CHAPTER SIX

Integrated Operations Planning

Chapter Outline

The dominant theme of supply chain management is achievement of operational integration. The benefits available from operational integration are directly related to capturing efficiencies between functions within an enterprise as well as across enterprises that constitute a domestic or international supply chain. This chapter focuses on the challenges of supply chain operational planning by examining how and why such planning creates value and by detailing the challenges related to developing an effective plan. The Sales and Operating Planning **(S&OP)** process is discussed from the perspective of effective cross-functional and cross-organizational collaboration. Following a brief discussion of collaborative planning, forecasting, and replenishment **(CPFR)**, the chapter is concluded with a comprehensive discussion of forecasting. Building on the technology discussion of Chapter 5, this final chapter of Part 1 serves to set the framework for the operational discussion presented in Part 2.

Supply Chain Planning

Supply chain operational planning requires the coordination of the processes identified in Chapter 1. Demand planning responsiveness, customer relationship collaboration, order fulfillment/service delivery, manufacturing customization, supplier relationship collaboration, life-cycle support, and reverse logistics must be coordinated to satisfy customers and effectively deploy resources. The framework to provide this coordination is supply chain planning.

The supply chain planning system and supportative information systems seek to integrate information and coordinate overall logistics and supply chain decisions while recognizing the dynamics between other firm functions and processes. The three factors driving effective planning are (1) supply chain visibility, (2) simultaneous resource consideration, and (3) resource utilization.

Supply Chain Visibility

The first reason for planning system development is the need for **visibility** regarding location and status of supply chain inventory and resources. Visibility implies not only being able to track supply chain inventory and resources but also that information regarding available resources can be effectively evaluated and managed. For example, at any given point in time, manufacturers may have thousands of shipments in-transit and inventory being held at hundreds of locations around the globe. Simply being able to identify shipments and inventory is not sufficient: supply chain visibility requires exception management to highlight the need for resource or activity plans to minimize or prevent potential problems.

While the United States and its allies demonstrated the benefits of effective military planning and technology deployment during the Gulf Wars, the Defense Department learned that its logistics and supply chain systems did not perform to the same standard. A major reason cited for poor logistical performance was lack of supply chain visibility. For deployment and security, the Defense Department and its key suppliers did not have integrated information systems capable of documenting or identifying inventory status or location. There was minimal integration between each military service (Army, Navy, and Air Force) and their logistics service providers, such as the Defense Logistics Agency. Such logistics integration had not historically received major attention. This lack of integration coupled with the fear that potential foes could gain an advantage by breaking into the tracking system or monitoring movements resulted in performance that was not reflective of modern supply chain management.

Limited visibility regarding inventory in-transit and expected arrival times resulted in significant uncertainty regarding product availability. The lack of certainty in a situation where product availability is critical resulted in additional inventory and requisitions to reduce the chance of stockouts. While it is clear that no military force can tolerate short supply, excessive inventories are expensive and typically wasteful of critical resources.

Simultaneous Resource Consideration

If planning system visibility determines resource status and availability, the second reason for a planning system is the need to consider combined supply chain demand, capacity, material requirements, and constraints. Supply chain design reflects customer demand for product quantity, delivery timing, and location. While some of these customer requirements may be negotiable, logistics must execute to the agreed-to requirements and standards.

The constraints to meeting customer requirements are materials, production, storage, and transportation capacity, which represent the physical limitations of processes and facilities. Traditional planning methods have typically considered these capacity constraints in a sequential manner. For example, an initial plan is made that operates within production constraints. The initial plan is then adjusted to reflect material and sourcing constraints. This second plan is then revised to consider storage and transportation constraints. While the processes and sequences may be different, sequential decision making results in suboptimal and inferior planning and capacity utilization.

Achieving desired supply chain performance requires simultaneous consideration of relevant requirements and capacity constraints to identify trade-offs where increased functional costs, such as in manufacturing or storage, might lead to lower total system costs. A planning system needs to quantitatively evaluate the trade-offs and identify plans to achieve desired overall performance.

Resource Utilization

Logistics and supply chain management decisions influence many enterprise resources, including production, distribution facilities and equipment, transportation equipment, and inventories. These resources consume a substantial proportion of a typical firm's fixed and working assets. Functional management must focus on resource utilization within its scope of responsibility. For example, production management is focused on minimizing plant and equipment required for manufacturing. The typical result is long production runs requiring minimum setups and changeovers. However, longer production runs invariably result in more finished inventory, as substantial quantities are manufactured in anticipation of projected demand. Any excess inventory increases working capital requirements and space requirements. Extended production runs also require longer-term and more accurate forecasts.

With functional resource trade-offs in mind, the final reason driving planning system development is the need for a coordinated approach that considers service requirements while minimizing combined supply chain resources. This is a critical capability when supply chain and firm performance place a strong emphasis on overall asset utilization.

Supply Chain Planning Applications

Supply chain planning is increasing in frequency and scope. Such applications are evolving to facilitate consideration of a broader range of activities and resources within the scope of supply chain plans. There are, however, some applications common for most planning environments. These include demand planning, production planning, and logistics planning.

Demand Planning

The increasing complexity of product offerings and marketing tactics in conjunction with shorter product life cycles requires increased accuracy, flexibility, and consistency in determining inventory requirements. Demand management systems seek to provide such capabilities.

Demand management develops the forecast that drives anticipatory supply chain processes. The forecasts are the projections of monthly, weekly, or daily demand that determine production and inventory requirements. Each projected quantity might include some portion of future orders placed in anticipation of customer demand along with some portion of forecasted demand based on history. Essentially, the demand management process integrates historically based forecasts with other information regarding events that could influence future sales activity, such as promotional plans, pricing changes, and new product introductions, to obtain the best possible integrated statement of requirements. Forecast techniques and procedures are discussed later in this chapter.

Another aspect of the demand management process focuses on creating forecast consistency across multiple products and warehouse facilities. Effective integrated management requires a single accurate forecast for each item and facility. The aggregate and combined requirements must reflect a plan that is consistent with divisional and overall firm sales and financial projections. The demand management system is the information technology component of the sales and operations planning **(S&OP)** process to develop the unconstrained marketing plan. The demand management system begins with a base forecast and then incorporates such factors as product life cycle, changes in distribution channels, pricing and promotional tactics, and product mix variations. The demand management system also rationalizes the detailed logistics plans, unique forecasts for each warehouse and product, with the aggregate product group and national plans. For example, the sum of individual warehouse facility sales should be consistent with national sales projections. Similarly, item level requirements need to be adjusted to reflect the activity level for related items. For instance, requirements for existing products may have to be reduced to reflect the market's reaction to a new product introduction or one item's requirements may need to be adjusted during the promotion of a substitutable item.

Production Planning

Production planning uses the statement of requirements obtained from demand management in conjunction with manufacturing resources and constraints to develop a workable manufacturing plan. The statement of requirements defines what items are needed and when. Although there has been a definite trend toward make-to-order **(MTO)** and assemble-to-order **(ATO)** manufacturing, such response-based practices are not always possible because of production technology, capacity, or resource constraints. The limitations occur in the form of facility, equipment, and labor availability.

