# 2 TACTICAL PLANNING FOR REINVENTING THE SUPPLY CHAIN

David Simchi-Levi

Massachusetts Institute of Technology
Cambridge MA

Edith Simchi-Levi

LogicTools Inc.
Chicago IL

Michael Watson

LogicTools Inc.
Chicago IL

## 1. Introduction

Fierce competition in today's global markets, the introduction of products with short life cycles, and the heightened expectations of customers have forced business enterprises to invest in, and focus attention on their supply chains. This, together with continuing advances in communications and transportation technologies, such as mobile communication and overnight delivery, has motivated the continuous evolution of the supply chain, and techniques to manage it.

In a typical supply chain, raw materials are procured, items are produced at one or more factories, shipped to warehouses for intermediate storage, and then shipped to retailers or customers. Consequently, in order to reduce cost and improve service levels, effective supply chain strategies must take into account the interactions at the various levels in the supply chain. The supply chain, which is also referred to as the *logistics network*, consists of suppliers, manufacturing centers, warehouses, distribution centers, and retail outlets, as well as raw materials, work-in-process inventory and finished products that flow between the facilities (see Figure 2.1).

What is the objective when managing this complex network of facilities and material? We define supply chain management as follows:

Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements.

This definition leads to several observations. First, supply chain management takes into consideration every facility that has an impact on cost and plays a role in making the product conform to customer requirements; from supplier and manufacturing facilities through warehouses and distribution centers to retailers and stores. Indeed, in some supply chain analyses, it is necessary to account for the suppliers'

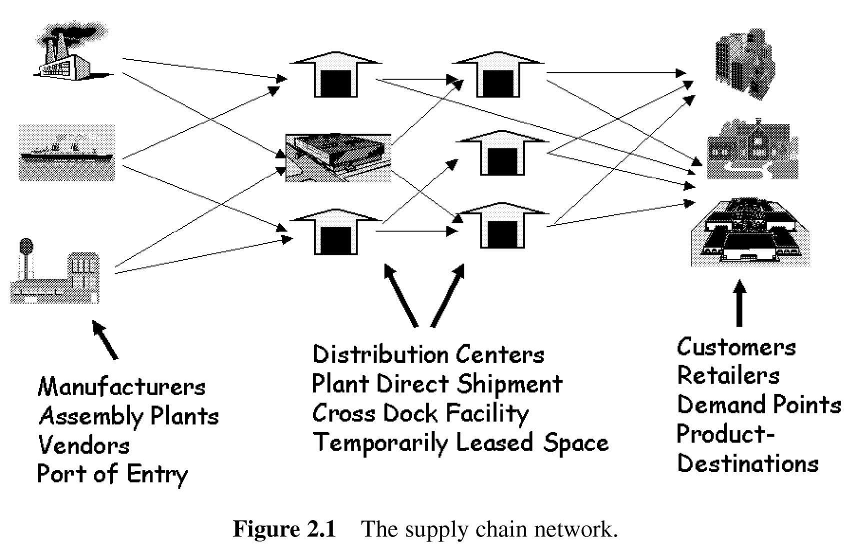


**Figure 2.1** The supply chain network.

suppliers and the customers' customers because they have an impact on supply chain performance.

Second, the objective of supply chain management is to be efficient and cost effective *across the entire system*; total system wide costs, from transportation and distribution to inventories of raw materials, work in process and finished goods, are to be minimized. Thus, the emphasis is not on simply minimizing transportation cost or reducing inventories, but rather, on taking a *systems approach* to supply chain management.

Finally, supply chain management revolves around *efficient integration of suppliers, manufacturers, warehouses and stores*, and hence it encompasses the firm's activities at many levels, from the strategic level through the tactical to the operational level:

- The *strategic level* deals with decisions that have a long lasting effect on the firm. This includes decisions regarding the number, location and capacity of warehouses and manufacturing plants, and the flow of material through the logistics network.
- The *tactical level* includes decisions which are typically updated anywhere between once every week, once every month or once every year. These include purchasing and production decisions, inventory policies, and transportation strategies including the frequency with which customers are visited.
- The *operational level* refers to day-to-day decisions such as scheduling, lead time quotations, routing, and truck loading.

Of course, in the last ten to fifteen years many companies have focused on improving strategic and operational decisions and in many instances, this is achieved using decision support systems. Examples include:

- *Network Design Models* In these models the focus is on key strategic decisions such as:
  1. Determine the appropriate number of plants and warehouses,
  2. Determine the location of each facility,
  3. Determine the size of each facility,
  4. Allocate space for products in each warehouse, and
  5. Determine which products customers will receive from each warehouse and where the products are made.

  The objective is to design or reconfigure the logistics network so as to minimize annual system-wide costs including production and purchasing costs, inventory holding costs, facility costs (storage, handling, and fixed costs), and transportation costs, subject to a variety of *service level* requirements.

  There are many examples of companies that used decision support systems to reconfigure their logistics network with the typical savings quoted at 5–10% of logistics costs. There are also many reasons to perform network studies relating to ongoing changes in the business such as increase in demand, construction of new plants, changes in suppliers. In addition, mergers and acquisitions motivate network design studies since consolidation of supply chains is a major driver to success.

