or contracting with the right type of carrier and transportation mode. As with all capacity planning, the goal is to have sufficient capacity while avoiding the costs of excess capacity. Getting capacity just right moves the organization away from the reactive and toward the proactive—in other words, from an emergency mentality to a graceful flow of logistics.

The main problem with traditional transportation forecasting is that it is uses actual orders rather than demand forecasts, so the time available for planning is very short. Historical averages can be used, but these fail to account for critical forward-looking information such as an upcoming product promotion.

Emerging transportation capacity forecasting tools, which may be part of a transportation management system, improve upon this system by linking to and incorporating the following types of information:

- Customer demand information from the organization's demand forecasting process
- Marketing information so planned promotions can be reflected as an increase in transportation capacity requirements
- Manufacturing and product strategies and decisions
- Required carrier mode, type, protection class, and other transportation details related to specific product characteristics

A good transportation forecast is broken down by transportation lanes such as various sea shipping lanes as well as by transportation mode.

Benefits of transportation capacity forecasting and planning

The benefits of integrating information from other parts of the supply chain into transportation forecasting include the following:

- The spot market for transportation is rarely used.
- Several weeks of notice can be given to supply chain managers responsible for carrier procurement.
- Carrier procurement can be detached from order creation. (The carriers will be reserved but given their assignments later.)
- It is easier to arrange for intermodal shipments (e.g., rail to truck), which can lead to significant savings.
- Backhauls can be planned with sufficient time to reduce deadheading (empty vehicle return trips).
- Sufficient transportation capacity can allow warehouse staffing to be planned more accurately.
- For owned fleets, transportation staff and equipment will be more accurately planned.
- Transportation becomes not only less expensive but more responsive, because you will have time to raise or lower capacity.
- Arranging things in advance allows for more time for collaboration between transportation providers and supply chain partners on the receiving end of the shipments.

Topic 2: Transportation Modes

When it comes to the method of transporting goods, a logistics manager first decides which mode of transportation best fits with the overall logistics needs for the product and the marketing channel. Modes of transportation include rail, motor, water, pipeline, air, and intermodal combinations.

Exhibit 2-93 shows the weight of freight shipments broken down by mode in millions of tons for 2012 and the projected usage for 2040 in the United States.

Exhibit 2-93: Weight of Freight Shipments by Mode in U.S. (millions of tons)

Shipment Mode	2012 Totals	2040 Projected Totals
Rail	2,018	2,770
Truck	13,182	18,786
Water	975	1,070
Pipeline	1,546	1,740
Air, air and truck	15	53
Intermodal and mail	1,588	3,575
Other	338	526
Total	19,622	28,520

Source: Adapted from the Freight Analysis Framework v 3.4, 2014, U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations

If you would like more information on these statistics, a link is provided online in the Resource Center.

Rail transport

Rail transport is very fuel-efficient. Based on data provided by the Association of American Railroads (AAR), in 2014 U.S. railroads averaged 479 ton-miles to the gallon (a railway fuel efficiency measurement that means an average train moved a ton of freight across 479 miles on a gallon of fuel), which makes it four times more fuel-efficient than truck transport. Transport by rail rather than truck reduces greenhouse gas emissions by 75 percent. Rail transport has increased its transportation volume by almost double from 1980 levels (2,222 tons per railcar in 1980, 3,606 tons per railcar in 2014) while reducing its overall fuel consumption by 103 percent from 1980 levels. (Fuel efficiency was only 235 ton-miles per gallon in 1980.)

Background

At one point, railroad transport accounted for more than half of the intercity freight in the United States. While deregulation stabilized rail's percentage share of the intercity transport market, it resulted in an ongoing decline in the number of large carriers, miles of track, and total revenues as rail carriers abandoned unprofitable lines and cut rates to be competitive. The U.S. trucking industry was the major beneficiary of the decline in rail.

Rail transport between countries of the European Union has never been especially efficient because of national differences in gauge widths and signaling systems and other differences in infrastructure and

organization as well as politics. Moreover, the reliance on rail for commercial transport entered into serious decline in the latter part of the 20th century under competitive pressures from other modes of carriage. In 1995, rail hauled 20.2 percent of freight in the EU, but this steadily declined over the years and in 2010 was at 16.2 percent. Over the same period, road transport increased its share of freight transport from 67.4 percent to 72.7 percent (as noted in the European Commission's "EU Transport in Figures Statistical Pocketbook 2012").

On the other hand, rail transportation has grown in importance in the national and international movement of goods in Asia. The following are reasons often cited for the increase:

- Twelve of the 30 landlocked countries of the world are located on the Asian continent, with the nearest ports often several thousands of kilometers/miles away.
- The distances linking the origins and destinations (both domestically and internationally) justify the economics of rail transport.
- There is a reliance on ports to connect national economies to the world's markets, especially in the context of growing containerization and intermodal transport. (Both containerization and intermodal transport are discussed later.)
- Several Asian countries are major exporters of mineral resources, and rail transport is crucial to their logistics.
- A steadily increasing volume of goods is being exchanged globally.
- Rail is recognized as environmentally friendly and safe.

Beyond Asia, rail transport is a crucial aspect of many other country and regional transport networks. Growing international trade, the establishment of free trade areas, and requirements for increased efficiency and improved quality of transport services are all factors that should sustain and grow rail transport for future decades in locales such as Australia, North Africa, the Middle East, and numerous other areas.

Capabilities

What railroads do especially well is to carry heavy loads of low-value goods over long distances at relatively low rates. The rough ride over steel rails and the jarring impact of coupling tends to cause more damage to cargo than occurs with other modes of transportation (about 3 percent of tonnage)—hence, in part, the focus on low-value, durable freight. Also, the relatively low rate structure—about one-tenth the cost per ton-mile of truck transport—makes rail transport attractive for low-value freight. As the value of the cargo declines, the cost of transportation consumes a greater portion of the selling price.

Rail transport offers a clear advantage in carrying very heavy loads when compared to motor carriers and airplanes. Compared to water transport, which is also well adapted to heavy loads, rail carriers have the edge in accessibility to diverse destinations and points of origin. Trains have an advantage over other modes of travel in bad weather conditions, which disrupt their travel times very little. They also offer the logistics manager considerable safety, although in exchange for safety the logistics manager must budget more for expensive packaging.

Trains have the capability to carry virtually any product or material except very bulky items—the need to cross bridges and pass through tunnels restricts the size of the items carried—but in recent years they have narrowed their focus to concentrate upon raw materials mined or harvested far from waterways. They have

also broadened their appeal by developing specialized equipment, such as refrigerated cars, cushioned cars for appliances, and double-stacked containers. Unit trains carrying one product, such as grain or coal, are able to speed up delivery times by avoiding switching yards and traveling directly to one destination.

Much of the U.S. rail business comes from carrying coal, with smaller slices allotted to chemicals and other raw materials or commodities.

Market conditions

The transportation manager who is considering available options for U.S. rail transport will find few rail carriers available. Because of high fixed costs for equipment, buildings, and tracks, railroads tend to be very large, heavily capitalized businesses. If high fixed costs are the bad news for rail economics, low variable costs are the good news. Since deregulation, U.S. railroads have lowered their variable costs even more by renegotiating labor agreements. Use of computers has also increased the efficiency of train movement, lowering expenses for fuel and labor.

When they were more tightly regulated, U.S. railroads were more numerous. Since deregulation, however, smaller lines have dropped out of business or consolidated into larger companies. About 560 companies have survived, but only a small number—big names such as Union Pacific and Burlington Northern—account for the majority of revenue.

There is little room for expansion in the industry in most countries because of the overwhelming expense of laying new track and the difficulty of locating available land for right of way. The exception to this rule may be China, which does have the room for putting in new track.

To compensate for limited ability to expand their service to new locations, railroads have begun entering into agreements to provide intermodal transport of goods. In combination with trucks, ships, or planes, trains can deliver goods to new domestic and overseas locations. In 2003, intermodal service overtook coal as the leading source of revenue for the freight rail industry. Not only is trucking freight rail's biggest competitor, it's also its biggest customer. Some transportation experts say that truckers are losing their edge because of highway congestion, higher fuel costs, driver shortages, and pending safety regulations. Meantime, railroads have made a huge bet on intermodal service, spending hundreds of millions of dollars on new facilities and upgraded tracks to handle the increasing traffic volume. We'll look at the types of intermodal transport later.

Limitations

Though rail lines reach more destinations than are available to waterborne carriers, their access to multiple destinations pales in comparison to the reach of highways. There is no flexibility in railroad right of way. Both shipper and recipient must have facilities near the tracks; otherwise they will have to arrange with another type of carrier to get their goods to or from the terminal. This makes rail virtually useless for direct delivery to a retail location.

Railroad transport is relatively slow. This can result from the necessity of stopping at numerous locations, from the slow procedures required to decouple and recouple cars in a switching yard, and from practical restrictions on speed related to current infrastructure.

In the EU, the problems with speed have been especially great because of the different standards among

nations. In addition to the generic constraints applying to all railroads, the EU's rail carriers are hampered by the need to change crews and locomotives at border crossings and by the requirement to give priority to passenger services. However, this last limitation has received EU regulatory attention. The European Rail Network for Competitive Freight (Regulation EU 913/2010) came into force in 2010 and requires better balance between freight and passenger service. Still, rail contract procedures are highly formalized and slower to complete than is the case with road carriers, and access has suffered in recent years as the number of sidings has decreased. With all these impediments, delivery times for European rail carriers have actually doubled or tripled from pre-1970 times, and on-time service has become far less predictable for trains than for trucks. European rail carriers simply can't provide the kind of service required by companies structured for lean production and Just-in-Time deliveries.

As mentioned earlier, rail transport tends to cause more damage to fragile products than other modes of transport, and consequently it requires special care to be taken in packaging fragile products.

Motor carriers

As rail transport has dwindled, trucking has expanded. Motor carriers haul produce, raw materials, parts, cars, stage sets, hazardous materials, fish, flowers, and farm animals through Europe, Asia, Africa, Australia, and the Americas. There are approximately four million miles of highway in the United States alone. From the smallest pickup truck to the longest semi with two or three trailers hitched to its cab, motor carriers have become absolutely essential to the world's supply chains.

Capabilities

The market for truck transport is the relatively small shipment of high-value items traveling a short distance. Accessibility is the strong suit of the motor carrier. There are virtually no locations that are off limits for trucks. They don't require ports, vast switching yards, or large terminals. All trucks need is a road to the shipper's and recipient's docks or door.

Assisted by the expansion of the road network, motor carriers in the United States have moved into parts of the market previously served by the railroads. Most freight arrives at retail stores via truck. Light and medium manufacturers also rely on trucking. When cargo travels by other modes, trucks often carry the freight to and from the port or rail yard.

Motor carriers also offer speedier delivery than rail or water transport. Barges, of course, are slow. Trains generally have to stop at switching yards to add or remove cars. Trucks can be more direct.

Market conditions

Motor carriers benefit from relatively low fixed costs, associated with the vehicles themselves and terminal facilities. Unlike trains, trucks ride on a surface built and maintained by taxpayers. American Trucking Association and IHS Global Insight research predicts that U.S. freight tonnage will grow about 24 percent over 2013 amounts by 2025, causing freight revenues to increase by 72 percent.

Compared with other transport modes, over-the-road hauling provides relative ease of entry. Currently there are about 65,000 general freight trucking companies in the U.S. (The 50 largest companies account for 40 percent of revenue.) Indeed, the industry depends on those (sometimes highly) independent operators who

get into the business by purchasing a cab, getting licensed, and offering their services to anyone with a trailer to haul. There are some regulatory limits placed on what a carrier can haul and where it can operate. For example, carriers may be limited to carrying only commodities, only explosives, only building materials, etc.

The trucking industry comprises three segments: truckload (TL), less than truckload (LTL), and specialty.

- The TL segment includes many carriers who compete on their rates. A truckload shipment weighs over 15,000 pounds (6,818 kilograms). Because they are fully loaded, trucks in the TL segment generally travel straight from the loading dock to the destination; they don't have to stop and take on more pallets to fill up the trailer.
- In the LTL segment, trucks start with loads of less than 10,000 pounds (4,536 kilograms). Because they have space in the trailer, these trucks often have to stop at intermediate locations to take on more cargo. This, of course, extends their delivery time, uses more fuel, and raises labor costs for the drivers and dockworkers. The higher costs of doing business in this sector have led to more consolidation than in the TL sector.
- Specialty carriers include companies such as United Parcel Service (UPS) and Federal Express.

Tradeoffs

Although motor carriers benefit from low fixed costs (trucks being much cheaper than ships or planes), they do have to contend with high variable costs. Trucking companies are beset by rising costs for equipment, repairs, and the wages paid to drivers and the laborers who load and unload cargo. Trucking is more labor-intensive than its competition, so it is impacted more than other modes by rising labor rates. Truckers address these cost challenges by various means, including computerized billing, mechanization at terminals, more efficient scheduling with fewer intermediate stops at terminals, and coordination with other modes of transport.

Since deregulation in the U.S. in 1980, competition for customers has increased in the trucking industry. The result has been lower rates, which are a boon for the logistics manager but have caused many carrier bankruptcies.

For high-value or less-durable goods, trucking may be less hazardous than rail or water transport. Air-filled tires provide a better cushion for cargo than steel wheels on steel rails. Vehicle suspensions, too, are better than they used to be, at least for the cargo. Riding long hours in the cab can still be hard on the operators.