Production planning systems match the requirements plan with the production constraints. The objective is to satisfy the necessary requirements at the minimum total production cost while not violating any constraints. Effective production planning results in a time-sequenced plan to manufacture the correct items in a timely manner while operating within facility, equipment, and labor constraints. Production planning identifies the items that should be produced in anticipation of need to remain within production constraints and yet minimize inventory.

Logistics Planning

Logistics planning coordinates transportation, warehousing, and inventory within the firm and between supply chain partners. Historically, purchasing and finished goods transportation both attempted to minimize their freight cost individually. Procurement minimized the expense of raw material movements by working with suppliers and inbound carriers. Logistics focused on minimizing outbound freight expense by working with customers and their transportation carriers. There is also often a third managerial focus related to international shipments. The individual perspectives of transportation often result in limited economies of scale, limited information sharing, and excessive transportation expense.

Logistics planning integrates overall movement demand, vehicle availability, and relevant movement cost into a common decision support system that seeks to minimize overall freight expense. The analysis suggests ways that freight can be shifted among carriers or consolidated to achieve scale economies. It also facilitates information sharing with carriers and other service providers to enable better asset utilization.

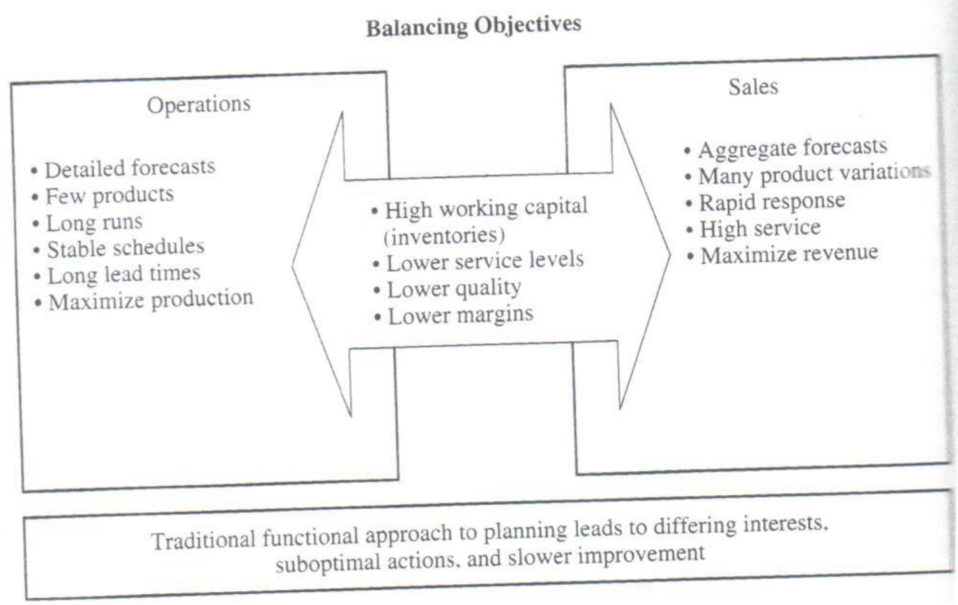
Logistics planning is essential for effective resource utilization. Lack of accurate and comprehensive logistics and supply chain planning tools historically resulted in poor utilization of production, storage, and transportation capacity. The increasingly strong focus on improved asset utilization in conjunction with improved information management and decision analysis capabilities and techniques has brought comprehensive planning systems to reality.

Effective planning requires a combination of information systems to provide the data and managers to make decisions. The following section illustrates some of the specific conflicts associated with S&OP and describes the major process and system components.

Sales and Operations Planning (S&OP)

An integrated S&OP process is increasingly necessary for effective supply chain operations. The S&OP process collaboratively establishes a coordinated plan for responding to customer requirements within the resource constraints of the enterprise. Traditionally, firms have sequentially and often independently developed financial, sales, and operations plans. First, finance develops revenue plans often designed to meet the expectations of Wall Street. Second, sales develops marketing plans and tactics that meet the revenue targets for the firm's product groups. This includes establishing specific product innovation, pricing, and promotion plans to achieve the desired results. Finally, supply chain operations develop materials, manufacturing, and logistics plans that can meet customer demands within the operating constraints of the firm and its supply chain partners. Figure 6.1 illustrates some of the conflicts involved. Sales would like to sell a wide variation of products, rapidly responding to customers, and with short lead times. In effect, the sales goal is to maximize revenue by providing the customers whatever they want and when they want it. Supply chain operations would prefer to minimize the product variations and production changeovers, constrain schedule variations, and extend lead times to take advantage of economies of scale. In effect, a major focus of supply chain operations is to take advantage of manufacturing, transportation, and handling economies of scale. Since there is significant potential for conflict in these objectives, meeting unique customer requests versus operations economies of scale, it is necessary

FIGURE 6.1
Planning Process Conflicts



to systematically consider the trade-offs and collaboratively create consistent plans. This includes developing and agreeing to forecasts, product introduction, marketing tactics, and operating plans that can meet financial and customer commitments within the constraints of the enterprise.

While S&OP has significant information technology considerations, it is not just an information technology application. It is a combination of information systems, with significant elements of financial, marketing, and supply chain planning elements, integrated with organizational processes, responsibility, and accountability to develop consensus and execute collaborative plans. Thus, an effective S&OP requires a blending of process and technology within a collaborative organization. Figure 6.2 illustrates the S&OP process. The first component of the S&OP process is a business plan in terms of a financial forecast and a corresponding budget. This plan is used to guide activity levels and determine aggregate volume and resource requirements. The second component of the S&OP is the sales plan, which is developed from the unconstrained marketing plan. The unconstrained marketing plan determines the maximum sales and profitability level that could be achieved if there were no supply chain operating constraints. As Figure 6 indicates, the unconstrained marketing plan synthesizes the information regarding on hand, current customers, new customers, competition, selling margins, ne potential, pricing, and the overall economy to project what sales could be i supply chain or operations constraints. The final component of the S plan, which is developed from the firm's internal and partner r operations plan synthesizes the resource demands and constr ... g ... ve potential trade-offs.

The business, unconstrained marketing, and reso nized through the S&OP process. The process re tify and evaluate the binding constraints a constraints might be released in the f marketing plans, overtime operati

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... an *Forecasting, Methods and Applications*, 3rd ed. (New York:

is completed for current and future time periods, the result is a common and consistent plan that synthesizes the firm's financial and marketing plans with its resource capabilities. Once this aggregate plan is approved, it becomes the basis of more detailed supply chain planning application systems. The next section discusses some of these applications in detail.[1]

While not every firm uses an integrated and coordinated S&OP process, virtually all firms develop business, marketing, and operational plans. When the S&OP process is not integrated and collaborative, there are no feedback loops or synchronization. The result is a high probability that they will not be consistent and conflicts will arise. As indicated in Figure 6.1, such conflicts will often result in unsatisfied customer and/or poor resource utilization. It is important to note that the arrows in Figure 6.2 are bidirectional, indicating that an effective S&OP process requires two-way information flow and collaboration. Firms are becoming increasingly interested in a more formal and collaborative S&OP process to facilitate meeting the precise requirements of increasingly demanding customers within the constraints that are being imposed by firms that are increasingly asset conscious.