- *Routing and scheduling* Operational systems can significantly improve performance through the automation of complex tasks such as routing and scheduling.

These systems reduce transportation costs by improving routes, by utilizing transportation capacity effectively, by increasing the ability to handle changes and by assisting management in tracking the equipment and staff.

Such is the case of Cemex, see (Slywotzky *et al*. 2000), a Mexican-based manufacturer and distributor of cement. Delivery of cement can be quite challenging—Cemex had to deal with short delivery time windows, customers making delivery changes at the last minute, urban traffic conditions, products with very low margins as well as a short-shelf life, typically 90 minutes. These challenging conditions forced Cemex, as well as many others in this industry, to commit to a 3-hour delivery window with a reliability of 34%. To overcome these problems, Cemex created an operational system that linked its production scheduling, distribution, and customer orders into one system that would automically schedule the plants and route the trucks. In addition, this decision support system ran in real time, so that as customer orders, traffic patterns, and plant status changed, the operational plan could be changed—trucks could be re-routed and production levels adjusted. This system allowed Cemex to promise 20-minute delivery windows with 98% reliability; improvements that translated into more loyal customers and the ability to charge a premium in a commodity business.

Only in the last few years, companies have recognized the importance of the tactical level. Namely, the importance of integrating production, transportation and inventory decisions into a cost-effective strategy. Thus, the objective of this chapter is to illustrate the opportunities and the challenges of optimizing tactical decisions.

For this purpose, we describe in section 2 a new supply chain paradigm, the Push–Pull supply chain strategy, and suggest a framework that helps identify the appropriate supply chain strategy for specific industries and individual products. In section 3 we discuss issues involved in implementing a Push–Pull strategy while in section 4 we discuss the relationships between Push–Pull strategies, demand planning and tactical planning. Section 5 analyzes the tactical planning process in detail and section 6 provides examples from various industries that illustrate both implementation issues and potential benefits associated with tactical planning.

## 2. Supply Chain Strategies

Traditional supply chain strategies can be classified as *Push*-based supply chain strategies in which production and distribution decisions are based on long-term forecasts. Typically, the manufacturer uses orders received from the retailer's warehouses to forecast demand. It therefore takes much longer for a Push-based supply chain to react to the changing marketplace. In addition, since long-term forecasts play an important role, it is important to understand the following three principles of all forecasts and their impact on the supply chain.

1. The forecast is always wrong,
2. The longer the forecast horizon, the worse is the forecast, and
3. Aggregate forecasts are more accurate.

Thus, the first principle implies that it is difficult to match supply and demand, and the second one implies that it is even more difficult if one needs to predict customer demand for a long period of time, for example, the next twelve to eighteen months. The third principle suggests, for instance, that while it is difficult to predict customer demand for individual SKUs, it is much easier to predict demand across all SKUs within one product family. Sometimes this principle is referred to as the *Risk Pooling* concept.

In contrast to a Push strategy, in a *Pull*-based supply chain strategy production and distribution are demand driven so that they are coordinated with true customer demand rather than forecast. That is, in a pure Pull system, the firm does not hold any inventory and only produces to order. These systems are intuitively attractive since they allow the firm to eliminate inventory while responding to customer demand.

Unfortunately, it is very difficult to implement a Pull-based supply chain strategy when lead times are so long that it is impractical to react to demand information. Similarly, in a Pull strategy, it is frequently more difficult to take advantage of economies of scale, since production and distribution decisions are made in response to specific customer demand and therefore batch production or efficient transportation modes, such as truckloads, are hard to achieve.

These advantages and disadvantages of Push and Pull supply chains have led companies to look for a new supply chain strategy that takes advantage of the best of both world; enter a hybrid of the two systems, *Push–Pull* supply chain strategies.

In a Push–Pull strategy, some stages of the supply chain, typically the initial stages, are operated in a Push-based manner while the remaining stages are operated in a Pull-based strategy. We typically refer to the interface between the Push-based stages and the Pull-based stages as the *Push–Pull boundary*. To better understand this issue, consider the *supply chain time line*, that is, the time that elapses between procurement of raw material (beginning of the time line) and the delivery of an order to the customer (end of the time line). The Push–Pull boundary is located somewhere along the time line and it indicates the point in time when the firm switches from managing the supply chain using one strategy, typically a Push strategy, to managing it using a different strategy, typically a Pull strategy, see Figure 2.2.

Consider a PC manufacturer who builds to stock and thus makes all production and distribution decisions based on forecast. This is a typical Push system. By contrast, an example of a Push–Pull strategy is one in which the manufacturer builds to order. This implies that component inventory is managed based on forecast but final assembly is in response to a specific customer request. Hence, the Push part is the portion of the manufacturer's supply chain prior to assembly while the Pull part is the part of the supply chain that starts with assembly and is performed based on actual customer demand. Hence, the Push–Pull boundary is at the beginning of assembly.

Observe that in this case the manufacturer takes advantage of the third principle of all forecasts, namely, that aggregate forecasts are more accurate. Indeed, demand for a component is an aggregation of demand of all finished products that use this component. Since aggregate forecasts are more accurate, uncertainty in component demand is much smaller than uncertainty in finished goods demand and this, of course, leads to safety stock reduction. Dell Computers has used this strategy very effectively and is an excellent example of the impact the Push–Pull system on supply chain performance.