Water transport

Water transportation forms an important part of domestic and international trade. It includes several categories: inland waterways, lakes, coastal and intercoastal ocean, and international deep sea. In international shipping, water is the dominant mode, and it is the most inexpensive method of shipping high-bulk, low-value commodities.

Capabilities

Water carriers can handle huge loads, measured either in weight or size. A barge traveling slowly down the Rhine or some other European waterway, for example, might be loaded down with 1,500 metric tons (or tonnes) of high-density cargo (approximately 1,654 U.S. tons), while a fully loaded semi-trailer truck traveling

across a bridge above it carries only 7 metric tons (7.7 U.S. tons) and itself weighs approximately 36.3 metric tons (40 U.S. tons). In other words, the barge could hold the weight equivalent of more than 30 fully loaded double-trailer trucks.

Rather like trains, however, barges and other floating carriers find their most fitting use in conveying low-value, high-density cargo over long distances, with loading and unloading accomplished mechanically.

Probably the largest vessels on the water are the oil tankers. They are usually classified by function and size. There are two functional types of the vessels: the crude tankers, which carry unrefined crude oil from the field to refineries, and the product tankers, which carry petrochemicals from refineries to market areas. Sizes range from inland or coastal tankers to gigantic supertankers. Most newer tankers have a double hull, thereby creating extra “safety” space between the storage tanks and the hull. Each very large ship can transport two million barrels of oil. In light of recent serious oil spills in oceans, both the U.S. and the EU have passed laws regarding pollution and double hull requirements that are in effect as of 2015 and 2010 respectively.

The primary value that water transport provides the logistics manager is low cost. At less than a penny charged per ton-mile, shipping by water is even cheaper than using a train. Water carriers also make highly efficient use of fuel. According to their 2012 annual report, the American Waterway Operators found that one gallon of fuel moves one ton of cargo 616 miles by inland barge, 478 miles by train, and only 150 miles by truck. Water transport can also relieve congestion on crowded highways—a significant consideration in the European Union and near urban centers generally. In the Asian region, more than one billion tons of freight moves by inland water carrier annually on waterways such as the Yangtze and the Ganges, and one-third or more of all cargo travels by water in Bangladesh, the Lao People’s Democratic Republic, and Myanmar. According to an article on Heartland by Wendell Cox titled “China’s Ascent in World Transport,” waterway freight transportation reached about 8,600 billions of tonne kilometers (moving one tonne [1,000 kilograms] one kilometer), which is higher than any mode of freight transport (even truck) and is up from less than 3,000 billions of tonne kilometers in 2003. In some areas of Asia where there are few roads or railroads, waterways constitute the sole means of connecting remote rural communities to urban centers.

Shipping containers play a big role in domestic and most international water shipments. In fact, it has been said that containerization has transformed global trade in manufactured goods as dramatically as jet planes have changed the way we travel and the internet has changed the way we communicate. The shipper places cargo into a container at its facility. The container is then transported by rail or trucking carriage to a water port for loading onto a containership. After arrival at the port, the container is unloaded and loaded onto a rail or trucking carrier and delivered to the customer.

Containers are typically 8 feet/2.44 meters high by 8 feet/2.44 meters wide and of various lengths, from 20 feet/6.1 meters to 53 feet/16.15 meters. Many new containerships are capable of carrying 18,000 20-foot equivalent units (TEUs) or the equivalent of that many 20-foot containers. (The largest can carry 19,224 TEUs.) But the container is much more than a box and has become increasingly sophisticated. Depending upon the cargo, there are stringent container temperature and storage requirements.

Market conditions

In the United States, water transport has remained stable, in the range of 15 to 17 percent of total ton-miles,

over the past five decades. During that time, however, the portion of that amount due to Great Lakes shipping (shipping on the five freshwater lakes of central North America between the United States and Canada, connecting midwestern U.S. ports with the Atlantic Ocean via the St. Lawrence Seaway) has declined to a fraction of its peak in the 1950s, while river and canal transport have increased to make up the difference. The ships used on the Great Lakes are deep-water vessels, which can harbor only in deep-water ports such as those on the Lakes or the coasts. Canal and river transport relies on flat-bottomed barges with more flexibility as to where they can travel. In the EU, freight moves on such major rivers as the Rhine, the Rhone, the Danube, and their many tributary canals. According to its official government website, China has publicly committed to strengthen the transport system for its inland waterways by 2020. It is estimated that by then it will have 19,000 kilometers of navigable waterways and will have further developed transportation on the Yangtze, one of its major rivers for transporting coal and steel. It also promises to build more river ports and enhance the infrastructure to accommodate an increase in capacity.

The primary products transported on inland waterways include commodities such as cement, chemicals, and some agricultural products. U.S. Great Lakes vessels mostly carry ore, coal, and grain. The bulk of this trade qualifies for exemption from government economic regulation. These exemptions, combined with low fixed costs (an amount somewhere between rail and road), mean that shippers can afford to transport goods in their own vessels rather than hiring a third-party carrier. Like trucks, and unlike trains, water carriers are relatively affordable. The waterways, like highways, are maintained by the taxpayers.

Despite the worldwide economic downturn in recent years, maritime transport has continued to grow. In 2012 containerships carried nearly 198 million deadweight tons of cargo compared to approximately 70 million tons in 2001. Maritime container volume is expected to continue to grow, with projections that nearly all nonbulk cargo will be containerized in the next 20 years. The area of oil transport has also shown significant growth in the last decade. In 2012 oil tankers moved over 450 million deadweight tons compared to 283 million tons in 2001.

Tradeoffs

There are two obvious drawbacks that might prevent a logistics manager from using water transport: limited accessibility and lack of speed. There are fewer miles of inland waterways than there are roads and railroad tracks, and if the shipper and the recipient have no direct access to a port, they have to use another mode of transportation to get products to and from the carrier.

Once on the water, progress is slow on a barge or in a deep-water vessel. Not only are barges—or the diesel-engine vehicle that tows them—slow-moving, but on natural waterways they must make their way through a series of locks. When rail lines run parallel to a waterway, trains make strong competitors for water carriers for transporting the kinds of heavy, low-value goods carried on barges. The tradeoff is between the greater speed of the train and the far lower rates for water transport.

Barges using major waterways must compete with other important uses, such as passenger transport, fishing, recreation, drinking water, and energy generation. Discharges from cargo carriers can be a significant source of pollution, along with runoff from mining and agriculture, and pollution is incompatible with the competing uses of rivers for recreation and drinking water. Some of the major waterways in Europe, which pass through many countries with separate and various levels of regulation, have become seriously

polluted over the years.

Globalization has increased the need for efficient and reliable international transport routes and networks. Their development requires creating new infrastructure or upgrading existing national and international infrastructures to accommodate the increase in maritime traffic volumes. The use of containers for intermodal logistics can reduce staffing needs, minimize in-transit damage and pilferage, and shorten transit time. But there can be problems at the ports impacting the timeliness of unloading containers from ocean liners. In some countries, the shortage of containers can limit supply chain capabilities. The increase in import volumes, aging port equipment, shortage of rail capacities, and limited numbers of truck drivers and carriers can lead to delays.

For example, the 2015 U.S. West Coast port strikes created severe backlogs for the trucking and container/tanker shipping industries. With 70 percent of imports from Asia coming through the West Coast, the strike impacted all organizations shipping or awaiting their goods. Ports were gridlocked, and dozens of containerships were queued for miles during the nine-month strike. Some supply chain managers had to resort to expensive air shipment, including Fuji Heavy Industries, which flew parts to its Subaru auto plants, adding approximately US$59 million per month in transportation costs.

The risk that terrorist organizations could use the mechanisms of international trade and commerce poses additional considerations, including specific concerns that containers could be used to transport dangerous goods or carry out large-scale attacks. The challenge is to advance port and maritime container security while ensuring continued free movement of legitimate trade.

Pipeline transport

There's a reason pipelines aren't the first mode of transport that comes to mind: Other modes move while their cargo remains stationary. The pipeline reverses that relationship by holding still while the cargo moves. Despite this inside-out relationship between the carrier and its cargo, pipelines move a higher percentage of U.S. freight than water transport, largely because of their special adaptation to conveying crude oil and petroleum products.

Natural gas is also transported in pipelines. Although there are about 305,000 miles of inter- and intrastate pipelines in the U.S., many carrying natural gas are nearing their capacity. Due to the aging infrastructure of some underground pipelines, gas companies are compelled to invest in ongoing maintenance and repair work.

Capabilities

Not only are pipelines unique in being stationary carriers; they generally move their cargo in only one direction—thus eliminating the need to be concerned about backhaul carriage. Also, no packaging is required to move cargo through a pipe. The pipe is the package and also a storage facility.

Pipelines are special, too, in that they are available for continuous use on all days, in all seasons, and at all hours. Unlike air, motor, and rail carriers, they pose no noise problems. They will, however, cease to move cargo during power outages, since the pumps that cause the contents to flow depend upon electricity. Also on the downside, pipelines are expensive to construct and maintain. Since pipelines are fixed in place, they

have the highest fixed costs of all modes of cargo transport but the lowest variable costs—a cost structure otherwise similar to that of rail transport. The fixed costs are mainly due to right of way, construction of facilities, and pumping capacity. The costs of operation are very low.

In general, the carrying capacity of pipelines increases relative to pipe diameter. Also, increasing diameter reduces the amount of liquid in contact with the pipe for a slight friction decrease and efficiency gain.

In the past, safety has been one of the major benefits of pipeline transport. They are unaffected by weather conditions and highly unlikely to rupture. Cargo damage and loss are virtually nonexistent. The main natural enemy of the pipeline is seismic activity. The catastrophic Hurricane Katrina that devastated the U.S. city of New Orleans in 2005 closed the port and destroyed much pumping and refining capacity but did not rupture the pipes that run cross-country to the East Coast. The rise of international terrorism, however, creates risk because long pipelines are difficult or perhaps impossible to secure against attack.

Aside from crude oil and petroleum products, pipelines carry manufacturing chemicals, municipal sewage and water, and dry materials such as cement that can be pulverized or flour that can be suspended in liquid. One coal slurry pipeline exists in the United States, and research continues into transporting other materials in suspension or slurry form.

Pipelines are natural monopolies, since constructing parallel pipelines to compete for the same business would be far too costly. In the United States, some pipelines are owned by shippers, but most operate as common carriers. (Common carriers are described later.)

Challenges

Only liquids or liquefiable products can move through the pipe. Construction is costly. Pipes are inflexible delivery vehicles, and access to the pipeline is limited to those with facilities adjacent to it. Others have to bring their product to the pipe using other modes of transport, thus losing the benefits of the pipeline for that portion of the trip and adding variable costs of loading, unloading, and operating a vehicle.

Pipelines are of limited use in international carriage, because they are vulnerable to political disputes between the countries whose borders they cross—also a problem for other modes of transport that cross boundaries.

Air transport

Airplanes constitute both the newest and the least-used method of transporting cargo, although they have been carrying mail for about 100 years. The primary business of the major air carriers is the transport of passengers; commercial cargo, for the most part, has been relegated to filling up space not occupied by people and their luggage.

Capabilities

The clear advantage in speed of delivery goes to the airplane over all other modes of transport. Cruising near the speed of sound, newer airplanes can cross entire continents and oceans in a matter of hours. This allows logistics managers to reduce or eliminate safety stock and warehouses. Because air travel is relatively smooth and fast, it is especially well suited to carrying valuable, fragile, and perishable cargoes.

However, air cargo is not limited to such items. Any commodity can travel by air, subject only to restrictions on weight and size. The military, perhaps the world's first and best logistics manager, air-lifts heavy equipment to battle zones. Cargo destined for travel in an airliner's hold requires significantly less packaging.

Air transport benefits from low fixed costs, ranking second in that regard only to over-the-road motor carriers. Airports are generally constructed and maintained by taxpayers—federal or local—with gates leased to carriers. Shippers can afford to purchase or lease their own fleet of airplanes. Variable costs, however, are high, due to the rising cost of fuel and the expenses accruing to a very labor-intensive business.

Market conditions

Some industries are important to a country but may not ever be considered profitable. Transportation is a market sector where this is particularly true, especially in the case of airlines. Around the world, airlines tend to be run by governments or may be regulated, with the requirement that they persist in serving markets that may be important from a public perspective but are not necessarily profitable.

The United States, where airlines have always been privately held, is the exception. Until 1978, the U.S. airline industry was highly regulated. After legislation eased regulation, airlines were allowed to set their own rates and choose which markets to serve or abandon. Since that time, air rates have fallen dramatically, and carriers once restricted to U.S. markets have added international flights. While this might seem to offer better access for logistics purposes, the downside of deregulation has been increased instability in the industry, including many airline bankruptcies. The terrorist acts of September 11, 2001, in the United States exacerbated these difficulties.

On the positive side, international air transport has become a strong competitor with water transport for transoceanic carriage. Air cargo (with the exception of small parcels) often flies on the same planes as passengers. Freight forwarders contract with these airlines. In addition, specialized package services, such as Federal Express and United Parcel Service in the United States, use dedicated cargo planes—no passengers allowed—to offer a range of transport services.