Making S&OP Work

Positioning S&OP as a core business planning process requires a well-understood operational framework. Successful S&OP requires collaborative analysis of available information, shared operational metrics, and senior leadership. The keys to successful S&OP implementation are presented in Table 6.1.

Senior Leadership Involvement

A common question concerning S&OP is organizational positioning. It is critical to understand that S&OP is a cross-functional process and not a specific job. A great deal of work is required to execute successful S&OP. The S&OP process is required to be performed and monitored on a continuous basis to assure successful execution. At a minimum a new or updated plan is necessary for each successive operating period. Given the repetitive aadetailed work required for successful S&OP, senior management might justify creating an organizational unit to undertake the continuous planning. While logical, creation of a specified S&OP organizational unit tends to make the planning process the responsibility of a specific organization as contrasted to a cross-organizational joint responsibility.

To be effective over time S&OP must be a shared responsibility among all functional groups within an organization. No single activity involved in supply chain management requires cross-organizational commitment and shared ownership more than successful S&OP. This means that functional leadership from all key operating areas must be committed to the S&OP process and be responsible for achieving success. Ideally this commitment is reinforced by two factors. First, a significant share of each functional management's compensation is tied to overall successful S&OP performance. Second, in addition to functional leadership, there should be regular involvement and accountability at the general management level in the S&OP process. Such commitment is essential to assure cross-functional integrated management.

Collaborative Planning, Forecasting, and Replenishment

The forecasting processes and techniques described above have achieved significant benefits in providing superior logistical performance. However, there can still be costly unplanned and uncoordinated events that distort smooth flow of product throughout the supply chain

[1] For a discussion of S&OP content, see Deep R. Parekh, "S&OP More Prevalent, Global," *American Shipper*, June 2008, pp. 28–33.

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Executing the Process Every Month

While the details of a good S&OP process, like any routine, can seem to be a bit of a grind, reducing the frequency of monthly meetings is only possible in best-case scenarios—for those businesses that experience little change in their markets, channels, supply lines, or product offerings. These businesses would have to operate with small deviations to their plan and have best-in-class key performance indicators (KPIs). Most do not, so they need to meet monthly.

Process Ownership and Clarity of Roles and Responsibilities

S&OP requires a process champion, someone to drive the entire process so that functional managers can direct operations that align with your business's long-term strategic plans. The ideal S&OP leader should be a process facilitator and manager who has direct involvement in determining the strategic direction for the business.

Organizational Commitment to Achieving High Forecast Accuracy

A business needs to have a long-term commitment and view to taking whatever actions are necessary to achieve high forecast accuracy. The Demand Plan drives the entire supply chain from the supply plan, production plan, inventory plan, sourcing plan, and the financial plan. If you don't have a good handle on what you expect customers to buy, it is then difficult to make good supply chain decisions.

Focus Should Be on the Next 3 to 12 Months

While it is important to understand where a business stands relative to the budget, the focus should not be on past results. It should be on looking forward, examining what the next 3 to 12 months are projected to look like. A proper S&OP process should really have an 18-month planning horizon. Companies that have a longer-term view have a better grasp of the demand drivers influencing their business; as a result their demand plans are much more reliable, predictable, and actionable.

One Integrated Plan That Integrates the Actions of the Entire Organization

The fundamental purpose of an integrated S&OP process is to review deviations in operational forecasts, new product plans, budgets, capital plans, and plans as they relate to achieving the goals of the business or company. Every step in your S&OP process should be governed by an overarching focus on executing the strategic plans of the business.

Senior Management Decision Making

In a best-in-class Sales and Operations planning process the endgame is decision making. If senior management is not willing to take action, the result will just be a lot of hand waving and will not have any benefit to the business. This problem is typical where the Executive S&OP Meeting serves more as a "reporting" session, from which few decisions are made and even fewer action items are assigned.

Measuring End-to-End Supply Chain Performance

Many leaders do not like the prospect of having their work conspicuously evaluated on a monthly basis and in public. Companies that embrace measurement as a starting point for continuous improvement are far better served by S&OP than those that resist measurement. In any S&OP process, the metrics are vital to ensuring success. They provide indicators of how well the business is performing, and they clearly illustrate progress that has been made to drive improvement.

S&OP Forecast versus Operating Plan or Budget

The majority of the time the S&OP forecast will not match a company's operating plan target or budget for a given year. It's alright that these two plans are not the same at any point in time. Companies should never artificially adjust the S&OP forecast to match the budget. Since the S&OP forecast should be driving all the other supply chain decisions, artificially adjusting a forecast will just increase costs and will not help to meet the budget. The greatest business value is realized when companies are willing to analyze the gaps between the forecast and budget and take the time to identify the actions that need to be taken to close the gaps.

These distortions occur because individual businesses frequently fail to coordinate their individual forecasts of final consumer demand and marketing events designed to stimulate demand. Imagine, for example, that at the beginning of the month, the manufacturer forecasts sales of 100,000 cases to a particular retail customer with planned advertising and sales promotions to support that level of sales. Meanwhile, that same retailer forecasts sales of 150,000 and plans specific promotional events to achieve that forecast. Clearly, joint planning and information sharing concerning such events would increase the likelihood of a successful relationship.

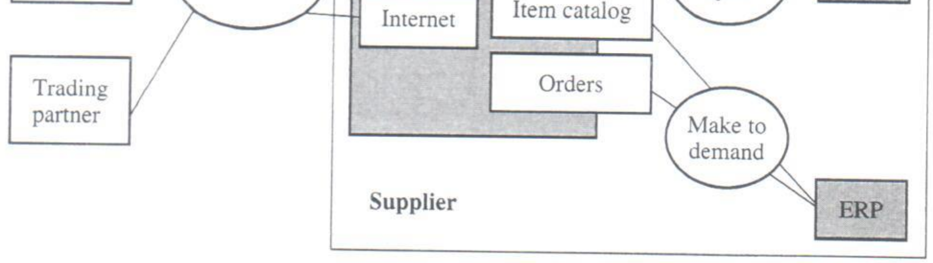
Collaborative planning, forecasting, and replenishment **(CPFR)** is a process initiated by the consumer products industry to achieve such coordination. It does not replace replenishment strategies but supplements them by a cooperative process. In essence, CPFR coordinates the requirements planning process between supply chain partners for demand creation and demand fulfillment activities. Figure 6.3 illustrates the base CPFR relationships. The CPFR solution shares information involving promotions, forecasts, item data, and orders, using either EDI or the Internet. The collaboratively developed information is then used jointly and iteratively by planners to generate demand, determine replenishment requirements, and match production to demands.