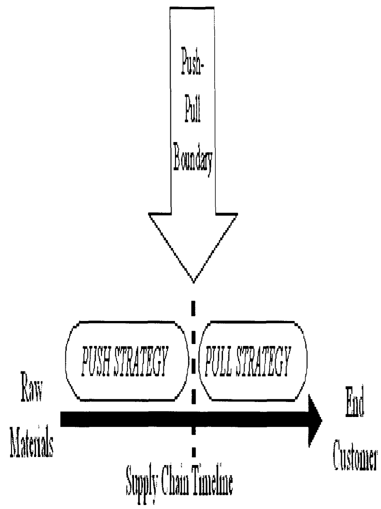


**Figure 2.2** Push–Pull supply chains.

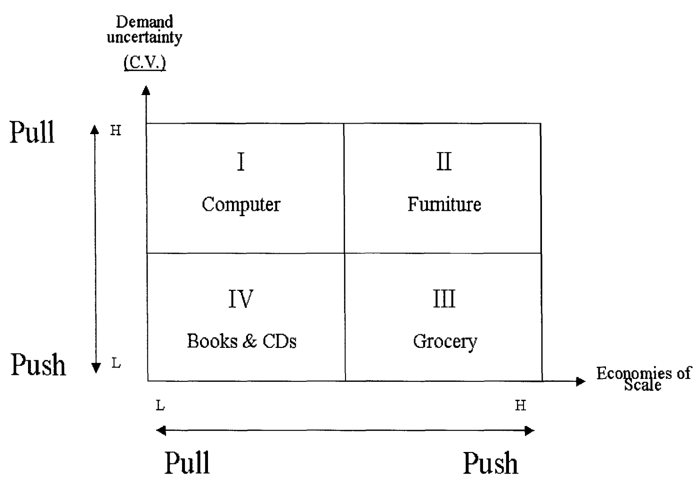


**Figure 2.3** Matching supply chain strategies with products.

Thus, the question is what is the appropriate supply chain strategy that the firm should apply for different products? Should the firm use a Push-based supply chain strategy, a Pull-based strategy or a Push–Pull strategy? Figure 2.3 above provides a framework to match supply chain strategies with products and industries. The vertical coordinate provides information on uncertainty in customer demand, while the horizontal coordinate represents the importance of economies of scale, either in production or distribution.

Intuitively, assuming everything else being equal, the higher the demand uncertainty the more the firm would prefer managing the supply chain based on realized demand, that is, based on a Pull strategy. Alternatively, the smaller the demand uncertainty, the more the firm would be interested in managing the supply chain based on long-term forecast, that is, based on a Push strategy.

Similarly, assuming everything else being equal, the higher the importance of economies of scale in reducing cost, the more important it is to aggregate demand and thus the more important it is to manage the supply chain based on long-term forecast, a Push-based strategy. Alternatively, if economies of scale are not important, aggregation does not reduce cost and hence the firm would be willing to manage the supply chain based on realized demand, a Pull-based strategy.

We partition the region spanned by these two dimensions into four boxes. The box marked I represents industries (or, more precisely, products) that are characterized by high uncertainty and situations in which economies of scale in production, assembly or distribution are not important, for example, the computer industry. Our framework suggests that a high degree of Pull-based supply chain strategy is appropriate for these industries and products, exactly what has been applied by Dell Computers.

The box marked III represents products that are characterized by low demand uncertainty and a situation in which economies of scale are very important. Products in the grocery industry such as beer, pasta, or soup belong to that category. Indeed, demand for these products is quite stable while reducing transportation cost by shipping full truckloads is critical to controlling cost in the supply chain. In this case, our analysis indicates that a Pull strategy is not appropriate. Indeed, a traditional retail strategy, that is, a Push supply chain strategy, is appropriate, since managing inventory based on long-term forecast does not increase inventory holding costs while delivery costs are reduced due to economies of scale.

The two boxes analyzed sofar represent situations in which it is relatively easy to identify an efficient supply chain strategy. The challenge is to analyze the remaining boxes. Evidently, in the remaining two cases there is a mismatch between the strategies suggested by the two attributes, uncertainty and the importance of economies of scale. Indeed, in these boxes uncertainty "pushes" the supply chain to have one structure while the economies of scale suggest a completely different structure.

For instance, the box marked IV represents products characterized by low demand uncertainty, indicating a Push supply chain, and situations in which economies of scale do not play an important role, suggesting a Pull-based supply chain strategy. For instance, many books and CDs fall in this category. In this case, a more careful analysis is required, since both, traditional retail strategies, that is, Push strategies, and more innovative Push–Pull strategies are appropriate, depending on the specific costs and uncertainties, see Simchi-Levi and Simchi-Levi (2001).

Finally, box II represents products and industries for which uncertainty in demand is high while economies of scale are important in reducing production and/or delivery costs. The furniture industry is an excellent example of this situation. Indeed, a typical furniture retailer offers a large number of similar products distinguished by shape, color, fabric, etc., and as a result demand uncertainty is very high. Unfortunately, these are bulky products and hence delivery costs are also high.