Tradeoffs

Speed is the air carriers' primary advantage, with low loss and damage rates tagging along behind, but with speed comes a higher price tag. At around three times the cost of road carriage and more than 30 times the cost per ton-mile of rail carriage, air transport exacts a high cost in exchange for rapid delivery. When comparing air to ocean transport in terms of efficiency and lower cost, items that fit into the categories of smaller, express, high-value, and time-sensitive shipments are still best served by air. Generally speaking, to justify the transport cost, air cargo almost always has to be high in value, at least to the buyer. For example, fresh fish for high-end restaurants is usually shipped via air.

Accessibility, too, is sacrificed for speed, especially in comparison to trucking. Airports are extremely expensive to build and very difficult to site. They require vast expanses of flat land and may require condemnation of existing homes and businesses, given their usual placement near cities. The major airports serve the world's large cities—for the convenience of the airlines' primary business of transporting passengers. There is little call for building airstrips near mines, forests, or farms for pickup of raw materials. However, many major cities have made huge investments in their airports in recent years, and many are now or are rapidly becoming world-class, with high capacity for cargo. In Asia, Beijing, Ho Chi Minh City,

Singapore, Bangkok, Hyderabad, and Bangalore are all examples.

Air transport can suffer from delays caused by weather conditions, though advances in air control and instrumentation have somewhat decreased these problems. Major air carriers are considered to be prime targets of terrorism, but this is a drawback they share with other modes. While security concerns may add to costs and delays, they probably are not major factors in the logistics manager's calculations.

Although air carriers have made some progress in establishing intermodal service with road carriers, there is a natural limit on the establishment of direct links between airports and rail terminals or ports.

Intermodal transport

Many deliveries cannot be accomplished by a single mode of transport—for reasons of access, price, size or weight of cargo, etc. Intermodal transport, which includes package delivery and container services, integrates the different modes of transportation in various combinations to take advantage of their specific capabilities. Since deregulation, the legal barriers to mixed mode and specialized services have decreased and new types of specialized or hybrid transport providers have entered the marketplace.

In global logistics, the question of what is the most efficient and cost-effective mode of international shipping poses additional considerations. There is no definitive answer as to the ideal mode. The choice in hybrid transportation modes is driven by an organization's specific needs and the capabilities of the shipping and logistics entities.

Package delivery services

Package delivery services developed because traditional single-mode operators have generally been unable to carry small packages at a reasonable cost. Among the challenges to overcome when delivering small parcels are collecting enough packages from diverse shippers to constitute a load and distributing the packages to diverse, perhaps inherently unprofitable, locations. Government-run postal services have traditionally filled this niche in the market alongside, or in place of, private carriers.

In the 1970s, specialized package carriers such as UPS, DHL Express, and Federal Express (FedEx) were growing in importance, generally beginning in the United States and then spreading around the world. In addition to those U.S. services, TNT began in Australia and eventually grew into another dominant worldwide express service—all of which developed sophisticated, multimodal logistics expertise. A 2011 article on Supply Chain Digital.com identified the top five shipping companies in the world, from largest to smallest, as UPS, DHL Express, FedEx, the United States Postal Service (despite serving only the U.S., it had 2010 revenue of over $67 billion, employs over 600,000 people, and has the world's largest civilian fleet), and Schenker AG of Berlin. Many other express carriers exist, such as OCS, a provider of worldwide delivery and logistics services based in Canada since 1963, and Aramex, based in Amman, Jordan, which primarily serves the Mideast.

The major benefit offered by the express carriers is speed; the major drawback is price. Manufacturers and distributors that value speed have come to depend upon same- and next-day service from express carriers. These include pharmaceutical companies, hospital suppliers, food retailers, financial services, and suppliers of repair parts to companies anxious to build customer loyalty. In the expanding marketplace of lean

manufacturing, Just-in-Time delivery, and global supply chains, however, speed is becoming more a competitive necessity and less a marginal benefit.

According to one study, in 2010, the express carrier industry had an employment base of around 1.3 million worldwide (supporting a total of 2.75 million jobs worldwide through indirect employment). The industry made a direct contribution to world GDP of US$80 billion, was estimated to have generated sales revenues of US$175 billion, and was growing at a significantly faster pace than the overall GDP. Express services not only assist other businesses; they are, in fact, substantial contributors to national and regional economies. Their hubs attract other businesses that rely upon the express carrier for their deliveries. Express services also play an essential part in the rapidly growing marketplace of goods sold outside of stores. Online sales depend upon national postal services and their express service competitors to make their businesses attractive to customers. Finally, because they can combine deliveries from many customers, package delivery services offer small and medium-sized companies a chance to benefit from economies of scale.

Intermodal services

Intermodal services include piggyback, trainship or containership, truck-plane, and freight truck on railcar.

- **Piggyback service (TOFC, COFC, roadrailer).** The nickname “piggyback” signifies the placement of a truck trailer or a container of cargo on a railroad flatcar, hence the names TOFC (trailer on flatcar) or COFC (container on flatcar). The cargo travels part of its way via truck and the rest of the way by train. While the trailer provides the more direct link between train and truck, the fact that it sits on wheels creates more wind resistance during the rail portion of the shipment. Aside from their better aerodynamics, cargo containers provide more efficiency and flexibility, since they can be double-stacked on railcars or loaded onto water carriers as well as flatcars and flatbed trucks.

  Roadrailers are trailers that ride on either regular tires/wheels or steel wheels. A simple change of wheels allows them to ride on the highway behind a tractor or be pulled along the tracks as short railcars. This eliminates the need for expensive materials-handling equipment. The roadrailer is highly cost-effective when compared with simple over-the-road hauling.

- **Trainship or containership service.** “Trainship” and “containership” refer to mixed mode transport that includes water carriage. It also is sometimes referred to as “fishyback.” As the names signify, the cargo is loaded into a truck trailer, a railcar (trainship), or a container that also spends part of its shipment time on board ship or barge.

  These combinations use domestic waterways—rivers, canals, the U.S. Great Lakes, and coastal waters, and similar setups are used in overseas transport. The land bridge, for instance, combines rail and sea transport. The land bridge route may run from the coast of Asia to the U.S. West Coast by ocean vessel, from the West to East Coasts on rails, and then from the Atlantic coast to Europe on another ship. The alternative is an all-water route through the Panama Canal. In contrast, the micro land bridge moves goods over water and then land, with the final destination inland. Mini land bridge traffic moves goods over water and then land, with the final destination being on the opposite coast.

- **Truck-plane services.** Air transport generally requires some intermediary surface travel (sometimes referred to as “birdyback” services), since airport terminals are not usually located near manufacturing,

harvesting, or extraction sites, and those sites are generally not equipped with their own private airstrips. Intermodal air-truck shipments, such as those routinely scheduled by UPS and FedEx, simply formalize the process and put it under unified management. But small package shippers are not the only ones relying upon truck-plane services. Other commodities travel via this mixture of modes, especially those that originate or conclude in smaller cities and towns not served by major airports and large planes. The package carriers do serve smaller cities, of course, but heavier freight generally goes to other carriers.

- **Freight truck on railcar.** In Europe (for instance, in Austria), there are now laws restricting driving at night by truck drivers hauling freight. So a truck is loaded onto a flatbed railroad car, which is transported to another location via rail while the truck driver sleeps on the train to continue moving during prohibited hours (the required rest period).

The intermodal concept offers logistics managers flexibility, efficiency, and reduced costs. The future of the combinations outlined above most likely rests upon the cargo container rather than the truck trailer or the railcar. The container provides the maximum flexibility, since it can be loaded onto trucks, trains, barges, or oceangoing ships.

Transportation management software is available to help determine the best intermodal combinations and can assist the logistics team with identifying the optimal mix in order to get materials to where they need to be in a timely manner as well as at the lowest price.

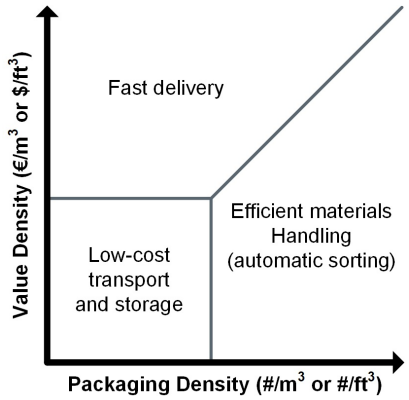
Topic 3: Mode and Carrier Selection

Transportation mode selection criteria

All types of carriers are not always competitive for every logistics manager's requirements. Each one has its own inherent advantages and disadvantages, and these vary depending upon the product type, size, weight, value, delivery speed, and lane volume needed to meet customer requirements. Lane volume is the volume of traffic in a given shipping lane (an origin-destination pairing) and is a factor in both land and water carrier pricing. The higher the volume in the lane, the lower the price for that transportation mode (and therefore the transportation mode needs to be highly efficient to compete). This is because low-volume lanes may not have available materials for backhaul, so carriers add fees due to the greater potential for empty vehicle return trips (deadheading).

Exhibit 2-94 shows that a reliable method to find the best mode of transportation for shipping a specific product type is to compare the product's value density (the value of units being transported per cubic foot or meter) versus its packaging density (the amount that can be packed per cubic foot or meter).

Exhibit 2-94: Value Density versus Packaging Density



To help weigh the importance of shipping options with different costs and delivery speeds, keep this in mind: Items with a higher value density usually merit shipping by a faster method, and items with lower value density can usually be sent by a slower method and then held in inventory. On the other hand, the more units that are handled per cubic foot or cubic meter, the more the need for automated materials handling.

Let's look at an example.

Postal offices or organizations do not own the letters they ship, so for them the value density is about zero. They collect letters from letterboxes and then bring them to a hub. Once there, the letters need to be sorted and sent forward to the next hub. At this second hub, the letters are re-sorted according to street address. The packaging density is very high (more than 10,000 letters per cubic meter), so the focus is on automatic materials handling. (In the Netherlands all letters are sorted on sorting machines.)

Bricks are an example of a product with low value density and low packaging density. The value per brick is very low, and bricks are sent to customers on pallets, so the packaging density is also low. The preferred way to treat this kind of low value/low density goods is to load the pallets at the manufacturing plant and directly transport them to the customer site using a low-cost transportation mode.

When looking at manufacturers of copy machines and digital cameras, you will discover that they use different modes of transportation. Copy machines have a low value density and are shipped in containers from the far east to the U.S. and Europe. Cameras have a high value density, so the emphasis is more on how to recover the invested money quickly. These products will be transported by airplane.

Types of carriers

After selecting the most effective mode, or modes, of transportation, the logistics manager must decide on the appropriate type of carrier—common (public), private, contract, or exempt. This decision is influenced by consideration of each carrier's "legal type," that is, the operating authority granted the carrier by the relevant government regulatory body. For example, in the U.S., the authority to operate under a given legal type is regulated by federal statute and the U.S. Surface Transportation Board (STB). In the EU, this is regulated by the European Commission's Directorate-General for Mobility and Transport.

The four types of carriers discussed below are generic in nature, and each provides a set of advantages and tradeoffs. While much of the discussion uses U.S. examples, these general types are relevant in many other countries.

Common (public) carriers

The *APICS Dictionary,* 16th edition, defines a **common carrier** as

> transportation available to the public that does not provide special treatment to any one party and is regulated as to the rates charged, the liability assumed, and the service provided. A common carrier must obtain a certificate of public convenience and necessity from the Federal Trade Commission for interstate traffic.

The opposite of a common carrier is a private carrier. "Public carrier," or simply "carrier," is a term used in continental Europe and elsewhere and is the functional equivalent of a common carrier. (However, to confuse the issue, in U.K. English, a public carrier refers to a contract carrier, defined later, not a common carrier.) The remainder of this discussion uses the term "common carrier."

Common carriers perform the bulk of shipping in the United States, form the basis of public, commercial transportation, and are used extensively in most logistics systems. Common carriers operate in the public interest. Granted the authority to enter the market by a country's federal government, they are also subject to the greatest amount of regulation governing rates and the scope of their service. Government licensing and regulatory restrictions are designed to guarantee that the economy will not suffer from a lack of commercial transportation at reasonable rates. While such regulation ensures logistics managers that carriers will be available for their products and within their geographic markets, it also means that managers must understand the relevant regulations and take their effects into account when selecting modes of transport and types of carriers.

To enter the common carrier business in the United States, for example, a company must demonstrate that it is able and willing to provide service. The U.S. STB governs entry into the common carrier market for rail, motor, and marine transport; the U.S. Department of Transportation (DOT) regulates entry into air transport.

Regulation of common carriers governs public service, liability, discrimination, and rates.

- **Public service.** Common carriers may be licensed to carry all types of goods or only certain types (household goods, computers, etc.), depending upon their capabilities. Within the scope of its license, the common carrier must transport whatever goods are offered to it and deliver the goods to any point within its designated territory.
- **Assumption of liability.** Common carriers assume the risks inherent in transport—a definite benefit for the shipping company. The carrier is responsible for any damage, loss, or delays that occur while the goods are in its custody—with certain exceptions, such as inherent product defects and acts of God, public enemies (criminals, terrorists, etc.), or the shipper itself.
- **No discrimination.** Common carriers are required to take all legitimate business within the scope of their licenses, even at a loss. They may not discriminate among shippers, products, or places by charging different rates or providing different levels of service. There is some flexibility for varying rates in line with differences in the costs of doing business. Common carriers in the trucking sector generally specialize in either full truckload or less-than-truckload carriage.
- **Reasonable rates.** Common carriers must publish their rates, and the rates must not be too high (thus limiting shippers) or too low (thus endangering the carriers).