The first step in the CPFR process is joint business planning, wherein a customer and supplier share, discuss, coordinate, and rationalize their own individual strategies to create a joint plan. The joint plan offers a common and consistent vision of what is expected to be sold, how it will be merchandized and promoted, in which marketplace, and during what time period. A joint calendar is created to share information determining product flow. A common sales forecast is created and shared between retailer and supplier based on shared knowledge of each trading partner's plan. CPFR includes an iterative process where the forecast and requirements plan is exchanged and refined between the partners until a consensus is developed. Using this consensus forecast, production, replenishment, and shipment plans are developed. Ideally, the collaborative forecast becomes a commitment between the two firms.

Relational distribution channels hold great promise for superior logistical performance. Conventional channels are primarily adversarial in nature, fail to acknowledge dependency, and are driven by information hoarding rather than sharing, so they cannot achieve the sophisticated logistical interfaces required by CPFR. Alliances and partnerships create long-term relationships between supply chain partnerships. When problems occur, as they inevitably will, they can be quickly resolved. Ultimately, the close-working arrangements reduce the cost of doing business for all channel members. Issues and concepts related to effective supply chain collaboration are discussed in greater detail in Chapter 15.

FIGURE 6.3
CPFR in the Retail Information Technology Environment

Source: Reprinted with permission from Matt Johnson, "Collaboration Data Modeling: CPFR Implementation Guidelines," *Proceedings of the 1999 Annual Conference of the Council of Supply Chain Management Professionals*, Oak Brook, IL, p. 17.



Forecasting

Accommodating customer requirements in most supply chain arrangements requires a forecast to drive the process. The forecast is the specific definition of what is projected to be sold, when, and where. The forecast identities requirements for which the supply chain must schedule inventory and operational resources. Since there are many logistics and supply chain activities that must be completed in anticipation of a sale, forecasting is a critical capability.

Table 6.2 illustrates how the need for forecasting is influenced by replenishment response time and economies of scale. Accurate forecasting should be a major focus for situations where there are long replenishment lead times and large economies of scale. On the other hand, accurate forecasts are not as critical when there are shorter lead times or lesser economies of scale. The variables in Table 6.2 can be applied two different ways. First, one could consider the product characteristics as requiring long lead time and high economies of scale and decide to place emphasis on forecasting. Alternatively, one could evaluate the potential for developing accurate forecasts, given short life cycle and high number of variations, and decide to place primary focus for this item on reduced lead time. These situations illustrate that, while improved forecasts are often desirable, there are other ways to achieve the objectives of enhanced service or reduced inventory. One is to forecast at a higher level of aggregation. The second is to develop a responsive supply chain capable of manufacturing to order, even further reducing inventory. While firms are using these methods to reduce their reliance on forecasting, there are still many situations where forecasting is necessary to achieve service objectives or take advantage of scale economies.

With the above considerations in mind, this section focuses on forecasting needs, benefits, methods, techniques, applications, and measures. It provides background to understand logistics applications of forecasting, forecast components, forecasting process, forecasting techniques, software applications, and forecasting error.

Forecasting Requirements

Effective logistics requires matching the product requirements of customers with the capacity capabilities of the enterprise and supply chain. Although consumer demands in terms of service level and product variations are increasing, the focus on reduced supply

TABLE 6.2
How Product Characteristics Influence the Need to Forecast

Source: Reprinted with permission from David J. Closs, *Forecasting and Its Use in Logistics*, Council of Supply Chain Management Professionals, Oak Brook, IL.

	Low Economies of Scale	High Economies of Scale
Long response time experienced in replenishing product	Detailed accurate forecasting is not as critical, as the firm has more production flexibility. For example, final product customization could be postponed so that it's only necessary to forecast the base units (i.e, at a higher level of aggregation) with final customization much nearer time of demand.	Accurate forecasting is critical in this case as it's necessary to forecast an extended time into the future to allow for production or transportation economies.
Short response time experienced in replenishing product	When it's possible to obtain product quickly and there are limited scale economies, the focus should shift from forecasting to the design of a responsive and flexible process.	Focus on developing an accurate short-term forecast with strong consideration of marketing and competitive tactics and less consideration of history.

chain assets simultaneously requires more timely and accurate forecasts. Logistics forecasts are necessary (1) to support collaborative planning, (2) to drive requirements planning, and (3) to improved resource management.

Collaborative Planning

Without collaboration, each partner tries to plan the level and timing of demand for its customers, both individually and collectively. The result is speculative inventory positioned in anticipation of independently forecasted demand resulting in a never-ending cycle of inventory excesses and out-of-stocks. Historically, manufacturers have scheduled their promotions, price changes, new product introductions, and special events, either independently or without collaboration with their major retailers. When no single retailer accounted for a substantial proportion of a firm's sales volume, such collaboration was not critical. However, when a single major customer can approach 25 percent of a firm's sales,which is the case of WalMart* with many of its suppliers, such coordination becomes essential.Without a collaborative plan, the supplier-customer combination typically results in either inventory excess or shortage. A collaborative forecast, jointly agreed to by supply chain partners, provides a common goal that can be the basis for developing effective operating plans. CPFR was discussed earlier in this chapter.

Requirements Planning

Once a collaborative forecast is developed, logisticians use the forecasts to drive requirements planning. The plan determines inventory projections and resulting replenishment or production requirements for the planning horizon. Sales and operations planning **(S&OP)**, discussed earlier in this chapter, integrates forecasts, open orders, available inventory, and production plans into a definition of periodic inventory availability and requirements. Ideally, the requirements planning process operates collaboratively and interactively both internally across the firm's operations and externally with supply chain partners to develop a common and consistent plan for each time period, location, and item.

Resource Management

Once the plan is completed, it can be used to manage critical supply chain processes such as production, inventory, and transportation. Accurate forecasts collaboratively developed by supply chain partners along with a consistent definition of supply chain resources and constraints enable effective evaluation of trade-offs associated with supply chain decisions. The trade-offs consider the relative costs of supply chain strategies such as maintaining extra production or storage capacity, speculative production or product movement, or outsourcing. Timely identification and evaluation of these trade-offs enable a better match of requirements to resources and better resource utilization.

Forecasting Components

The forecast is generally a monthly or weekly figure for each stockkeeping unit **(SKU)** and distribution location. The forecast components include: (1) base demand, (2) seasonal, (3) trend, (4) cyclic, (5) promotion, and (6) irregular. Assuming the base demand as the average sales level, the other components, except for irregular, are multiplicative factors of the base level available to support positive or negative adjustments. The resulting forecast model is:

$$F_t = (B_t \times S_t \times T \times C_t \times P_t) + I$$

where

F_t = forecast quantity for period t

B_t = base level demand for period t

S_t = seasonality factor for period t

T = trend component index reflecting increase or decrease per time period

C_t = cyclical factor for period t

P_t = promotional factor for period t

I = irregular or random quantity.