Thus, in this case, there is a need to distinguish between the production and the distribution strategy. The production strategy has to follow a Pull-based strategy since it is impossible to make production decisions based on long-term forecasts. On the other hand, the distribution strategy needs to take advantage of economies of scale in order to reduce transportation cost. This is exactly the strategy employed by many retailers that do not keep any inventory of furniture. When a customer places an order, it is sent to the manufacturer who orders the fabric and produces to order. Once the product is ready, it is shipped, typically using truckload carriers, together with many other products to the retail store and from there to the customer. For this purpose, the manufacturer typically has a fixed delivery schedule and this is used to aggregate all products that are delivered to stores in the same region, thus reducing transportation costs due to economies of scale. Hence, the supply chain strategy followed by furniture manufacturers is, in some sense, a *Pull–Push* strategy where production is done based on realized demand, a Pull strategy, while delivery is according to a fixed schedule, a Push strategy.

## 3. Implementing a Push–Pull Strategy

The framework developed in the previous section attempts to characterize the level of Pull/Push required for different products. For instance, the framework suggests a high degree of Pull for products that belong to box I. Of course, achieving a high degree of Pull depends on product complexity, manufacturing lead times and supplier–manufacturer relationships, to name just a few important issues. Evidently, there are many ways to implement a Push–Pull strategy, depending on where the Push–Pull boundary is located in the supply chain. For instance, Dell is implementing the Push–Pull strategy by locating the boundary at the assembly point while furniture manufacturers locate the boundary at the production point. See Simchi-Levi and Simchi-Levi (2001) for other examples from industries, such as the automotive and book industries, where the boundary is located at the manufacturer distribution center or at the distributor warehouse.

Evidently, the Push part is applied to the portion of the supply chain where demand uncertainty is relatively small and thus managing this portion based on long-term forecast is appropriate. On the other hand, the Pull part is applied to the portion of the supply chain time line where uncertainty is high and hence it is important to manage this part of the supply chain based on realized demand. This distinction between the two portions of the supply chain has an important impact on the objective of the supply chain strategy as well as on organizational skills required in each case.

Since uncertainty in the Push part of the supply chain is relatively small, service level is not an issue and hence the focus in this portion of the supply chain is on *cost minimization*. In addition, this portion of the supply chain is characterized not only by low demand uncertainty and economies of scale in production and/or transportation, but also by long lead times and complex supply chain structures including product assembly (bill of material) at various levels. Thus, cost minimization is achieved by better utilizing resources such as production and distribution capacities while minimizing inventory, transportation and production costs.

On the other side, the Pull portion of the supply chain is characterized by high uncertainty, simple supply chain structure and a short cycle time. Hence, the focus here is on service level. Specifically, a high service level is achieved by deploying

**Table 2.1** Characteristics of the Push and Pull Portions of the Supply Chain

| Portion | Push | Pull |
|---|---|---|
| Objective | Minimize cost | Maximize service level |
| Complexity | High | Low |
| Focus | Resource allocation | Responsiveness |
| Lead time | Long | Short |
| Processes | Tactical planning | Order fulfillment |

a *flexible* and *responsive* supply chain, see Fisher (1997). That is, a supply chain that can adapt quickly to changes in customer demand.

The analysis above implies that different processes need to be applied to different portions of the supply chain, see table 2.1. Since the focus in the Pull part of the supply chain is on service level, *order fulfillment* processes are typically applied. Similarly, since the focus of the Push part of the supply chain is on cost and resource utilization, *tactical planning* processes are used here to develop an effective strategy for the next few months.

Notice that the only part of the supply chain where the two strategies interact is at the Push–Pull boundary. This is the point along the supply chain time line where there is a need to coordinate the two supply chain strategies typically through *buffer inventory*. However, this inventory plays a different role in each portion. In the Push portion, buffer inventory at the boundary is part of the output generated by the tactical planning process, while in the Pull part it represents the input to the fulfillment process.

Thus, the interface between the Push portion of the supply chain and the Pull portion of the supply chain is forecast demand. This forecast, which is based on historical data obtained from the Pull portion, is used to drive the tactical planning process.

## 4. Demand Driven Strategies

The framework developed so far requires integrating demand information into the tactical planning process. This information is generated by applying two different processes:

- *Demand Forecast*   A process in which historical demand data is used to develop long-term estimates of expected demand, that is, forecasts.
- *Demand Shaping*   A process in which the firm determines the impact of various marketing plans such as promotion, pricing discounts, rebates, new product introduction and product withdrawal on demand forecasts.

Of course, in either case, the forecast is not completely accurate, see the first principle of all forecasts, and hence an important output from the Demand Forecast and

Demand Shaping processes is an estimate the *accuracy* of the forecast, the so-called *forecast error*, measured according to its *standard deviation*. This information provides insight into the likelihood that demand will be higher (or smaller) than the forecast.

Evidently, high demand forecast error has a detrimental impact on supply chain performance resulting in lost sales, obsolete inventory and inefficient utilization of resources. The question therefore is can the firm increase forecast accuracy and thus decrease forecast error? We identify the following strategies:

- Select the Push–Pull boundary so that demand is aggregated over one or more of the following dimensions:
  - Demand is aggregated across products.
  - Demand is aggregated across geography.
  - Demand is aggregated across time.