Private carriers

A private carrier is a company that owns or leases a fleet of vehicles to transport its own products. A private carrier that purchases a fleet of vehicles incurs the costs of ownership—such as maintenance, insurance, depreciation, and financing. The vehicles also count as assets on the balance sheet, which worsens certain financial ratios. Ownership requires decisions about when to buy and sell the vehicles; leasing eliminates some of the concern with depreciation, financing, and term of possession. Ownership and leasing are otherwise similar. In both cases the vehicles are in the possession of the company and are its responsibility.

To qualify as a private carrier, a company must own or lease vehicles for its use, manage their operation, and not be primarily in the transportation business. While private carriers are free from economic regulations that apply to other legal types of carriers, they must follow regulations that apply to hazardous materials, safety, and other matters regulated by the government.

Owning or leasing a fleet has advantages and disadvantages. On the positive side, the company has control of the vehicles for its own use. On the negative side, the size of the fleet is relatively inflexible. If business turns down, the company either has to maintain unused vehicles or divest itself of some vehicles through sale or a lease buy-out. Neither tactic is likely to be profitable.

Before deregulation in 1980 in the U.S., private carriers were forbidden to carry the goods of other companies. Since deregulation, they have been able to do so, and some private carriers are licensed in more than one legal class—a significant benefit if the vehicles can fill up with another company's products

when they would otherwise be making empty backhaul trips.

At first the benefits of deregulation resulted in an increase in the number of private carriers. Eventually, however, that trend reversed as more companies sold off their private fleets and outsourced logistics functions in order to focus on their core businesses.

Contract carriers

Unlike common carriers, contract carriers are not required to make their services available to the general shipping public, though they do require government authorization to do business and are governed by economic regulations. They enter into contracts with terms specific to the customer and then receive a permit to carry out the business defined by the contract. Contracts specify rates, type of service (number and frequency of trips, etc.), and liability.

Although U.S. contract carriers were once subject to strict regulatory limits on the number and terms of their contracts, since the Motor-Carrier Act of 1980 they are more free to compete with other types of carriers. For example, before 1980 contract carriers were limited by law to have no more than eight active contracts; now they may serve an infinite number of current customers.

Contract carriers offer several advantages to logistics managers. Their rates are generally lower than those of common carriers, and because they aren't required to serve the general shipping public, they can adapt their business to a customer's specific needs by, for example, scheduling special deliveries or using specialized equipment. They rival private carriage in that regard while providing added flexibility.

The independent trucker is a special type of contract carrier who owns a tractor (and perhaps a trailer) and makes arrangements to subcontract with other types of carriers, including common, private, contract, and exempt carriers.

Exempt carriers

Exempt carriers are not subject to economic regulation of their rates and terms of service. They are, however, responsible for compliance with state laws governing licensing and regarding safety, and in the U.S. they must publish their rates if they operate across state lines. (Most exempt carriers operate locally.) The market determines their rates, services, and availability.

Exemptions are granted for specific commodities and for certain areas of operation, such as the zones around airports. Typical exempt commodities include raw materials and unprocessed agricultural products. Logistics managers rely on exempt carriers for a significant amount of business in their niches, such as local transport of agricultural products. The primary benefit offered by exempt carriers is lower rates. Their primary drawback is limited availability for many products and a limited range of operation.

Chapter 13: Monetary, Regulatory, and Trade Considerations

This chapter is designed to

- Explain the process and considerations in the exchange of currency between countries
- Define the Incoterms® trade terms used in foreign trade contracts and distinguish where and when cost responsibilities shift between seller and buyer
- Enumerate the operational considerations of importing and exporting
- Identify and describe the intermediaries involved in import and export
- Describe how the Harmonized Tariff Schedule is used in import and export transactions
- Define free trade zones and describe the requirements for and benefits of participation
- Explain trading blocs and how they impact the participants as well as those outside the supply chain.

This chapter looks at monetary, regulatory, and trade considerations related to the supply chain. We'll begin with the monetary factors: payment terms, currency issues, and funds flow. Then we'll examine regulatory factors, including Incoterms® trade terms and customs. The chapter concludes with a discussion of trade considerations, including free trade zones and trading blocs.

Topic 1: Monetary Considerations

Payment terms

In any trade or financial transaction, there is a risk that the other party (the counterparty) will fail to honor the terms of the agreement. This is called, obviously, counterparty risk. The seller always runs the risk that the buyer won't pay on time or won't pay at all or will pay but in counterfeit currency, just as the buyer risks taking delivery of inferior goods or no goods at all.

Organizations need to specify payment terms in contracts with suppliers or customers. The *APICS Dictionary,* 16th edition, defines **payment terms** as "conditions surrounding payment for a sale, providing a time frame in which a customer can pay without late penalties or additional fees." These terms specify when payment is due, whether shipment will occur before or after payment is made, and the method of payment that is required.

Very few transactions, domestically or cross-border, are financed by payment in advance or cash on delivery (COD)—although both do occur, generally if the parties are closely related, as in the case of subsidiaries or if one party is well established and the other unknown. However, for established mutual relationships, trade credit or an open account is often extended, which is essentially an unsecured, trust-based transaction between the parties.

Trade credit is the sale of goods or services in which payment is not due right away. Trade credit encourages sales because it is effectively offering free financing over the payment period. The buyer has time to convert the good or service into revenue before making payment. With an open account, a buyer has a credit limit with the organization or a bank and can place orders or write drafts up to the limit to pay for goods or services on receipt or on a deferred basis. When an open account is with the organization, it is synonymous

with trade credit. Trade credit and open accounts are offered only to trading partners with good credit records and healthy financials (e.g., financial ratios and reports) because of the possibility of default.

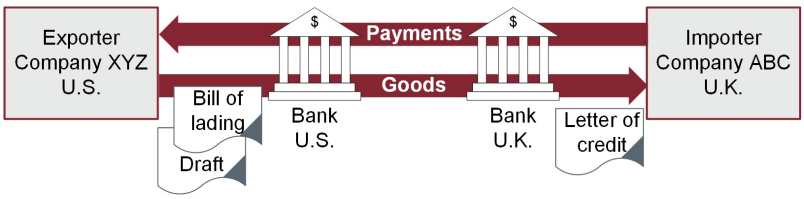
In addition to providing a deadline for payment without penalties, many organizations offer a discount to encourage early payment. For example, payment terms of 1/10 net 30 mean that the buying organization will receive a 1 percent discount if payment is made within 10 days but has up to 30 days to make the full (net) payment with no late penalties. An organization's accounts payable or treasury personnel can calculate whether taking a discount is worth more or less than the ability to wait longer to make the payment. Similarly, the invoicing organization's finance professionals will craft any discount to make financial sense for the organization: nearly equivalent either way, with a small tip in the direction they want the buyer to choose.

Documentation for domestic business-to-business customers usually includes an invoice and a bill of lading (B/L). Invoicing internationally has far greater documentation requirements, in addition to requiring that payment be made in some secure manner such as a letter of credit (discussed next). International documentation will be discussed elsewhere.

Letters of credit

Since trade credit or an open account may not offer the risk protection that either party desires in an international transaction, organizations need a more sophisticated form of payment, and in many import-export transactions this takes the form of a letter of credit (L/C). The letter of credit (illustrated in Exhibit 2-95) offers security from counterparty risk in a tidy, but complicated, package.

Exhibit 2-95: Letter of Credit



A letter of credit is just what its name implies: a letter in which a bank assures the seller that the buyer can pay the purchase price of the goods and that the bank will therefore honor the buyer's checks to the seller up to that amount. The bank makes this assurance either because it has reason to believe that the buyer's credit is good or because the buyer has an account with the bank.

The sequence of events goes something like this:

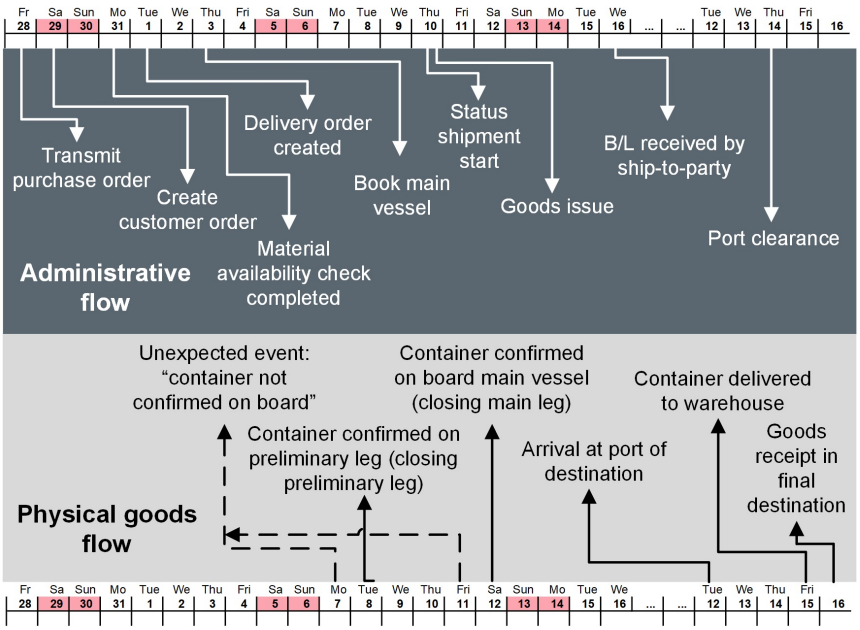
- **L/C is issued.** After agreeing to the terms of sale, the buyer/importer goes to its bank and gets a letter of credit demonstrating that the bank has faith in the buyer/importer's ability to pay the purchase price.
- **Seller's bank is notified.** The buyer's bank notifies the seller's bank that the L/C has been issued. This assures the seller's bank that it can honor drafts from the seller up to the amount of the purchase price as long as the bank receives the proper documentation.

- **Seller ships cargo.** Confident of receiving payment when the goods have arrived as specified, the seller has the cargo shipped. The carrier sends a B/L (or waybill for air carriage) to the seller's bank.
- **Seller asks its banker for money.** After shipping the cargo, the seller sends a draft for the purchase price to its banker, who now has the seller's draft plus the carrier's B/L.
- **Seller's bank asks buyer's banker for money.** The seller's bank forwards the documents to the buyer's bank. The B/L from the carrier usually assigns ownership of the goods to the buyer's bank, not directly to the buyer. This provides the bank with some security since it can wait to release the ownership documents to the buyer until it is sure of being repaid.
- **Buyer's bank waits for cargo (perhaps).** When the buyer's bank receives a draft and B/L (or waybill) from the seller's bank, the cargo may still be en route (if it has been shipped by marine carrier). Therefore the drafts may be payable at some future date rather than immediately. Payment may or may not depend upon the buyer's officially taking delivery of the cargo.
- **Everyone gets paid.** At the time specified—say, when the buyer approves the cargo and accepts delivery—all outstanding drafts are honored. The buyer pays its banker; its banker pays the seller's banker; the seller's banker pays the seller. The order may not be quite so neat; this is a credit transaction, after all, and some level of trust may be involved. The deal can break down at this point. For example, an unethical buyer might refuse to accept delivery and leave the cargo sitting on the wharf while attempting to negotiate a better price with the seller, who cannot afford to ship the goods back home. In some cases, payment is due before the buyer takes possession. (The contract can specify a grace period.) If the goods turn out to be damaged, substandard, or otherwise unacceptable, the buyer may reject the shipment and is at risk of not getting a refund and having to write the whole deal off on its taxes.

Although the L/C is the standard method of financing international trade, other methods are used on occasion, such as trade credit or an open account. In addition, a buyer might pay in advance, taking on the greatest amount of risk. And in a consignment transaction, goods are shipped for resale—say, from one division of a company to another division in a foreign country.

Exhibit 2-96 provides a real-world example of tracking both the physical flow of exported goods and the physical or electronic document trail that accompanies the goods from purchase order on the left to receipt at the final destination on the right. Note the "unexpected events" at the bottom. It's not always smooth sailing in global trade.

Exhibit 2-96: Export Processes—Administrative and Physical



Source: BASF

Currency issues

Just as cargo can sometimes get tripped up at a border crossing, so can payments have their difficulties getting from one country to the next. (As can information, for that matter.) In multicurrency situations, the buyer and the seller both may experience currency exchange risk—a risk caused by the fluctuating rate of exchange between their two currencies. A buyer might make a commitment to pay the equivalent of 200,000 euros to a Japanese seller (who, of course, wants yen, not euros) and actually wind up paying, say, 215,000 euros when trading the euro for yen to make the payment. If, on the other hand, the yen were to weaken against the euro, the buyer would get, in effect, a discounted price.

Impact of currency selection

Organizations have some leeway under accounting rules to select the primary currency with which they conduct the bulk of their transactions—called their home currency for accounting purposes—and this can minimize the total amount of foreign exchange that is needed. They can also maintain foreign currency bank accounts to buy and sell in the same currencies as their trading partners, thus avoiding the need for foreign exchange. Of course, the value of the funds in these accounts will fluctuate for accounting purposes, but such accounts do avoid foreign exchange fees. These tactics can work well for the major currencies of the world; organizations tend to avoid working with currencies that have less established trading markets.

Currency exchange risk creates **operating exposure** for an organization, which the *APICS Dictionary,* 16th edition, defines as

> the risk introduced by flexible exchange rates when operating in the global environment, including production, storage, and buying and selling prices.