While some forecasts may not include all components, it is useful to understand the behavior of each so that each component can be tracked and incorporated appropriately. For example, some forecasting techniques cannot effectively address seasonality whereas others can.

The **base demand** represents the long-term average demand after the remaining components have been removed. The base demand is the average over an extended time. The base demand is the forecast for items having no seasonality, trend, cyclic, or promotional components.

The **seasonal** component is an annually recurring upward and downward movement in demand. An example is the annual demand for toys, which reflects low demand for three-fourths of the year and then increased demand just before Christmas. It should be noted that the seasonality discussed above refers to consumer retail seasonality. Seasonality at the wholesale level precedes consumer demand by approximately one quarter of a year.

The **trend** component is the long-range shift in periodic sales. Trend may be positive, negative, or neutral in direction. A positive trend means that sales are increasing over time. For example, the trend for personal computer sales during the decade of the 1990s was increasing. Over the product life cycle, trend direction may change a number of times. For example, beer consumption changed from a neutral to an increasing trend during the past decade. Increases or decreases result from changes in overall population or consumption patterns. Knowledge of which factor is primarily influencing sales is important in making such projections. For example, a reduction in the birth rate implies that a reduction in the demand for disposable diapers will follow. However, a trend toward usage of disposable as contrasted to cloth diapers may result in increased demand of a specific product category even though overall market size is decreasing. The above are obvious examples of forecast trend. While the impact of trend on short-range logistics forecasts is subtle, it still must be considered. Unlike the other forecast components, the trend component influences base demand in the successive time periods. The specific relationship is

$$B_{t+1} = B_t \times T$$

where

B_{t+1} = base demand in period $t + 1$

B_t = base demand in period t

T = periodic trend index.

The trend index with a value greater than 1.0 indicates that periodic demand is increasing, while a value less than 1.0 indicates a declining trend.

The **cyclic** component is characterized by periodic shifts in demand lasting more than a year. These cycles may be either upward or downward. An example is the business cycle in which the economy typically swings from recession to growth cycles every 3 to 5 years. The demand for housing, as well as the resulting demand for major appliances, is typically tied to this business cycle.

The **promotional** component characterizes demand swings initiated by a firm's marketing activities, such as advertising, deals, or promotions. These swings can often be characterized by sales increases during the promotion followed by sales declines as customers sell or use inventory purchased to take advantage of the promotion. Promotions can be deals offered to consumers or trade promotions offered only to wholesalers and retailers. The promotion can be regular and thus take place at the same time each year. From a forecasting perspective, a regular promotion component resembles a seasonal component. An irregular promotion component does not necessarily occur during the same time period, so it must be tracked and considered separately. The promotional component is particularly important to track, especially for consumer industries, since it has a major influence on sales variation. In some industries, promotional activity explains 50 to 80 percent of volume variations. Thus, promotion results in demand that is more lumpy than would otherwise be the case. The promotional component is different from the other forecasting components in that its timing and magnitude are controlled, to a large extent, by the firm. Thus, it should be possible to input information from the firm's sales or marketing departments regarding the timing and likely impact of scheduled promotional plans. The benefits of coordinating such promotional offerings among channel partners provide the rationale for collaborative forecasting practices.

The **irregular** component includes the random or unpredictable quantities that do not fit within the other categories. Because of its random nature, this component is impossible to predict. In developing a forecast process, the objective is to minimize the magnitude of the random component by tracking and predicting the other components.

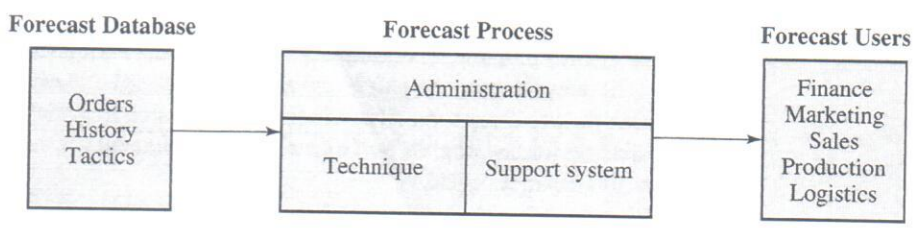
Forecasting Process

Logistics planning and coordination require the best possible estimate of SKU/location demand. Although forecasting is far from an exact science, the forecast management process should incorporate input from multiple sources, appropriate mathematical and statistical techniques, decision support capability, and trained and motivated individuals.

Supply chain operational forecasts are normally developed for daily, weekly, or monthly periods. An effective forecast management process requires a number of components, as illustrated in Figure 6.4. The process foundation is the forecast database, including open orders, demand history, and the tactics used to stimulate demand, such as promotions, special deals, or product changes. The forecast database is ideally part of an enterprise resource planning system **(ERP)** central data warehouse, although some firms maintain independent forecast databases. Other environmental data, such as the state of the economy and competitive action, are often included in this database. To support effective forecasting, this database must include timely historical and planning information in a manner facilitating its manipulation, summarization, analysis, and reporting.

Finally, the development of an effective forecast requires a process that integrates three components: forecast technique, forecast support system, and forecast administration. The box on the right side of Figure 6.4 illustrates that it would be ideal if a firm could use a common and consistent forecast for all planning functions.

FIGURE 6.4
Forecast Management Process



Technique

The technique component is the mathematical or statistical computation used to combine base, seasonal, and cyclical components and elements of promotion history into a forecast quantity. Techniques include time series modeling, in which sales history is a major factor, and correlation modeling, in which relationships with other independent variables are the major forecast drivers. Specific techniques are discussed in the forecast technique section of this chapter. While techniques can easily connect historical patterns into future forecasts, they do not do as well at incorporating the input of anticipated future events. As a result, it is increasingly apparent that accuracy requires integration of the forecast techniques with appropriate support and administrative systems.

Support System

The forecast support system includes the supply chain intelligence to gather and analyze data, develop the forecast, and communicate the forecast to relevant personnel and planning systems. This component allows consideration of external factors such as the impact of promotions, strikes, price changes, product line changes, competitive activity, and economic conditions. For example, if the firm plans to promote 12-packs of a beverage, it is reasonable to assume 2-liter sales will decrease. The system must be designed not only to allow the consideration of these factors but also to encourage them. As another example, the marketing manager may know that the promotion scheduled for next month is likely to increase sales by 15 percent. However, if the forecast support system makes it difficult to adjust the forecast figures for next month, the forecast adjustments may not occur. Similarly, when a package size change is announced, it is likely that forecast history should be changed to reflect the new package size so that future forecasts will reflect correct sizes and volumes. If this is difficult to accomplish within the system constraints, the individual completing the forecast will probably not consider the adjustments. It is thus very important that an effective forecasting process include a support system to facilitate the maintenance, update, and manipulation of the historical database and the forecast.