  The objective is clear. Since aggregate forecasts are more accurate, the result is an improved forecast accuracy.
- Use market analysis, demographic, and economic trends to improve forecast accuracy.
- Determine the optimal assortment of products by store so as to reduce the number of SKUs competing in the same market. Indeed, we have collaborated with a large retailer who used to keep in each store more than 30 different types of garbage cans. It was relatively easy to predict aggregate demand across all SKUs in the garbage can category, but very difficult to predict demand for an individual SKU.
- Incorporate collaborative planning and forecasting processes with your customers so as to achieve a better understanding of market demand, impact of promotions, pricing events and advertising.

At the end of the demand planning process the firm has a demand forecast by SKU by location. The next step is to analyze the supply chain and see if it can support these forecasts. This process called *Supply and Demand Management* is the process in which the firm tries to match supply and demand by identifying a strategy that minimizes total production, transportation and inventory costs, or a strategy that maximizes profits. In this process the firm also determines the best way to handle volatility and risks in the supply chain. This is precisely the tactical planning process.

Of course, this is an iterative process in which one switches between demand planning and tactical planning to identify:

- The best way to allocate marketing budgets and an associated supply and distribution strategy,
- The impact of deviations from forecast demand,
- The impact of changes in supply chain lead times, and
- The impact of competitors' promotional activities on demand and supply chain strategies.

A classic example of the perils of not including supply chain analysis in market plans was Campbell's Soup winter promotion. In one unfortunate season the marketing department decided to promote chicken noodle soup in the winter, which is the seasonal spike in demand for soup anyway. The seasonal demand requires preparing and storing chicken and ingredients in huge quantities in the spring and fall in order to meet the demand. In addition, production has to start early and use overtime capacity in order to meet the expected demand. The cost of the excess production and inventory requirements far exceeded the revenue from the promotions. Analysis of the true cost would have allowed better planning of promotions—for instance in the off-season so consumers will increase consumption and flatten out demand during the spike. For more see Clark (1994).

## 5. Tactical Planning

As observed earlier, tactical planning is applied to the push portion of the supply chain and its objective is to allocate production, transportation, and inventory resources effectively. We define tactical planning as:

The process of developing effective strategies across the supply chain over multiple time periods that minimizes transportation, inventory and production costs or maximizes profit. The plan considers all capacities, lead times, bill of material structures, forecast demand, product shelf life and the various cost parameters.

Evidently, the challenge of allocating production, transportation and inventory resources in order to satisfy demand can be daunting. This is especially true when the firm is faced with seasonal demand, limited capacities, competitive promotions or high volatility in forecasting. Indeed, decisions such as when and how much to produce, where to store inventory, and whether to lease additional warehouse space may have enormous impact on supply chain performance.

It is therefore not surprising that tactical planning cannot be done manually or just with a spreadsheet. To optimize these decisions, taking into account the interaction between the various levels of the supply chain, the firm needs to use an *optimization-based* Decision Support System. These systems, which model the supply chain as large-scale *mixed integer linear programs*, are analytical tools capable of considering the complexity and dynamic nature of the supply chain. Typically, the output from the tool is an effective supply chain strategy that coordinates production, warehousing, transportation, and inventory decisions. The resulting plan provides information on production quantities, shipment sizes and storage requirements by product, location, and time period. This is typically referred to as the *supply chain master plan*.

In some applications, the supply chain master plan serves as an input for a detailed production scheduling system. In this case, the production scheduling system employs information about production quantities and due dates received from the supply chain

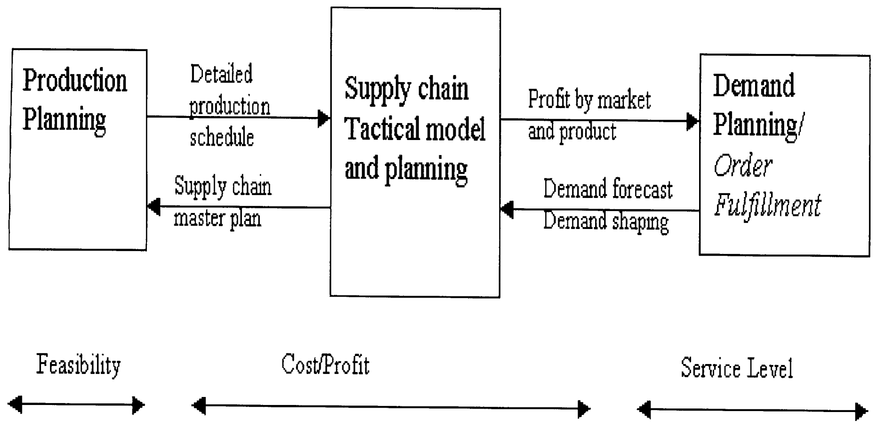


**Figure 2.4** The extended supply chain: from manufacturing to order fulfillment.

master plan. This information is used to propose a detailed manufacturing sequence and schedule. This allows the planner to integrate the back-end of the supply chain, that is, manufacturing and production, and the front-end of the supply chain, that is, demand planning and order replenishment, see Figure 2.4. This diagram illustrates an important issue. The focus of order replenishment systems, which are part of the Pull portion of the supply chain, is on service level, and the focus of the tactical planning, which is in the push portion of the supply chain, is on cost minimization or profit maximization. On the other hand, the focus in the detailed manufacturing scheduling portion of the supply chain is on *feasibility*. That is, the focus is on generating a detailed production schedule that satisfies all production constraints and meets all the due date requirements generated by the supply chain master plan.