Thus currency exchange risk affects not only the effective prices for supplies and for sales to customers but also operating and storage costs and inventory value. The accounting value of one's inventory will fluctuate if it is produced and valued in the currency of a country that isn't the organization's home currency. In such cases, the value of the assets will be adjusted up or down for financial reporting purposes to account for the exchange rates between the countries. This can, in turn, positively or negatively impact the organization's financial ratios and thus its market value (e.g., stock price) and ability to access credit.

Currency hedging

If you aren't dealing in the same currency as your counterparty in an import-export transaction, you have to find ways of making or collecting a payment with minimal risk. One technique is currency hedging, which is used to offset the risks associated with the changing value of currency. An array of financial products can be used toward this end, including forwards, futures, swaps, and options. The most common tool used in currency hedging is currency futures, in which one party agrees to buy/sell a fixed amount of a given currency at a fixed exchange rate on a fixed date in the future. Futures are traded on organized exchanges or clearinghouses; these third parties reduce counterparty risk by serving as intermediaries to both buyer and seller.

Currency hedging is not always available, but it is readily found in the major currencies of the world economy. While most large corporations now have entire departments devoted solely to hedging and risk management, small companies often lack the resources necessary to engage in currency hedging. In this case, a broker/dealer organization can perform these services for a fee.

Currency hedging and conducting transactions in various currencies are both addressed in more detail elsewhere.

Funds flows in supply chains

As you recall from the supply chain model illustrating the different types of flows within the chain, the flow of money or funds goes upstream from customer to producer and from producer to supplier as intermediate or final products or services are paid for. This funds flow is not linear, since some upstream payments may occur long before the final good or service is even purchased.

While the flow of funds is mandatory for a supply chain to exist, it is often an uncoordinated and suboptimized flow. Many mid-size and even some large corporations still work with paper invoices and checks. However, this practice appears to be declining given that many international transactions require the buyer to pay up front with a credit card, wire transfer, or letter of credit.

Why is it critical to improve the flow of funds within a supply chain? There are several advantages to better flows:

- The improved turnover of funds improves customer-supplier relationships through lower perceptions of risk, improved reliability, and better communications, which, in turn, tends to further improve the flow of funds. More prompt and consistent payments also tend to improve relationships, yielding a win-win situation throughout the supply chain.
- Improved cash flows tend to reduce imbalances between the larger and smaller players in the supply chain. Consistent rules for integrated cash flows across the supply chain help avoid the situation in

which sizable retailers request more liberal payables terms from manufacturers and large manufacturers do the same with their smaller suppliers.

The cash-to-cash cycle time (also called the cash conversion cycle) is a key metric for measuring the efficiency of the flow of funds.

Topic 2: Regulatory Considerations

While Module 3 addresses certain government regulatory requirements, this topic addresses regulatory considerations related to procuring and delivering goods and services, including Incoterms® trade terms and customs (both importing and exporting).

Incoterms® trade terms

Incoterms® (International Commercial Terms) trade terms, as defined in the *APICS Dictionary,* 16th edition, are

> a set of rules established by the International Chamber of Commerce that provides internationally recognized rules for the interpretation of the most commonly used trade terms in foreign trade and are routinely incorporated in the contracts for the sale of goods worldwide to provide guidance to all parties involved in the transaction.

The terms are used in foreign trade contracts to identify which parties are responsible for which transportation and customs clearance costs as well as when responsibility for the cargo transfers to the other party. Instead of waiting for title to transfer, which may be held up by the financing side of the transaction, the transfer of control and thus risk of damage or loss is specified by these terms. Some Incoterms® trade terms define who needs to get insurance for which parts of the journey; others leave this up to the parties to specify themselves. Some of the terms also outline import or export obligations for customs clearance and packaging requirements.

The terms are defined and issued by the International Chamber of Commerce (ICC) in Paris. Although Incoterms® trade terms are not legally binding, exporters and importers around the world accept them as the standard terms to use in contracts of carriage (not contracts of sale). The Incoterms® rules are frequently included on shipping company websites and are frequently added to purchase orders to clarify the terms and conditions.

The ICC recommends using their most recent version, Incoterms® 2010, although parties to a contract for the sale of goods can agree to choose older versions. It is important, however, to clearly specify the chosen version—Incoterms® 2010, Incoterms® 2000, or any earlier version, along with the specific trade term being used and a location. Depending on the point of responsibility transfer, the location is either an origin shipping port, a port of call for pickup, or a plant location for local pickup or delivery. For example, CIF Los Angeles, U.S.A., Incoterms® 2010 would show that cost, insurance, and freight are paid by the seller when exporting to the Port of Los Angeles.

Incoterms® trade terms are organized into two groups:

- Rules for any mode or modes of transport
- Rules for sea and inland waterway transport

A complete list of Incoterms® 2010, organized into these two groups, and a definition of each term appear in Exhibit 2-97. The items shaded in gray in the exhibit are infrequently used terms. Buyer and seller responsibilities are shown in Exhibit 2-98.

For more detailed information or to order a copy of the terms, visit the ICC website.

Exhibit 2-97: Incoterms Trade Terms—Definitions

Terms for any Mode or Modes of Transport	
EXW	*Ex Works (buyer loads goods and takes control at seller's location)* The buyer pays all transportation costs and bears all risks for transporting the goods to their final destination. Therefore, the buyer must be able to carry out export tasks in the country of supply.
FCA	*Free Carrier (seller delivers to main carrier; buyer loads)* The seller delivers the goods into the carrier's custody. This is where risk passes from seller to buyer. The buyer pays for the transportation from the named place. The seller is responsible for correcting and paying for any problems or costs of clearing export customs.
CPT	*Carriage Paid To (seller selects and pays for main carriage)* The seller pays for the freight to the named destination. Risk transfers when the goods are delivered into the first carrier's custody.
CIP	*Carriage and Insurance Paid To (seller pays main carriage and insurance)* Risk transfers when the goods are delivered into the first carrier's custody. Afterward, the buyer bears all risk and costs. CIP is similar to CPT except that the seller also pays for the insurance. Under CIP, the seller is also required to clear the goods for export.
DAT	*Delivered at Terminal (seller delivers goods to terminal)* The seller delivers the goods at a named terminal at a named port or destination. Parties should specify at which point within the terminal the risk is transferred from seller to buyer. If the parties agree that the seller is responsible for the costs and risks of taking the goods to another place, then DAP may apply.
DAP	*Delivered at Place (seller delivers goods and buyer unloads them)* The seller delivers the goods to the buyer, who assumes responsibility for their unloading at a named destination. Parties should specify exactly what point at the destination the risks transfer from seller to buyer. If the seller is responsible for clearing customs and paying duties, then DDP may apply.
DDP	*Delivered Duty Paid (seller incurs all costs, including import duty)* The seller pays for all transportation costs, bears all risk until the goods have been delivered, and pays the duty.
Terms for Sea and Inland Waterway Transport	
FAS	*Free Alongside Ship (buyer lifts cargo onboard)* The seller pays for transportation of the goods to the port of shipment. This includes oversized bulk or commodity cargo tendered to the carrier at the inland waterway or ocean port of loading. The buyer pays loading costs, freight, insurance, unloading costs, and transportation from the port of destination. Risk is passed once the goods are delivered to the quay (pier) at the port of shipment.
FOB	*Free on Board (seller puts goods on main transport vessel)* This term is only for ocean shipments. It is useful for bulk cargo, break-bulk cargo, and roll-on-roll-off cargo. Containerized cargo is better handled using DAT. FOB shifts control when goods are "on board" the vessel. (Passing the ship's rail is no longer relevant for Incoterms® 2010.) "On board" is true after an ocean bill of lading or sea waybill is issued. Sellers pay for all costs to transport and load the cargo on the ocean vessel, including export customs. Buyers pay ocean carrier costs and inbound customs.
CFR	*Cost and Freight (seller selects/pays main carriage)* The seller pays for costs and freight of the goods to the named destination port. The buyer pays for the insurance and transportation from the port of discharge (POD). Risk of loss shifts when the goods are on board at the port of shipment. CFR is inappropriate for most container

	sea shipments. (The correct term for these is CPT.) CFR is intended for use in shipping ocean freight pier-to-pier cargo that is not containerized (e.g., oversized or overweight goods).
CIF	*Cost, Insurance and Freight (seller pays main carriage and insurance)* A price quoted as CIF means that the selling price includes the cost of the goods, the freight or transport costs, and the cost of marine insurance. Under CIF, the seller must obtain in transferable form a marine insurance policy to cover the risks of transit. The seller's control transfers when the goods have been delivered on board the vessel at the port of shipment.

Exhibit 2-98: Buyer/Seller Responsibilities (B—Buyer, S—Seller)

	Terms for any Mode or Modes of Transport							Terms for Sea and Inland Waterway Transport			
	EXW	**FCA**	**CPT**	**CIP**	**DAT**	**DAP**	**DDP**	**FAS**	**FOB**	**CFR**	**CIF**
Export packing	S	S	S	S	S	S	S	S	S	S	S
Export clearance	B	S	S	S	S	S	S	S	S	S	S
Inland transport (domestic)	B	B/S	S	S	S	S	S	S	S	S	S
Forwarder's fees	B	B	S	S	S	S	S	B	B	S	S
Loading on vessel	B	B	S	S	S	S	S	B	S	S	S
Ocean/airfreight	B	B	S	S	S	S	S	B	B	S	S
Cargo insurance	*	*	*	S	*	*	*	*	*	*	S
Duties, taxes, customs clearance	B	B	B	B	B	B	S	B	B	B	B
Delivery to destination	B	B	B	B	B	B	S	B	B	B	B

** Incoterms®2010 recommend explicitly stating who will pay for the insurance in a contract or quote. Incoterms®trade terms indicate where risk/liability is transferred but do not actually obligate the buyer or seller to carry insurance except when explicitly noted in the term. In most cases, companies will maintain cargo insurance as a backup.*

Customs

Customs refers to government regulation of import and export trade at its international ports and borders. The purposes of customs are to ensure border security, to collect all required tariffs, and to enforce trade restrictions. A **tariff,** according to the *APICS Dictionary,* 16th edition, is "an official schedule of taxes and fees imposed by a country on imports or exports."

Organizations that engage in international trade use global trade management to ensure that interactions with customs proceed in a smooth and cost-effective manner. The *APICS Dictionary,* 16th edition, defines **global trade management** as

> the management and optimization of shipments across international borders including: ensuring compliance with all international regulations and documentation, streamlining and accelerating the movement of goods, to improve operating efficiencies and cash flows.

Prior to discussing the role of customs in exporting and importing, we'll look at the various participants involved in global trade management.

Export-import participants

International commerce takes place between an exporter (the seller) and an importer (the buyer or customer). A number of intermediaries may perform one or more specialized services before the items sold in one country arrive at the customer's dock in another. Earlier we discussed the growing use of logistics specialists to carry out specific operations for a client company (3PLs) or to coordinate the entire logistics function (4PLs). The use of specialized logistics intermediaries is even more common in the export-import business than in domestic supply chains. There are simply many more issues to contemplate when you send a product across borders into countries with different rules, different currency, and a different language. And so it may be cost-effective for a company sending, or receiving, an international shipment to pay out considerable sums in fees or commissions to acquire these services.

We'll explore the roles of several types of intermediaries who assist in getting cargo across borders and through customs: freight forwarders, non-vessel operating common carriers, consolidators, customs house brokers, export management and export trading companies, shipping associations, ship brokers and ship agents, and export packing companies.

Freight forwarders

The freight forwarder, foreign freight forwarder, or just plain forwarder is a company that arranges transportation for commercial cargo. The *APICS Dictionary,* 16th edition, defines a **freight forwarder** as

> the "middle man" between the carrier and the organization shipping the product. Often combines smaller shipments to take advantage of lower bulk costs.

The *Dictionary* defines a **foreign freight forwarder** as

> an entity that picks up goods at the production site and coordinates transport to the foreign customer's location.

Foreign freight forwarders are not themselves carriers, nor do they buy and resell space on carriers. They are, instead, independent agents. In the United States, for example, they are regulated by the Federal Maritime Commission.

A great majority of international shippers use forwarders. Small companies use them because they can't afford to maintain a staff with the expertise required to handle foreign shipping and because one of the forwarder's functions is to consolidate smaller shipments into larger ones that qualify for discounts. But even large companies use forwarders, because they can benefit from the expertise of such specialists. Thousands of forwarders operate around the world, so there are plenty for logistics managers to select from.

Forwarders may perform many different functions in the course of moving goods across international borders, including

- Quoting carrier rates
- Arranging charters or booking vessel space
- Preparing and presenting documents
- Obtaining insurance
- Handling payments
- Translating
- Tracing and expediting shipments

- Arranging inland transportation.

Although forwarders must be licensed by the government in the United States, they are not subject to certification requirements. However, certification is available for ocean forwarders from the U.S. National Customs Brokers and Forwarders Association, which will designate someone as a “Certified Ocean Forwarder” based upon a combination of experience and passing a certification exam.

Airfreight forwarders may be either independent contractors or affiliated with a single air carrier. They require neither licensing nor certification. However, they may obtain certification from the relevant country’s regulatory body. In the U.S., this is the U.S. Federal Aviation Administration (FAA). In that jurisdiction, clients generally prefer to work only with FAA-certified airfreight forwarders. A major source of competition for airfreight forwarders comes from the carriers themselves, who can work directly with shippers. Companies like FedEx and UPS Air also compete with forwarders for small shipments.

Forwarders derive income from a combination of fees, markups, and commissions from carriers.