Administration

Forecast administration includes the organizational, procedural, motivational, and personnel aspects of forecasting and its integration into the other firm functions. The organizational aspect concerns individual roles and responsibilities. It is important these impacts be specified in detail in defining the forecast administration function. If an integrated forecast is desirable, it is necessary to specifically define each organization's forecasting responsibility and then hold it accountable with specific measurements. Effective forecast administration requires that organizational responsibility and procedural guidelines are documented and measured. Effective administration also requires that forecast analysts be trained in both the process and the input of forecasts on supply chain logistics operations.

Dynamic simulation illustrates the impact of forecast inconsistency across multiple members of the supply chain. From initial stimulant to feedback, the cost of direct communication of sales or forecasts is overshadowed by the cost of a faulty message. Since a great deal of supply chain action is initiated in anticipation of future transactions, communications containing overly optimistic predictions or projections may stimulate a fever of ultimately useless work. Analysis of communications between channel members suggests that anticipation has a tendency to amplify as it proceeds between supply chain participants, particularly as the information gets further from the ultimate consumer. Each error in the interpretation of transaction requirements creates a disturbance for the total logistical channel. In a classic work, Forrester simulated channel interrelationships to demonstrate how the total channel may enter into an oscillating corrective pattern, resulting in a series of over-and-under adjustments to real market requirements.[2] Figure 6.5 illustrates the channel inventory oscillations that are stimulated when the retailer increases demand by 10 percent but does not directly inform the other members of the channel.

Figure 6.5 illustrates that an increase of retail demand by 10 percent without clear communication back to other members of the supply chain results in inventory swings of 16 percent for the distributor, 28 percent for the factory warehouse, and 40 percent for factory production. These swings, commonly referred to as the bullwhip effect, obviously increase supply chain variance, which increases costs and diminishes asset utilization.

By the very nature of its mission, a distribution channel must respond to transaction requirements. The system must stand ready to initiate logistical action upon receipt of a message. Extreme care must be taken to structure the communication function with a high degree of reliability while retaining the flexibility required for change and adaptation.

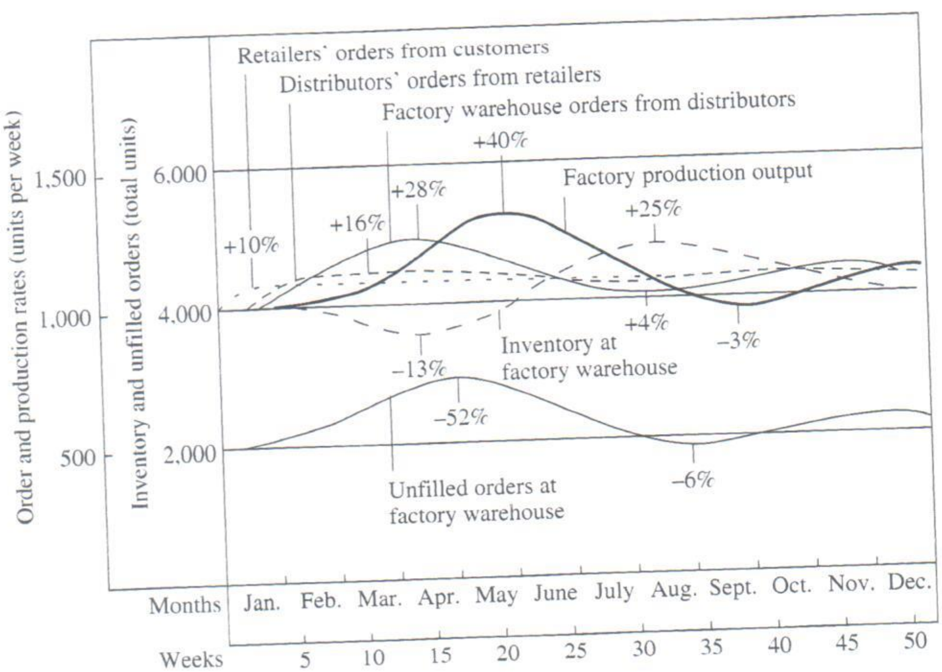
It is important to realize that a meaningful forecast process requires an integrated and consistent combination of components. Historically, it was thought that intensive effort in one of the individual components such as technique could overcome problems in the other components. For example, it was thought that a "perfect" forecast technique could be identified that would overcome the need for systems support and a consistent process. There is increasing realization that all three components must work together. The design process must adequately consider the strengths and weaknesses of each individual component, and design for the optimal performance of the integrated system.

Even though the forecast technique is only one component of the overall demand management process, it is useful to understand the breadth of techniques available and the measures to evaluate them.

[2] Jay W. Forrester, *Industrial Dynamics* (Cambridge, MA: The MIT Press, 1961).

FIGURE 6.5
Response of a Simulated Production/ Distribution System to a Sudden 10 Percent Increase in Sales at the Retail Level

Source: Reprinted with permission from Jay W. Forrester, *Industrial Dynamics* (Waltham, MA: Pegasus Communications, 1961). www.pegasuscom.com.



Forecasting Techniques

Demand forecasting requires the selection of appropriate mathematical or statistical techniques to generate periodic forecasts. The effective use of a technique requires matching the characteristics of the situation with the abilities of the technique. Some criteria for evaluating the applicability of a technique include: (1) accuracy, (2) forecast time horizon, (3) the value of forecasting, (4) data availability, (5) type of data pattern, and (6) experience of the forecaster.[3] Each alternative forecast technique must be evaluated both qualitatively and quantitatively with respect to these six criteria.

There are three categories of forecast techniques: (1) qualitative, (2) time series, and (3) causal. A qualitative technique uses data such as expert opinion and special information to forecast the future. A qualitative technique may or may not consider the past. A time series technique focuses entirely on historical patterns and pattern changes to generate forecasts. A causal technique, such as regression, uses refined and specific information regarding variables to develop a relationship between a lead event and forecasted activity.

Qualitative

Qualitative techniques rely heavily on expertise and are quite costly and time-consuming. They are ideal for situations where little historical data and much managerial judgment are required. Using input from the sales force as the basis of the forecast for a new region or a new product is an example of a supply chain application of a qualitative forecast technique. However, qualitative methods are generally not appropriate for supply chain forecasting because of the time required to generate the detailed SKU forecasts necessary. Qualitative forecasts are developed by using surveys, panels, and consensus meetings.

Time Series

Time series techniques are statistical methods utilized when historical sales data containing relatively clear and stable relationships and trends are available. Using historical sales data, time series analysis is used to identify seasonality, cyclical patterns, and trends. Once individual forecast components are identified, time series techniques assume the future will reflect the past. This implies that past demand patterns will continue into the future. This assumption is often reasonably correct in the short term, so these techniques are most appropriate for short-range forecasting.

When the rate of growth or trend changes significantly, the demand pattern experiences a turning point. Since time series techniques use historical demand patterns and weighted averages of data points, they are typically not sensitive to turning points. As a result, other approaches must be integrated with time series techniques to determine when turning points will likely occur.