Of course, the output from the tactical planning process is shared with supply chain participants to improve coordination and collaboration. For example, the distribution center managers can now better use this information to plan their labor and shipping needs. Distributors can share plans with their suppliers and customers in order to decrease costs for all partners in the supply chain and promote savings. Specifically, distributors can realign territories to better serve customers, store adequate amounts of inventory at the customer site and coordinate overtime production with suppliers.

In addition, tactical planning tools can identify potential supply chain bottlenecks *early* in the planning process, allowing the planner to answer questions such as:

- Will leased warehouse space alleviate capacity problems?
- When and where should the inventory for seasonal or promotional demand be built and stored?
- Can capacity problems be alleviated by rearranging warehouse territories?
- What impact do changes in the forecast have on the supply chain?
- What will be the impact of running overtime at the plants or outsourcing production?
- What plant should replenish each warehouse?

- Should the firm ship by sea or by air. Shipping by sea implies long lead times and therefore requires high inventory levels. On the other hand, using air carriers reduces lead times and hence inventory levels but significantly increases transportation cost.
- Should we rebalance inventory between warehouses or replenish from the plants to meet unexpected regional changes in demand?

Another important capability that tactical planning tools have is the ability to analyze demand plans and resource utilization to maximize profit. This enables balancing the effect of promotions, new product introductions and other planned changes in demand patterns and supply chain costs. Planners now are able to analyze the impact of various pricing strategies as well as identify markets, stores or customers that do not provide the desired profit margins.

A natural question is when should one focus on cost minimization and when on profit maximization? While the answer to this question may vary from instance to instance, it is clear that cost minimization is important when the structure of the supply chain is fixed or at times of a recession and therefore oversupply. In this case the focus is satisfying all demand at the lowest cost by allocating resources effectively. On the other hand, profit maximization is important at time of growth, that is, at time when demand exceeds supply. In this case, capacity can be limited because of use of limited natural resources or because of expensive manufacturing processes that are hard to expand as is the case in the chemical and electronic industries. In these cases, deciding who to serve and for how much is more critical than cost savings.

Finally, an effective tactical planning tool must also be able to help the planners improve the accuracy of the supply chain model. This, of course, is counter-intuitive since the accuracy of the tactical planning model depends on the accuracy of the demand forecast that is an input to the model. However, notice that the accuracy of the demand forecast is typically time dependent. That is, the accuracy of forecast demand for the first few time periods, say the first ten weeks, is much higher than the accuracy of demand forecast for later time periods. This suggests, that the planner should model the early portion of the demand forecast at a great level of detail, that is, apply weekly demand information. On the other hand, demand forecasts for later time periods are not as accurate and hence the planner should model the later demand forecast month by month or by groups of 2–3 weeks each. This implies that later demand forecasts are aggregated into longer time buckets and hence, due to the risk pooling concept, the accuracy of the forecast improves.

## 6. Examples

The analysis so far illustrates that tactical planning can be either integrated into a company's planning process or employed to analyze specific constraints and circumstances. To better emphasize these issues we provide below three different examples.[1]

[1] The material in these examples does not represent any particular implementation; rather it is loosely based on our experience with several companies.

The first example demonstrates how tactical planning is applied to analyze the impact of seasonality on inventory build up. The second example illustrates the use of tactical planning by a food manufacturing company. In this case the manufacturer applies tactical planning in a dynamic fashion by updating production schedules in response to ongoing changes in demand and taking into account product shelf life constraints. Finally, we show an example of a retail company employing tactical planning to plan for promotions. We should point out that the three examples describe situations in which the same tactical planning decision support system was used to optimize supply chain decisions.

### *6.1. Case Study: Chemical Manufacturer Company*

Consider a specialty chemical company that produces and sells about 200 unique SKUs (i.e., different chemicals) at multiple plants, each of which has multiple production lines. Each SKU can be produced on multiple lines at multiple locations and significant set-up times are incurred between batches produced on the same production line. Different products have different costs and characteristics. Specifically, products are distinguished by run-times on the production lines, inventory holding cost and the amount of working capital associated with an SKU. The firm owns five warehouses and leases an additional ten to handle the peak demand.