Non-vessel operating common carriers

The non-vessel operating common carrier (NVOCC) buys space on inland carriers and resells it to shippers at a marked-up price. NVOCCs handle only the part of the shipment traveling from a port to the importer’s dock or from an exporter’s dock to a port.

NVOCCs originated in the United States in the 1970s as a cost-effective alternative to the carriers. At the time, trains and trucks often returned to port empty after unloading cargo at inland destinations and charged the shipper for both halves of the round trip—even though the shipper made no money on the turnaround. The NVOCCs were able to solve the problem by finding cargo for the return trips to port.

Using their own containers for the inland journey, NVOCCs scout around for port-bound shipments to consolidate into those same containers for the trip back to port. They also provide container service for trips to and from foreign ports. Both shippers and carriers benefit from the intermediary work of the NVOCCs. The shippers receive reduced rates; the carriers gain access to a wider market.

NVOCCs can be distinguished from forwarders in three ways:

- NVOCCs actually buy and resell space on carriers; forwarders do not.
- NVOCCs perform the physical work of consolidating, loading, and unloading cargo; forwarders do not provide labor.
- NVOCCs can handle the freight in many cases, such as shipping by a motor freight carrier from Charlotte, North Carolina, to Hawaii.

A freight forwarder could perform those inland functions for the NVOCC and could very well be a division of the freight line or their contractor. The NVOCC can arrange for transport. These are common carriers that do not operate the vessels by which the ocean transportation is provided and are shippers in their relationship with an ocean common carrier.

Some NVOCCs are affiliated with freight forwarders; some are independent and are therefore able to work with a variety of forwarders. The independent NVOCCs can offer lower rates than those affiliated with a

forwarder, but the affiliated NVOCC and forwarder can offer door-to-door service.

Though they neither own nor operate vessels, NVOCCs are regulated in the U.S. by the Federal Maritime Commission, which requires them to publish rates and not discriminate in hiring. However, they are also subject to different regulations from carriers, and this may put them at a disadvantage. Under the Ocean Shipping and Reform Act (OSRA) of 1998, for instance, NVOCCs are forbidden to enter into service agreements with shippers, while carriers are allowed to do so.

Consolidators

The consolidator combines small shipments into larger ones to qualify for full-vehicle discounts. Generally this service is provided to fill containers for intermodal shipment, such as turnarounds carrying cargo between an inland warehouse and a port.

Consolidators are distinct from NVOCCs, but they may work under them. A consolidator that is not affiliated with an NVOCC contracts with a forwarder or a carrier to arrange the transportation.

Customs house brokers

Customs house brokers assist importers by moving shipments through customs. Their job is to ensure that all documentation required to pass customs is complete and accurate.

These days, the information required to clear customs passes through computer interfaces, such as the Automated Broker Interface System in the United States and the Pre-Arrival Review System in Canada. Replacing paperwork with electronic data transfer has sped up the process of getting cargo through customs.

The customs house broker pays all import duties under a power of attorney from the importer. Liability for any unpaid duties lies with the importer, not the broker.

Export management companies and export trading companies

When companies want to expand from domestic to foreign markets, they may turn for assistance to foreign trade specialists in either export management companies (EMCs) or export trading companies (ETCs) rather than adding internal expertise. While there may be some overlap in the types of services offered by EMCs and ETCs, there is a distinct line between their approaches. The EMC is generally not an exporter itself but rather a consultant to the exporters that hire it. The ETC, on the other hand, is itself an exporter.

A common reason to hire an EMC is to acquire representation in a particular market where the EMC has special knowledge and connections. By working with an EMC, the exporter gains access to current information about the preferences of consumers in that market and about local customs and government regulations. Knowledge of local conditions enables an EMC to help the exporter avoid offending consumers or officials by inadvertent misinterpretations of the culture or the politics of the importer’s country. Finally, EMCs often cultivate friendly relationships with host governments, and this can help ease the exporter’s goods through customs. EMCs may also buy the exporter’s goods and resell them in the foreign market (in the manner of an ETC), but generally they act as a company’s long-term consulting partner, not as a buyer of its products.

An ETC, by contrast, looks for companies making goods that it wants to buy and resell in a foreign market. Its functions, therefore, may include locating importers to buy the goods, overseeing export arrangements, preparing and presenting documentation, arranging transportation overseas and inland, and complying with regulations.

More expansively structured ETCs are known as general trading companies. These entities may comprise banks, steamship lines, warehouses, insurance services, a communications network, and a sales force. Japan's success in international trade has been facilitated by such general trading companies, known in Japan as "sogo shosha." These enormous conglomerates are some of the world's highest revenue generators, including familiar names such as Mitsui and Mitsubishi. With offices in over 100 countries, the sogo shosha handle more than three-fifths of Japan's imports and over one-third of its exports. Other countries with very large general trading companies include Germany, South Korea, China, and the Netherlands.

Shipping associations

Before deregulation, ocean liners were required to publish their rates. Smaller shippers, seeing the rate schedules, could ask for similar deals. Since deregulation, carriers and the larger shippers have been able to sign confidential rate agreements. In response smaller shippers have formed shipping associations—usually nonprofit organizations—to negotiate with carriers for rate discounts on the same terms as larger shipping companies.

Ship brokers and ship agents

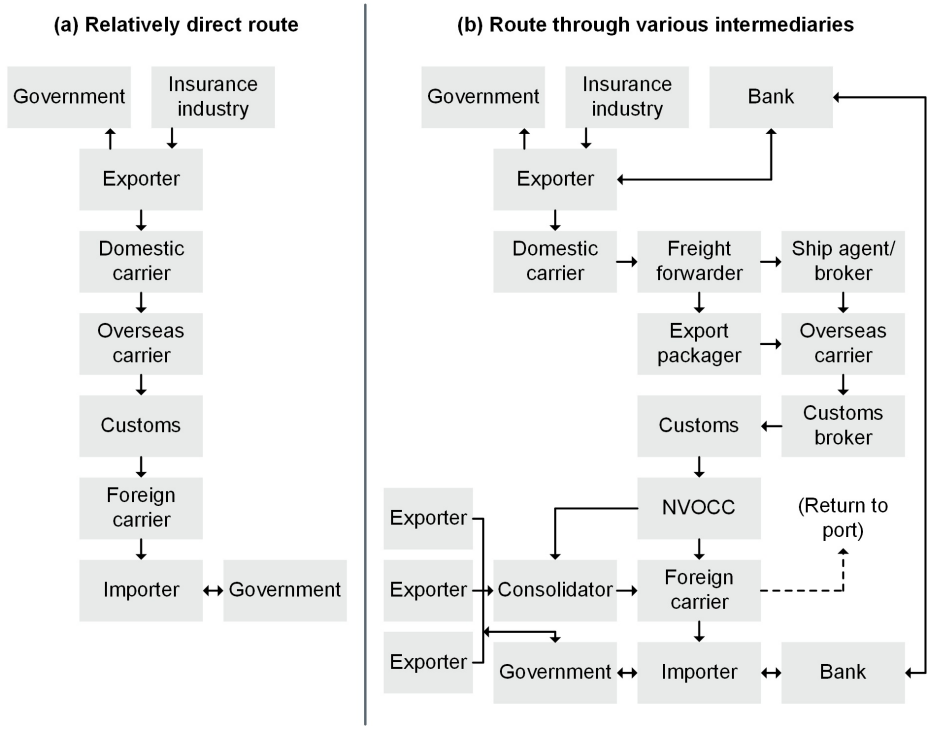
Ship brokers and ship agents assist exporters with the details of arranging ocean transport. A ship broker is an independent contractor that brings exporters together with ship operators that have appropriate vessels available to carry the shipper's freight. With detailed knowledge of carrier schedules, the broker can help the exporter find a ship that will be in port when its cargo is ready to travel. A ship agent works for the carrier rather than being an independent contractor. When a ship is headed for port, the ship agent arranges for its arrival, berthing, and clearance; while the ship is in port, the agent coordinates unloading, loading, and fee payment. Shippers contact ship agents for information about the arrival and availability of ships.

Export packing companies

Export packing companies provide the specialized packaging services required for cargo that may have to undergo long journeys and pass customs inspections in another country. The packing company can choose packaging materials that provide adequate protection with the least bulk and weight.

Exhibit 2-99 illustrates two paths that cargo might travel to get from an exporter to an importer—(a) the simplest possible journey and (b) a journey aided by a full complement of intermediaries.

Exhibit 2-99: Export-Import Flowcharts



In sum, the participants in export-import trade have the features and advantages described in Exhibit 2-100.

Exhibit 2-100: Roles of Export-Import Participants

Participant	Role
Exporter	Shipper and seller of the cargo
Importer	Exporter's customer, who buys the cargo and is sometimes responsible for payment of import duties at customs (usually handled by customs house broker)
Domestic carrier	Train, truck, or air carrier that takes cargo to the outgoing port
Overseas carrier	Ship operator or air carrier that takes the cargo from the domestic port to the foreign port (assuming overseas transport)
Freight forwarder	Contractor responsible for getting goods from dock to dock and who arranges transportation for exporter's cargo
NVOCC	Non-vessel common carrier that arranges transport of cargo from port to importer and contracts for or purchases space on the ocean vessel for resale or its own use
Consolidator	Independent company or affiliate of NVOCC that consolidates shipments to load into empty vehicles for return trip from importer's dock to port
Customs house broker	Licensed broker who has the expertise to move a shipment through customs expeditiously and to ensure complete, accurate documentation
Export management company (EMC)	Company that acts as a consultant or an export department for one or several producers of goods and services; often has well-established network of foreign distributors, accelerating the access into foreign markets

Export trading company (ETC)	Company that identifies companies making goods that it wants to buy and resell in a foreign market
Shipping association	Nonprofit association of smaller shippers banded together to negotiate better rates from carriers
Ship broker	Independent contractor who brings together the exporter with a ship operator that has a vessel available with the right services at the right time
Ship agent	Representative of a ship operator who is available to coordinate in-port activities for the shipper with cargo to export
Export packing company	Specialist in packaging cargo for export so as to combine lightest practical weight (for reduced duties) with maximum protection

Importing

Most countries are eager to promote the international sale of domestic manufactures and agricultural products. Getting the goods into the buyer's domain can often be more of a struggle. The consignee's country has to worry about the balance of trade, contaminants, invasive species, and collecting the full amount of import duties. The customs office is the focal point of the importing country's concerns.

In this section on the concerns of importers, we'll look at

- Classifying merchandise using the Harmonized Tariff Schedule
- Declared value and duty drawbacks
- Calculating import costs
- Import requirements and restrictions.

Harmonized Tariff Schedule

It's imperative that all parties, including customs, know exactly what is being shipped. The Harmonized Tariff Schedule (HTS), which is administered by the World Customs Organization in Brussels, serves as a set of standard numerical descriptions of products exchanged in export-import transactions.

The *APICS Dictionary,* 16th edition, defines the **Harmonized Tariff Schedule** as follows:

> The mechanism by which international tariffs are standardized. Importers and exporters classify all goods moved across international borders using the Harmonized System of the country of import. Then based on this classification the HTS is used to determine the amount of tariff they must pay.

A synonym is the **harmonized system classification codes,** which the *APICS Dictionary,* 16th edition, defines as

> an internationally standardized description of goods that uses a system of numbers to provide increasingly detailed classification and descriptions.

The HTS coding system is used by more than 200 countries and economies as a basis for their customs tariffs and for the collection of international trade statistics. Over 98 percent of the merchandise in international trade is classified in terms of the HTS. It is important to note that while HTS codes are required for businesses selling merchandise internationally, they are not currently required for individuals (for example, selling from a website like eBay and shipping internationally). If you do not provide a code while shipping an item, the broker will typically assign an HTS code.

The basic HTS number is made up of six digits. Each country can assign up to four additional numbers, to make a 10-digit code. The United States, for example, maintains two versions of the harmonized code, both expanded to 10 digits. One is used for imports and is administered by the U.S. International Trade Commission (USITC); the other, called Schedule B, is used to classify exports and is administered by the Census Bureau. Many other countries use six- to nine-digit versions of the HTS number. For instance, Japan uses 39 codes to classify its salmon products. As you see in the excerpt of codes in Exhibit 2-101, Japan has used nine-digit codes to classify its live, fresh, chilled, and frozen salmon products.

Exhibit 2-101: Import and Export Salmon Commodity Codes for Japan

Live	
0301.99-290	Fish (excluding ornamental fish, fry for culture and 0301.99-210), live (import)
0301.99-900	Other live fish (export)
Fresh or chilled	
0302.11-000	"Masu" (*Salmo trutta, Oncorhynchus mykiss, O. clarki, O. aguabonita, O. gilae, O. apache* and *O. chrysogaster*) (import and export)
0302.12-000	Pacific, Atlantic or Danube *sake* (export only)
0302.12-011	"Benizake", red salmon *O. nerka* (import only)
0302.12-012	"Ginzake", silver salmon *O. kitsutch* (import only)
0302.12-019	Pacific salmon excluding *O. nerka* and *O. kitsutch* (import only)
0302.12-020	Atlantic or Danube Salmon (import only)
0302.70-000	Livers, eggs and soft roe of fishes (export only)
0302.70-090	Livers, eggs and soft roe of fishes (not *Clupea, Gadus* or *Merluccius* spp.) Fish livers and roes nes) (import only)
Frozen	
0303.10-000	Pacific sake (prior to 2002) (export only)
0303.11-000	"Benizake" Sockeye salmon or red salmon *O. nerka* 2002 onward (imports and exports)—prior to 2002, code 0303.10-010 was used for imports and 0303.10-000 was used for exports)
030.19.000	Other Pacific "sake" 2002 onward (export only)
030.19-010	"Ginzake" silver salmon *O. kisutch* 2002 onward—previously 0303.10-020 (prior to 2002) (import only)

Declared value and duty drawbacks

Once the exporter has determined the identity of the cargo by reference to the harmonized code, the importer is responsible for declaring the value of the cargo. That value, along with other factors, influences the amount of any import duty. According to the World Trade Organization (WTO), the declared value of the cargo should ideally be the actual price paid (or to be paid) by the importer. Goods shipped between one company's divisions located in different countries are valued by a transfer price, which is a standard cost plus a surcharge. The WTO recognizes other reasonable ways of determining value, such as the value of identical or similar merchandise.