Time series techniques include a variety of methods that analyze the pattern and movement of historical data to establish recurring characteristics. On the basis of specific characteristics, techniques of varying sophistication can be used to develop time series forecasts. Four time series techniques in order of increasing complexity are (1) moving averages, (2) exponential smoothing, (3) extended smoothing, and (4) adaptive smoothing.

Moving average forecasting uses an average of the most recent period's sales. The average may use any number of previous time periods, although 1-, 3-, 4-, and 12-period averages are common. A 1-period moving average results in next period's forecast being projected by last period's sales. A 12-period moving average, such as monthly, uses the average of the last 12 periods. Each time a new period of actual data becomes available,

[3] Spyros Makridakis, Steven Wheelright, and Robert Hyndman, *Forecasting, Methods and Applications*, 3rd ed. (New York: John Wiley & Sons, 1997).

it replaces the oldest time period's data: thus, the number of time periods included in the average is held constant.

Although moving averages are easy to calculate, there are several limitations. Most significantly, they are unresponsive or sluggish to change and a great amount of historical data must be maintained and updated to calculate forecasts. If the historical sales variations are large, average or mean value cannot be relied upon to render useful forecasts. Other than the base component, moving averages do not consider the forecast components discussed earlier.

Mathematically, moving average is expressed as

$$F_t = \frac{\sum_{i=1}^{n} S_{t-i}}{n}$$

where

F_t = moving average forecast for time period t

S_{t-i} = sales for time period i

n = total number of time periods

For example, an April moving forecast based on sales of 120, 150, and 90 for the previous 3 months is calculated as follows:

$$\begin{aligned} F_{\text{April}} &= \frac{120 + 150 + 90}{3} \\ &= 120. \end{aligned}$$

To partially overcome these deficiencies, weighted moving averages have been introduced as refinements. The weight places more emphasis on recent observations. Exponential smoothing is a form of weighted moving average. **Exponential smoothing** bases the estimate of future sales on the weighted average of the previous demand and forecast levels. The new forecast is a function of the old forecast incremented by some fraction of the differential between the old forecast and actual sales realized. The increment of adjustment is called the **alpha factor.** The basic format of the model is

$$F_t = \quad D_{t-1} + (1 - \quad)F_{t-1}$$

where

F_t = forecasted sales for a time period t

F_{t-1} = forecast for time period $t - 1$

D_{t-1} = actual demand for time period $t - 1$

α = alpha factor or smoothing constant $(0 \leq \alpha \leq 1.0)$

To illustrate, assume that the forecasts for the most recent time period were 100 and actual sales experience was 110 units. Further, assume that the alpha factor being employed is 0.2. Then, by substitution,

$$\begin{aligned} F_t &= \alpha D_{t-1} + (1 - \alpha)F_{t-1} \\ &= (0.2)(110) + (1 - 0.2)(100) \\ &= 22 + 80 \\ &= 102 \end{aligned}$$

So the forecast for period t is for product sales of 102 units.

The prime advantage of exponential smoothing is that it permits a rapid calculation of a new forecast without substantial historical records and updating. Thus, exponential smoothing is highly adaptable to computerized forecasting. Depending on the value of the smoothing constant, it is also possible to monitor and change technique sensitivity.

The major decision when using exponential smoothing is selecting the alpha factor. If a factor of 1 is employed, the net effect is to use the most recent period's sales as the forecast for next period. A very low value, such as .01, has the net effect of reducing the forecast to almost a simple moving average. Large alpha factors make the forecast very sensitive to change and therefore highly reactive. Low alpha factors tend to react slowly to change and therefore minimize response to random fluctuations. However, the technique cannot tell the difference between seasonality and random fluctuation. Thus, exponential smoothing does not eliminate the need for judgment. In selecting the value of the alpha factor, the forecaster is faced with a trade-off between eliminating random fluctuations or having the forecast fully respond to demand changes.

Extended exponential smoothing incorporates the influence of trend and seasonality when specific values for these components can be identified. The extended smoothing calculation is similar to that of the basic smoothing model except that there are three components and three smoothing constants to represent the base, trend, and seasonal components.

Like basic exponential smoothing, extended smoothing allows rapid calculation of new forecasts with minimal data. The technique's ability to respond depends on the smoothing constant values. Higher smoothing constant values provide quick responsiveness but may lead to overreaction and forecast accuracy problems.

Adaptive smoothing provides a regular review of alpha factor validity. The alpha value is reviewed at the conclusion of each forecast period to determine the exact value that would have resulted in a perfect forecast for the previous period. Once determined, the alpha factor used to generate the subsequent forecast is adjusted to a value that would have produced a perfect forecast. Thus, managerial judgment is partially replaced by a systematic and consistent method of updating alpha. Most forecast software packages include the capability to systematically evaluate alternative smoothing constants to identify the one that would have given the best performance in the most recent time periods.

More sophisticated forms of adaptive smoothing include an automatic tracking signal to monitor error. When the signal is tripped because of excessive error, the constant is automatically increased to make the forecast more responsive to smoothing recent periods. If the recent-period sales demonstrate substantial change, increased responsiveness should decrease forecast error. As the forecast error is reduced, the tracking signal automatically returns the smoothing constant to its original value. While adaptive techniques are designed to systematically adjust for error, their weakness is that they sometimes overreact by interpreting random error as trend or seasonality. This misinterpretation leads to increased errors in the future.

Causal

Forecasting by regression estimates sales for an SKU on the basis of values of other independent factors. If a good relationship can be identified, such as between expected price and consumption, the information can be used to effectively predict requirements. Causal or regression forecasting works well when a leading variable such as price can be identified. However, such situations are not particularly common for supply chain applications. If the SKU forecast is based upon a single factor, it is referred to as **simple regression.** The use of more than one forecast factor is **multiple regression.** Regression forecasts use the correlation between a leading or predictable event and the dependent demand SKU's sales. No cause/effect relationship need exist between the product's sale and the independent event if a high degree of correlation is consistently present. A correlation assumes that the forecasted sales are preceded by some leading independent factor such as the sale of a related product. However, the most reliable use of regression forecasting of sales is based on a cause/effect relationship. Since regression can effectively consider external factors and events, causal techniques are more appropriate for long-term or aggregate forecasting. For example, causal techniques are commonly used to generate annual or national sales forecasts. From the preceding discussion, it should be clear that forecasting software offers a wide range of capabilities in terms of both techniques and sophistication. Table 6.3 provides a summary of applications and limitations of available forecast techniques.

Forecasting Accuracy

Forecast accuracy refers to the difference between forecasts and corresponding actual sales. Forecast accuracy improvement requires error measurement and analysis. While forecast error can be defined generally as the difference between actual demand and

TABLE 6.3
Forecast Technique Summary

Source: Reprinted with permission from David J. Closs, *Forecasting and Its Use in Logistics*, Council of Supply Chain Management Professionals, Oak Brook, IL.