Figure 2.5 shows the relationship between production capacity and expected demand over a period of twelve months. As can be seen from the figure, demand is strong in the summer, but unfortunately, manufacturing is difficult in warmer months and hence production capacity is reduced exactly at the time it is needed the most. In addition, the manufacturing process is such that it is too expensive to add enough capacity to meet peak demand. Therefore, the company must manufacture product early. Complicating the problem is the fact that for insurance and safety reasons, the

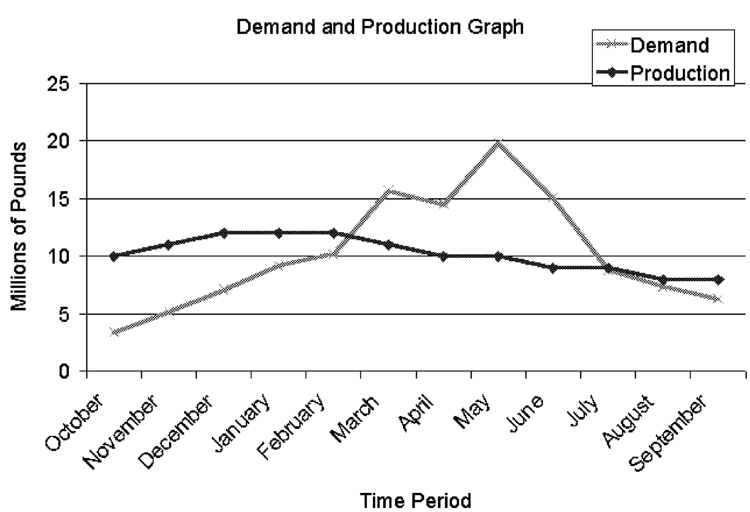


**Figure 2.5** Chemical company's production capacity and expected demand.

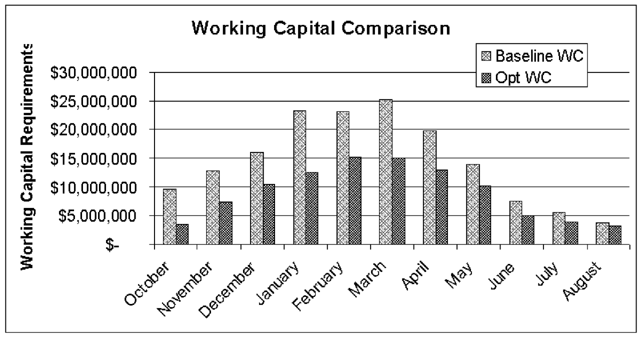


**Figure 2.6** Comparison of current and optimized working capital investment.

manufacturer is not allowed to store more than 2 million pounds of the product in any one location. This implies that production decisions, such as when and where to produce a specific SKU cannot be made in isolation. Indeed, when making production decisions, the firm needs also to consider storage location and quantities for each SKU.

Historically, the company made production and storage decisions without planning tools. They were using a rule-of-thumb measure for determining how to run the supply chain. Using tactical planning they were able to reduce a significant amount of working capital by coordinating production and storage decisions and taking into account production, distribution, inventory, and overflow warehouse costs. Specifically, the planning model includes forecast demand by product by distribution center for a twelve-month horizon. The objective was to minimize total cost for the entire planning horizon, subject to (i) storage capacity constraints and product dependent storage requirements, (ii) limited available production times on each production line and product dependent production rates, and (iii) the need to satisfy demand without shortages or backlogging.

Figure 2.6 shows investment in working capital for both the baseline strategy, based on rule-of-thumb, and for the optimized strategy, applying a tactical planning tool. As can be seen, during the peak of the pre-build, the company was able to identify an approximate 10 million dollars reduction in working capital. These were funds that could be channeled into other areas of the company and could help relieve the debt burden.

### *6.2. Case Study: Food Manufacturer Supply Chain*

The following example shows how tactical planning can be used dynamically and consistently to help a large food manufacturer manage the supply chain. The food manufacturer makes production and distribution decisions at the division level. Even at the division level, the problems tend to be large-scale. Indeed, a typical division may include hundreds of products, multiple plants, multiple production lines within a plant, multiple warehouses (including overflow facilities), bill-of-material structures to account for different packaging options, and 52-week demand forecast for each product for each region. The forecast accounts for seasonality and planned promotions. The annual forecast is important because a promotion late in the year may require production resources relatively early in the year. Production and warehousing capacities are tight and products have limited shelf life that need to be integrated into the analysis. Finally, the scope of the plan spans many functional areas including purchasing, production, transportation, distribution, and inventory management.

Traditionally, the supply chain planning process was done independently by each function in the company. That is, the production plan would be done at the plant, independently from the inventory plan and would typically require the two plans to be somehow coordinated at a later time. This implies that divisions typically end-up "optimizing" just one parameter, usually production costs. The tactical planning process introduced in the company required the integration of the decision support system with the company's ERP system. This allows planners to use the system on a weekly basis, down-loading from enterprise systems information such as new demand forecasts and inventory positions throughout the supply chain and generating a supply chain master plan.

The impact was a reduction in system-wide cost and better utilization of resources such as manufacturing and warehousing. As you would expect, the specific results varied across divisions depending on the number of facilities, the current facility utilization and sourcing flexibility. The following illustrative results show that with the traditional (manual) method production costs were minimized at the expense of system-wide costs. By introducing this type of analysis, the production team had to accept higher costs to achieve the overall benefit. (See Figure 2.7 for illustrative results.)