Duty drawback is a refund of all or part of duty paid on goods that were first imported and then reexported. Governments differ on the details of drawbacks. In every case, however, the importer pays the import duty when the goods initially come into the country and then applies for the drawback after reexporting. The duty

will be based on the increase in value based on a component or module, not on the increase in value due to transformation.

Calculating import costs

The assessment of costs due at customs varies from country to country. In addition to the import duty or tariff (the words “duty” and “tariff” are interchangeable), there will be customs-related fees and, in some countries, a value-added tax (VAT). Note that Canada has a VAT equivalent called a goods and services tax (GST) and that the provincial tax plus the federal GST is called a harmonized sales tax (HST).

Import duties are generally assessed as a percentage of either the Incoterms® CIF (Cost, Insurance, Freight) or FOB (Free on Board) value (note that there is also a UCC F.O.B. term used just in North America but this is not what is being discussed here). The FOB value includes the cost of goods plus the amounts paid by the exporter to transport the freight from its dock and load it on the ship. If the cargo consisted of goods subject to a 5 percent tariff and the CIF were 1 million euro, then the tariff (duty) would be 50,000 euro.

Value-added taxes (which resemble sales taxes in the United States) are assessed on the CIF or FOB plus the import duties. In the EU countries, for example, VAT is assessed against the CIF plus the import duty. VAT percentages in the EU are subject to change, of course, but as of September 2018, the standard VAT in the U.K. was set at 20 percent. Reduced or zero VAT (5 or 0 percent) rates are available from each country for certain goods and necessities such as home energy, food, clothing, and books.

Import requirements and restrictions

Governments generally look with less favor on importing than on exporting, since exports bring money into the country and imports take money out. Moreover, goods coming into the country may pose various threats, including such hazards as competition with domestic goods; potential contamination of the environment; infectious diseases affecting livestock, wildlife, or humans; and terrorism.

Governments around the world create numerous import licensing requirements, regulations, and restrictions to guard against these dangers, and they enforce these regulations through customs inspections. These restrictions pose problems for importers and exporters alike. The problems for importers are obvious enough. In the United States, for example, there might be a market for European cheeses produced from nonpasteurized milk, but the Department of Agriculture won’t license a distributor to sell such cheeses in the U.S. market—ostensibly for health reasons. Japan protects its domestic rice growers from imported rice for cultural reasons. On the other side of such restrictions, exporters may be easily able to acquire an export license from their own government but not able to find an importer licensed to buy their products.

The World Trade Organization, which includes in its membership the vast majority of trading nations, takes as part of its mission the creation of free and fair trade around the world by eliminating many of these barriers against imports. It pays special attention to providing less-developed nations with better access to world markets for their exportable products.

Membership in the WTO also means that businesses headquartered in one member nation should be able to open branches in another member nation and be subject to the same rules applying to domestic businesses in that nation, thus gaining access to their markets directly rather than through imports. After China joined the WTO in 2001, for example, many foreign companies rushed in, hoping to capture a slice of the potentially

enormous market there. These early efforts were sometimes disappointing for a variety of reasons.

Even when trade and investment barriers begin to fall, the export-import business may still be stymied by problems with entrenched bureaucracy, lack of infrastructure, and simple lack of buying power.

Export documentation

From the exporting side, let's consider documentation. We learned earlier that export requires considerably more extensive documentation than domestic transactions. Using the U.S. as an example, an overview of the major document types follows.

Export declaration

The U.S. Census Bureau uses the Automated Export System (called AES*Direct*) to capture and store U.S. export data electronically. AES*Direct* is provided free of charge to allow exporters to self-file their Electronic Export Information (EEI), previously known as the Shipper's Export Declaration (SED). The EEI must be filed for exports valued at US$2,500 or more when shipped to any country except Canada. (Shipments to Canada are exempt from the AES regulation.) Paper copies of the EEI are no longer accepted. In most cases, the broker will file the EEI instead of an individual person working in the supply chain. Related links about the AES program and AES*Direct* are available online in the Resource Center.

The U.S. form includes such basic information as

- A description of the commodity
- The shipping weight (with packaging)
- A list of marks and numbers on the containers
- The number and dates of any required export license
- The place and country of destination
- The parties to the transaction.

Although some commodities are forbidden for export or limited in some way, the form exists as much for the purpose of compiling trade statistics as for enforcement.

Export license

Shippers need to acquire an export license. The licenses come in two types:

- A general export license allows export of most goods without restrictions.
- A validation export license is required for shippers who wish to sell military hardware, computer chips, and other strategically sensitive items abroad. (Countries may limit export of certain items of strategic significance, including military hardware and some high-tech products.)

Commercial invoice

The commercial invoice states the value of the goods in the shipment and specifies payment terms and methods. It constitutes the seller's and buyer's invoice for the transaction. It also may be required for the letter of credit and by other entities that need to know the value of the goods for insurance or the assessment of duties. The information required and the language it's written in may vary from country to country.

A consular invoice, required by many countries for incoming shipments, is similar to the commercial invoice but also contains information needed for customs in the importer's country. Generally the consular invoice

must be written in the language of the importing country, where it will be used for compiling trade statistics.

A pro forma commercial invoice may be sent to a potential buyer in advance of the actual sale. It may contain the same information as a regular commercial invoice and serve as both a price quote and documentation for the potential buyer to use in securing a letter of credit to finance the purchase. Carefully documenting all costs in the pro forma invoice can help the exporter properly price the product by including hidden costs, such as unforeseen costs arising from risks and human errors.

ATA Carnet

Containers traveling under an ATA Carnet can cross several boundaries duty- and tax-free without customs inspection. (ATA stands for “Admission Temporaire/Temporary Admission.”) The Carnet convention was adopted for western Europe in 1961 and was intended to apply to commercial samples, professional equipment, and items for presentation at tradeshows and other similar events that were merely passing through a jurisdiction, not being imported into it. Despite their original use for these specific purposes and items, Carnets now cover almost any type of goods, excluding disposable and consumable items, and they are used worldwide.

Certificate of origin

A certificate of origin provides information on the country where the goods were produced (country of origin) for assigning tariffs and for compliance with government trade restrictions. It often accompanies cargo exported into a country that has signed a treaty granting favorable import duty rates to the exporting country. The certificate states that the goods actually did originate in the exporting country and are not merely being reshipped from there to benefit from the lower duty. There is more discussion on the complexities of the origin of goods elsewhere.

Bills of lading and air waybills

We learned about bills of lading (B/Ls) earlier. A shipping company issues a B/L with the buyer as a way of demonstrating ownership of goods. All international shipments are initiated by a B/L that serves as the carrier’s contract and receipt for goods the carrier will transport from one destination and shipper to another specified destination and recipient. The B/L also serves to document claims if the shipment is delayed, damaged, or lost.

An international shipment may be covered by multiple B/Ls, each initiating a new leg of the journey. An export B/L applies to the carriage from the exporter’s dock to its country’s port, while an ocean B/L governs the port-to-port portion of the shipment. A combined transportation document groups the B/Ls from various modes into one document.

Order bills of lading provide evidence of ownership and are negotiable. Sellers may use them to transfer title to an intermediary, bank, or importer. A straight bill of lading, by contrast, is nonnegotiable and governs cargo that must be delivered straight to the consignee. A clean bill of lading, issued by the carrier, certifies that the goods have arrived at the ship undamaged. If the goods appear to have been damaged, the carrier will note that on the original B/L and will not issue a clean bill.

The ship’s manifest, based on processed B/Ls, summarizes the vessel’s cargo, noting the port where the

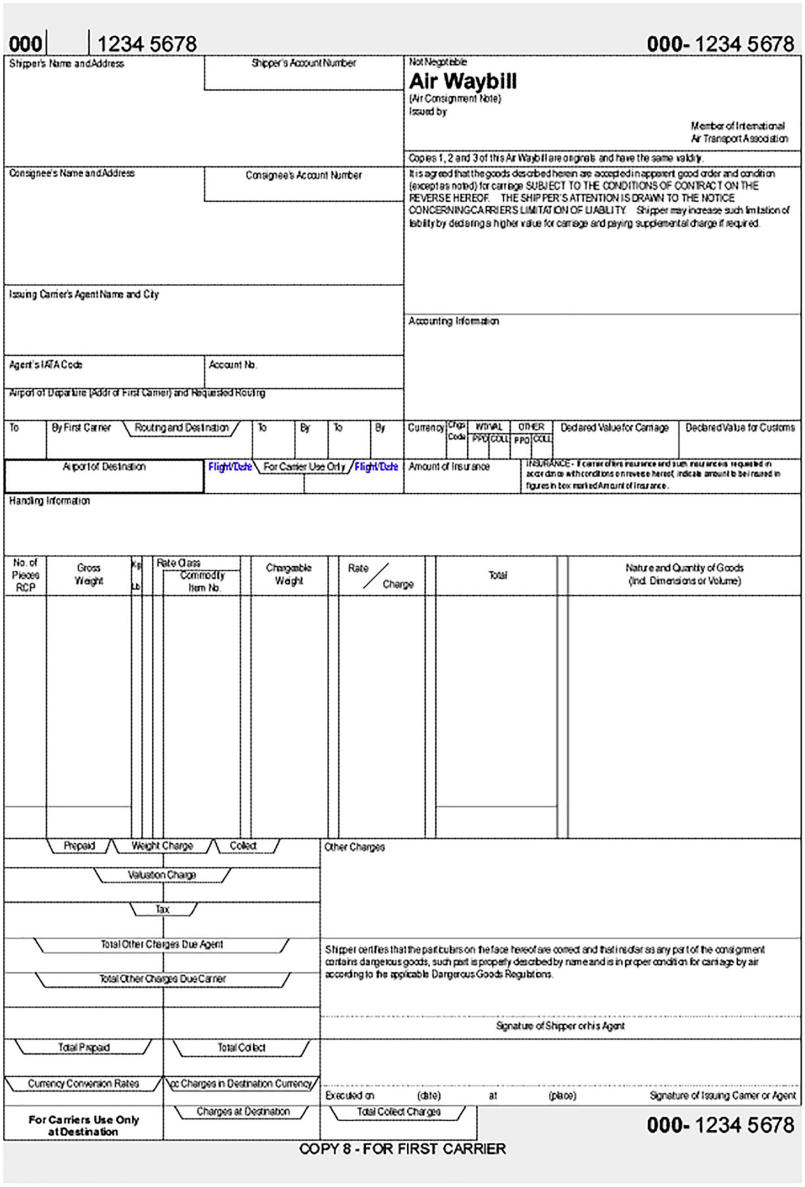
cargo came aboard and the port to which it's bound.

A statement of liabilities appears in the primary B/L. According to the U.S. Carriage of Goods by Sea Act (1936), the shipper bears responsibility for losses that result from perils of the sea, acts of God, acts of public enemies (such as pirates or terrorists), or its own negligence. The carrier is responsible for maintaining the ship in good working order—literally, "ship-shape"—and is liable for its own acts of negligence. (Ocean carriers have fewer legal responsibilities than overland carriers.)

The air waybill (AWB), or airway bill of lading, is a standardized form used for all air shipments. Use of one uniform document has reduced processing costs for air shipping and facilitated faster clearing through customs. Unlike a steamship B/L (and except for a straight B/L), the air waybill doesn't provide title to the cargo. Instead, it serves only as a receipt for goods and as evidence of the contract of carriage. The cargo is delivered straight to the consignee named in the letter of credit financing the transaction—which may be either the importer or the bank issuing the L/C. If the goods are not designated for delivery to the bank, the importer can simply show up at the carrier's destination and claim the cargo. Therefore, unless there has been a cash payment to the exporter (or the importer is known and trusted at the destination), the AWB arrangement involves some risk. Some destinations provide for cash on delivery, with consignment contingent upon receipt of the payment from the importer. The exporter often engages a freight forwarder or consolidator to handle the shipment and provides a Shipper's Letter of Instructions authorizing the forwarding agent to sign the AWB on its behalf.

Exhibit 2-102 shows an air waybill.

Exhibit 2-102: Universal Air Waybill



000 1234 5678 000- 1234 5678

Shipper's Name and Address | Shipper's Account Number

Not Negotiable

Air Waybill

(Air Consignment Note)

Issued by

Member of International Air Transport Association

Copies 1, 2 and 3 of this Air Waybill are originals and have the same validity.

Consignee's Name and Address | Consignee's Account Number

It is agreed that the goods described herein are accepted in apparent good order and condition (except as noted) for carriage SUBJECT TO THE CONDITIONS OF CONTRACT ON THE REVERSE HEREOF. THE SHIPPER'S ATTENTION IS DRAWN TO THE NOTICE CONCERNING CARRIER'S LIMITATION OF LIABILITY. Shipper may increase such limitation of liability by declaring a higher value for carriage and paying supplemental charge if required.