Forecast Technique	Description	Application	Limitations
Moving average	An unweighted average of the previous periods of sales	Useful when there are only base and irregular demand components	Not useful when there is significant seasonality or trend
Exponential smoothing	An exponentially weighted moving average using smoothing constants to place greater weights on more recent demands	Useful when necessary to maintain data and generate forecasts for a large number of items that incorporate individual trend and seasonality components	Not as useful when there are other factors influencing demand, such as promotions, price changes, or competitive actions not regularly scheduled
Time series	Uses time period as the independent variable to predict future demand patterns	Useful when demand patterns repeat with some cyclic, seasonal, or trend components	Not particularly responsive to change, as it takes numerous periods for the model to identify changes in patterns and for the forecast to respond to the pattern changes; also requires judgment in selecting variables that should be included
Regression	Uses other independent variables, such as price, promotion plans, or related product volumes, to predict sales	Useful when there's a strong linear or nonlinear relationship between independent variables and demand	Not particularly responsive to change, as it takes numerous periods for the model to identify changes in patterns and for the forecasts to respond to the pattern changes; also requires judgment in selecting which variables should be included
Multivariate	Uses more complex statistical techniques to identify more complex demand history relationships; techniques include spectral analysis, Fourier analysis, transfer functions, and neural networks	Useful when there's a complex, generally nonlinear relationship between historical patterns and demand. The analyses identify and evaluate alternative sets of parameters to determine the best fit and use it to predict future demand. These techniques are often more useful for predicting macro forecasts, such as energy consumption, economic growth, or aggregate transportation.	While there are quantitative factors for selecting the best model, there is often substantial judgment involved as well, so these techniques are often nonsuited for detailed item–location –time period forecasts.

TABLE 6.4
Monthly Personal Computer Demand and Forecast

(1) Month	(2) Demand	(3) Forecast	(4) Error	(5) Absolute Error
January	100	110	−10	10
February	110	90	20	20
March	90	90	0	0
April	130	120	10	10
May	70	90	−20	20
June	110	120	−10	10
July	120	120	0	0
August	90	110	−20	20
September	120	70	50	50
October	90	130	−40	40
November	80	90	−10	10
December	90	100	−10	10
Sum	1200	1240	−40	200
Mean	100	103.3	−3.3	16.7[a]
Percent (error/mean)				17.1%[b]

a = Mean absolute deviation (MAD).
b = Mean of (Monthly forecast error/monthly demand).

forecast, a more precise definition is needed for calculation and comparison. Table 6.4 provides monthly unit demand and forecast for a specific personal computer model at a regional distribution center. This example illustrates alternative forecast error measures.

One approach for error measurement is to sum up the errors over time, as illustrated in column 4. With this approach, errors are summed over the year and a simple average is calculated. As illustrated, the average error is very near zero even though there are some months with significant error. The concern with this approach is that the positive errors cancel negative errors, masking a significant forecasting problem. To avoid this problem, an alternative approach is to ignore the "sign" and evaluate absolute error. Column 5 illustrates the computation of the absolute error and the resulting Mean Absolute Deviation **(MAD)**. To compare forecasts, error percentages are usually calculated. Mean absolute percentage error **(MAPE)** is calculated by dividing mean absolute error by mean demand.

Another consideration is the measurement level or aggregation. Assuming that individual SKU detail is recorded, forecast error can be calculated for individual SKU location combinations, groups of SKUs or locations, and nationally. Generally, more aggregation results in lower relative forecast errors. For example, Figure 6.6 illustrates comparative forecast errors at the national, brand for groups of SKUs, and SKU location level. The figure illustrates the minimum, maximum, and mean relative forecast error for a sample of firms marketing consumer products. As Figure 6.6 illustrates, while a relative error of 40 percent is average for a SKU/location level of aggregation, it would reflect very poor forecasting if measured at the national level.

Summary

Effective supply chain management requires both cross-functional and cross enterprise planning and collaboration. Successful supply chain planning requires (1) supply chain visibility, (2) simultaneous resource consideration, and (3) joint resource utilization. Successful achievement of all three of these requirements depends on collaboration.

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November	80	90	−10	10
December	90	100	−10	10
Sum	1200	1240	−40	200
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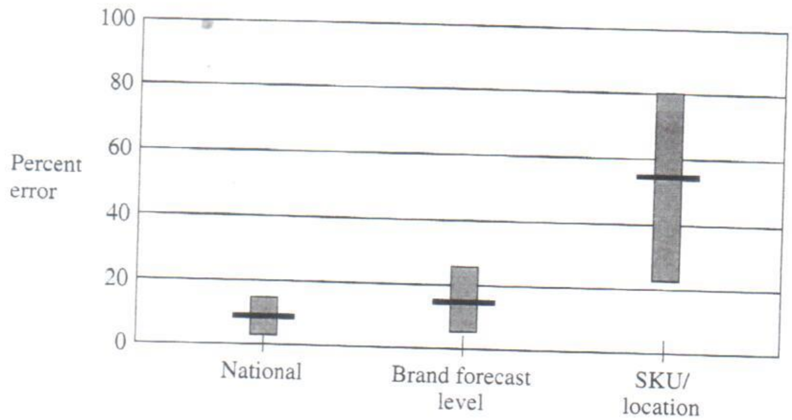
FIGURE 6.6
Comparative Forecast Errors



The synchronized execution of demand planning, production planning, and logistics planning is necessary to achieve an integrated overall plan. Most firms have implemented an S&OP process to drive successful integrated planning. To be successful, S&OP requires continuous senior leader attention and guidance. While there is much work and coordination required for successful S&OP, it is important to keep foremost in mind that it is a process and not an individual's or organization's job. It has become common practice for supply chain participants from multiple organizations to jointly develop and implement CPFR processes.

In most supply chains, customer requirements must be anticipated by using forecasts. Forecasts include a number of components with the major ones being level, trend, and seasonality. While these external components are significant, demand variation also results from operational actions such as promotions, price changes, and new product introductions. The forecasting process must incorporate a combination of techniques, support systems, and administration. Forecasting techniques provide a quantitative starting point, the support system refines the data in consideration of changes in the market, and forecast administration provides a management process to guide and monitor the overall effort. There are qualitative and causal forecasting techniques, but most logistics and supply chain forecasts are developed by using time series methods. While there have been some advancements in forecasting techniques and methods, the most substantial forecast improvements have been achieved through the use of collaborative techniques such as CPFR, involving multiple supply chain partners.

Challenge Questions

1. How does improved supply chain visibility improve the planning process?
2. How are demand management and production planning linked to logistics planning?
3. What factors other than transportation are important to logistics planning?
4. In your words, what is the primary goal of the S&OP process?
5. Why is senior leadership ownership essential to successful S&OP?
6. How are CPFR and S&OP related?
7. Identify and discuss the major forecast components. Why is it important to decompose demand into these components when developing new forecasts?

8. Compare and contrast the basic logic differentiator of time series and causal forecast techniques. Under what conditions would each be appropriate?
9. Discuss how error accountability can be a major factor in improving forecast performance.
10. Discuss how a minor change in demand at the retail level can significantly impact supply chain variation at distributors, manufacturers, and suppliers.