Every week, the planners could then use an optimization based tactical planning tool to create a plan for the next 52 weeks; this is done on a rolling horizon basis and thus allows the planner to take into account forecast updates or changes in supply. The new plan also accounts for starting inventory by SKU and by location, remaining shelf life, frozen production plan by SKU by week by line as well as all production constraints and supply chain costs. This allows the planner to determine how to best use the existing and future states of the supply chain to meet future requirements. The plan output includes new production plans and order quantities from suppliers, inter-facility moves and a new inventory strategy. Therefore, as the supply chain evolves and changes over time, the food manufacturer always has an up-to-date and complete supply chain plan.

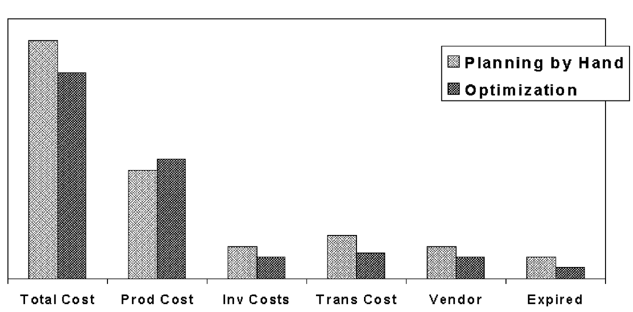


**Figure 2.7** Comparison of manual versus optimized scenarios.

### *6.3. Case Study: Retail Company*

Consider a retail company that purchases mostly generic household products from external suppliers all over the world. It stocks the inventory in major distribution centers within a day's drive to its stores throughout the US. Competition in this industry together with low margins forces our retailer to be extremely responsive to the market and to competitor's promotions and price reductions.

Demand planning tools were introduced to help create reliable forecasts and coordinate sales, marketing, logistics, and purchasing strategies. While demand planning did improve the company's capabilities and lower inventory costs there were questions that could not be answered by the tool. For instance, how much would it cost to build up inventory for a promotion? This includes the cost of advance purchase and storage of inventory in anticipation of a demand spike. Should product pricing be the same in every region or should the promotions be offered only in certain locations? How will current supplier capacity be able to handle the increased demand produced by the promotional price? How much inventory should be kept at the distribution centers taking into account long transportation leadtimes for some of the off-shore suppliers? To answer these questions the planners needed a tool to match supply and demand over time and provide an analysis of the supply chain from supplier to delivery to the end user, or at least the regional distribution centers.

Deploying a tactical planning tool that includes the company's supplier and supply chain network information as well as the demand forecast plan and inventory information produced by the demand planning system allows the company to analyze the plans more rigorously. The tactical planning tool is used to maximize profit based on the new pricing and the supply chain cost. Supplier and inventory plans are tested for feasibility and cost. Figure 2.8 describes the new planning process adopted by the

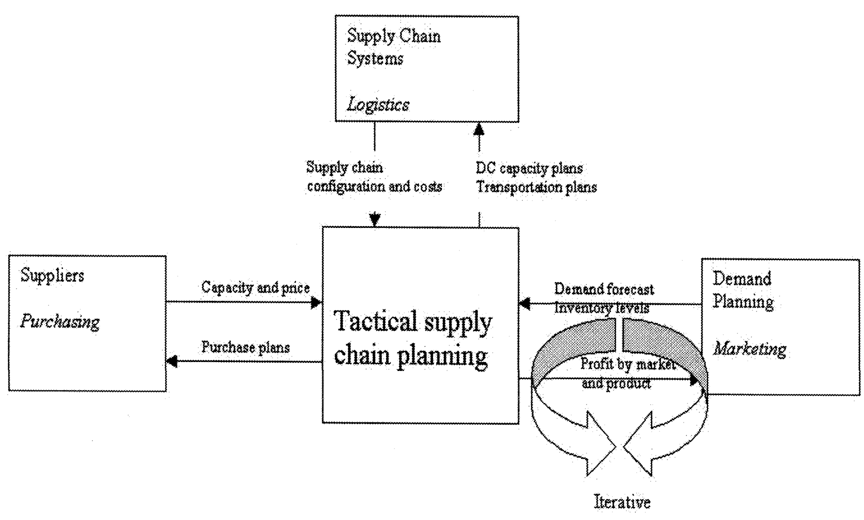


**Figure 2.8** Retail company's planning process.

company. The results are more cost-effective promotions and better coordination between the various departments.

## 7. Conclusions

In recent years many companies have improved supply chain performance; reducing cost, increasing service levels, reducing the bullwhip effect, and improving responsiveness to changes in the market place, by integrating the supply chain. In many cases, this was facilitated by the implementation of Push–Pull strategies. In this chapter we focused on three issues related to Push–Pull systems:

1. A framework for matching products with strategies. Specifically, we provide a framework that helps companies determine whether they should use a Push, a Pull or a Push–Pull strategies in their supply chain.
2. Issues associated with implementing Push–Pull strategies. In particular, our analysis suggests that in the Push portion of the Push–Pull process the focus should be on cost minimization, achieved through resource utilization, while in the Pull portion the focus is on service level. The interface between the Push portion and the Pull portion of the supply chain time line is forecast demand.
3. The integration of the front-end of the supply chain, that is, demand information, with the back-end of the supply chain, that is, production planning. This is done by developing the so-called supply chain master plan.

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