Issuing Carrier's Agent Name and City

Accounting Information

Agent's IATA Code | Account No.

Airport of Departure (Addr. of First Carrier) and Requested Routing

To	By First Carrier	Routing and Destination	To	By	To	By	Currency	CHGS Code	WT/VAL PPD / COLL	OTHER PPD / COLL	Declared Value for Carriage	Declared Value for Customs

Airport of Destination | Flight/Date | For Carrier Use Only | Flight/Date | Amount of Insurance | INSURANCE - If carrier offers insurance and such insurance requested in accordance with conditions on reverse hereof, indicate amount to be insured in figures in box marked Amount of Insurance.

Handling Information

No. of Pieces RCP	Gross Weight	kg / lb	Rate Class / Commodity Item No.	Chargeable Weight	Rate / Charge	Total	Nature and Quantity of Goods (incl. Dimensions or Volume)

Prepaid | Weight Charge | Collect

Valuation Charge

Tax

Total Other Charges Due Agent

Total Other Charges Due Carrier

Other Charges

Shipper certifies that the particulars on the face hereof are correct and that insofar as any part of the consignment contains dangerous goods, such part is properly described by name and is in proper condition for carriage by air according to the applicable Dangerous Goods Regulations.

Signature of Shipper or his Agent

Total Prepaid | Total Collect

Currency Conversion Rates | cc Charges in Destination Currency

Executed on (date) at (place) Signature of Issuing Carrier or Agent

For Carriers Use Only at Destination | Charges at Destination | Total Collect Charges

000- 1234 5678

COPY 8 - FOR FIRST CARRIER

Dock receipt

A dock receipt, issued by a ship agent, signifies that a steamship company has received cargo from a domestic carrier.

Certificate of insurance

If the terms of sale require insurance, a certificate of insurance will attest that either the buyer or the seller (according to the relevant Incoterms® trade terms) has taken out a policy covering the cargo. The certificate indicates types of insured losses, the amount of insurance, who issued it, and so on.

ATR certificate

The *APICS Dictionary,* 16th edition, defines an **ATR certificate** as

> a certificate that is required for trade between the EU and Turkey. It grants zero duty to “free circulating” goods in the EU, which are goods originating in the EU or imported to the EU with all import duties and taxes paid. Agricultural goods, minerals, and steel are excluded and must use form EUR1.

Security regulations

Security regulations are a customs role that has increased in importance as laws designed to combat terrorism have come into force. The impact on organizations is increased potential for delays at borders as goods are checked. One way to improve the chances of getting goods through smoothly is to participate in a trade partnership with each government that offers such a program.

Security regulations and trade partnerships designed to ease passage of goods through the security portions of customs (e.g., C-TPAT in the U.S.) are discussed elsewhere.

Topic 3: Trade Considerations

This topic discusses the importance of taking advantage of free trade zones and trading blocs.

Free trade zones

A free trade zone (FTZ), called a foreign trade zone in the United States, is a geographic area in a country in which some normal trade barriers such as tariffs and quotas are eliminated and bureaucratic requirements are lowered in hopes of attracting new business and foreign investments. It also may be referred to as an export processing zone (EPZ). Typically, goods may be landed, handled, manufactured or reconfigured, and reexported without the intervention of the customs authorities. Only when the goods are moved to consumers outside the zone do they become subject to the prevailing customs duties.

Free trade zones are usually organized around major seaports, international airports, and national frontiers. The United Arab Emirates has created 21 “free zones,” including one at its international airport. Others are being created, such as one in Shanghai that opened in September 2013, hoping to attract more European companies to invest in mainland China due to a more easily accessible market.

In the U.S., a foreign trade zone is a federally sanctioned site where foreign and domestic goods are considered to be outside of U.S. customs territory. Merchandise can be brought into an FTZ to be stored, exhibited, repackaged, assembled, or used for manufacturing free of customs duty, quota, and other import restrictions until the decision is made to enter the goods into the U.S. market. No duty is ever paid on foreign goods that are reexported from the FTZ. There are approximately 250 FTZs in the United States, with at least one in each of the 50 states.

Benefits

Importers and manufacturers benefit from FTZs in the following ways:

- **Exemption from customs formalities, duties, or quotas.** Shippers land their goods in FTZs without going through customs formalities or import duties. They are also exempt from quotas.
- **Exemption from duties or quotas on reexports.** Goods can be reexported from an FTZ without having been subject to duties and, therefore, without having to go through a lengthy process to receive a duty drawback refund.
- **Deferral of duties on imports.** Duties and federal excise taxes are deferred on imports while they are in the FTZ. They will go through customs on the way out of the zone into customs territory.
- **Avoidance of fines.** Imports can be processed, remarked, and repackaged in an FTZ before going through customs. Therefore, a shipment with potential compliance problems can be brought into compliance in the FTZ before going through customs.
- **Reduction of import duties on some cargoes.** Shippers can land cargo in an FTZ, complete the break-bulk, and then go through customs with just those goods destined for that country.
- **Inspection of merchandise before paying duties.** An importer can have cargo brought into an FTZ for inspection and testing before paying import duties, thus eliminating the possibility of having to reject

a shipment after paying the duty on it.

- **Avoidance of quota problems.** If a shipment of goods exceeds an import quota, the shipper can hold the cargo in an FTZ until it can come in under quota.
- **Indefinite, cost-effective storage.** Goods can be stored in an FTZ indefinitely without being subject to local and state inventory taxes. The zones are under customs control, so they provide excellent security for stored items.
- **Manufacture and assembly without "inverted duties."** When the duty on imported components is higher than the duty on the finished product, it is called an "inverted duty." To avoid paying an inverted duty, a domestic manufacturer can bring low-priced production materials into an FTZ and process them into a finished product for export. When going through customs, the manufacturer pays the duty on either the components or the finished goods, whichever is more advantageous. The FTZ board (in the United States) must approve any manufacturing or processing that results in a tariff reclassification.

It's important to emphasize that any retail trade is forbidden in a free trade zone.

Drawback

A disadvantage of having a free trade zone is that the host country receives reduced revenues from import duties. However, with the numerous advantages of an FTZ, many countries do provide them.

Trading blocs

As defined in the *APICS Dictionary,* 16th edition, a **trading bloc** (or **trade bloc**) is

> an agreement between countries intended to reduce or remove barriers to trade within member countries. Frequently, but not always, those countries are geographically close.

According to Mansfield and Milner in their book *The Political Economy of Regionalism,* there are different types of trading blocs, including

- Free trade areas or zones
- Preferential trade agreements (which allow member countries to have preferential access to certain products from other member countries)
- Customs unions (made up of free trade areas with common external staff)
- Common markets (made up of free trade areas in which physical, technical, and fiscal barriers are reduced as much as possible)
- Economic unions (made up of common markets and customs unions as described above)
- Customs and monetary unions (made up of customs and currency unions that share the same external trade policy and currency)
- Economic and monetary unions (made up of common markets and customs and monetary unions).

In these instances, "union" refers to a group of two or more countries that form a unit that shares the same philosophies on certain aspects of trade. (This is not be confused with an employee collective bargaining group.)

Countries can belong to a variety of different trading blocs, and the World Trade Organization tracks the

status of proposed blocs. There are also regional trading blocs that form when nations within a particular region join together to reap the benefits. The European Union (EU) is a regional organization that is a trade bloc. Some of the larger stand-alone agreements between states to form trading blocs include the North American Free Trade Agreement (NAFTA), the European Free Trade Association (EFTA), the Caribbean Community (CARICOM), the African Union (AU), the Union of South American Nations (UNASUR), the Eurasian Economic Community (EurAsEC), the Arab League (AL), the Association of Southeast Asian Nations (ASEAN), the Central European Free Trade Agreement (CEFTA), Trans-Pacific Partnership (TPP), and the Pacific Islands Forum (PIF).

There is a dynamic exchange of opinions on how trading blocs impact the global economy—that is, whether they create or divert trade. According to the author of the *Routledge Encyclopedia of International Political Economy,* the answer is not clear-cut.

Now let's take a closer look at one of the major trading blocs, NAFTA.

NAFTA

The North American Free Trade Agreement of 1994 aims to create a unified free trade zone comprising Canada, the United States, and Mexico by eventually eliminating all barriers to trade such as tariffs and other protective measures.

Requirements

Under NAFTA, a large number of tariffs were dropped immediately and the rest scheduled for gradual elimination. However, some documentation requirements remain to challenge exporters and importers in the region—along with perhaps deeper problems arising from cultural and political differences, the movement of labor and companies across borders, and inadequate infrastructure in Mexico.

The primary problem in export documentation arises from the requirement to establish the country of origin of exported goods to qualify for low or no import duty. Under NAFTA, various goods receive preferential treatment, with the greatest benefit going to goods qualifying as having originated in the region. Determining the "local content" of an item can be troublesome. The section of NAFTA governing the definition of "originating in the region" is Article 401, which also prohibits countries outside the region from attempting to benefit from the low import duty by shipping their goods through Canada, the United States, or Mexico.

To provide a sense of how tricky this can be, here are the four provisions of Article 401 for determining which goods qualify for preferred treatment:

- Goods wholly obtained or produced in the NAFTA region
- Goods produced in the NAFTA region wholly from materials originating in the region
- Goods meeting the Annex 401 origin rule (described below)
- Unassembled goods and goods classified with their parts that do not meet the Annex 401 rule of origin but contain 60 percent regional value content using the transaction method or 50 percent regional value using the net cost method

Annex 401 describes the condition under which goods created from nonregional materials may qualify as original if the foreign components or ingredients undergo a tariff change under the international system governing classification of goods for tariff purposes. Here's an example: Pork sausage can qualify even if the

pork comes from eastern Europe and the spices from Jamaica if the sausage fits under a different classification in the tariff system than any of its nonregional ingredients.

It isn't necessary to understand all these rules, only to know that the documentation problems can become complex.

Other impediments to free trade in the region are common. The Mexican transportation infrastructure, for instance, places real difficulties in the way of constructing an efficient supply chain: The roads are bad, air service is limited, there is only one railroad, and there is little or no provision for less-than-truckload trucking. Feuding has been constant between the United States and Mexico over provisions on both sides that inhibit access of the one country's trucks to the other country's highways.

Benefits

The immediate benefit of NAFTA to importers who bear responsibility for paying import duties was to eliminate tariffs on a number of items and schedule the rest for phaseout over the subsequent five, ten, or 15 years. Some benefits envisioned for a free trade zone in North America have been partly realized by the lowering of tariff barriers but there is room for improvement.

A side effect of NAFTA has been the growth of the companies called "maquiladora"—facilities for manufacturing or assembly of duty-free components. Many are located in northern Mexico, and, while the maquiladora operations did not come into being with NAFTA, they have thrived since the inception of the agreement, becoming steadily more integral to the supply chains crossing the border between the United States and Mexico. U.S. companies are able to profit from the difference between labor costs in the United States and in Mexico.

In the usual case, a U.S. company either operates the maquiladora or subcontracts operations to it, such as manufacturing, processing, or assembly. The U.S. company may send a partly finished product to a maquiladora and then reimport the finished goods. Because of NAFTA, the duty on the transfer of materials and goods across the border is assessed only on the value added in Mexico, which is primarily attributable to labor costs.

Drawbacks

While the freer access to markets and labor among the three countries provides benefits to manufacturers, other conditions in the area can be drawbacks, such as

- The lack of adequate infrastructure in Mexico
- The complex paperwork related to country of origin of exported items
- The ongoing problems with restrictions on trucking both coming into and going out of Mexico
- Ill will among the countries occasioned by plant closings and job losses.

Effects of trading blocs on supply chains

In order to have the complete picture of trading blocs, the effects on supply chains within and outside blocs should be explained.

Effects within blocs

The gravity model is used by social scientists to predict the movement of people and ideas between two

population centers as a function of the population of each area and the distance between the areas. According to the gravity model, countries that are geographically closer tend to have a high volume of trade. Because transportation costs and trade barriers tend to be lower, countries that are closer to one another are more likely to become trading partners by forming a trading bloc. Supply chains in the respective member countries usually reap the benefits of volume, quantity, and better prices and terms as well as lower levels of tariffs.

With membership in a bloc, supply chain management may find that it's easier and less complicated to negotiate with fewer partners. With this smaller number, concessions between members can be more easily made and enforced, making the process less headache-ridden.

Supply chains from lesser-developed member countries with more economic and political variability can take advantage of agreements with larger entities that they would otherwise not have access to.

Effects outside blocs

If a trading bloc is large, nonmembers may see their prices and demand for exports decrease. This can result in deterioration in trade terms and decreased market power of these nonmembers. Seeing a decrease in their exports, they may resort to protectionistic tactics and increase their lobbying efforts.

The effects of trade diverted from nonmembers' supply chains can impact the nonmembers' ability to make multicountry negotiations feasible and increase the difficulty of doing business across borders, even if it's with the country right next door or one with which they've previously traded. Sometime if they are fortunate enough to continue to trade, the nonmembers may be forced to pay optimal tariffs to the bloc members.

In summary, the optimal presence of trading blocs depends on the level of the potential positive effects of creating trade as well as the potential negative effects of diverting trade and creating adverse changes in trade terms for nonmembers.

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