Reading: Ch. 4. The Value of Information (excerpt) *(Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies)*

Author: Simchi-Levi, David; Kaminsky, Philip; Simchi-Levi, Edith

Editor: N/A

Publisher: McGraw-Hill/Irwin Publication Date: 2003 Pages: 91-110

Course: COMR_V 398 201 202 2024W2 Introduction to Business Processes and Operations
Course Code: 202 Term: 2024 Winter Term 2

Department: COMR_V

The Value of Information

CASE Barilla SpA (A)

Giorgio Maggiali was becoming increasingly frustrated. As director of logistics for the world's largest pasta producer, Barilla SpA (Societa per Aziont translates as "Society for Stockholders" and is interpreted as "Inc."), Maggiali was acutely aware of the growing burden that demand fluctuations imposed on the company's manufacturing and distribution system. Since his appointment in 1988 as Director of Logistics, he had been trying to make headway on an innovative idea proposed by Brando Vitali, who had served as Barilla's director of logistics before Maggiali. The idea, which Vitali called just-in-time distribution (JITD), was modeled after the popular "just-in-time" manufacturing concept. In essence, Vitali proposed that, rather than follow the traditional practice of delivering product to Barilla's distributors on the basis of whatever orders those distributors placed with the company, Barilla's own logistics organization would instead specify the "appropriate" delivery quantities—those that would more effectively meet the end consumer's needs yet also would distribute the workload on Barilla's manufacturing and logistics systems more evenly.

For two years Maggiali, a strong supporter of Vitali's proposal, had tried to implement the idea, but now, in the spring of 1990, little progress had been made. It seemed that Barilla's customers were simply unwilling to give up their authority to place orders as they pleased; some were even reluctant to provide the detailed sales data upon which Barilla could make delivery decisions and improve its demand forecasts. Perhaps more disconcerting was the internal resistance from Barilla's own sales and marketing organizations, which saw the concept as infeasible or dangerous, or both. Perhaps it was time to discard the idea as simply unworkable. If not, how might Maggiali increase the chances that the idea would be accepted?

COMPANY BACKGROUND

Barilla was founded in 1875 when Pietro Barilla opened a small shop in Parma, Italy, on Via Vittorio Emanuele. Adjoining the shop was the small "laboratory" Pietro used to make the pasta and bread products he sold in his store. Pietro's son Ricardo led the company through a significant period of growth and, in the 1940s, passed the company to his own sons, Pietro and Gianni. Over time Barilla evolved from its modest beginnings into a large, vertically integrated corporation with flour mills, pasta plants, and bakery-product factories located throughout Italy.

In a crowded field of more than 2,000 Italian pasta manufacturers, Pietro and Gianni Barilla differentiated their company with a high-quality product supported by innovative marketing programs. Barilla revolutionized the Italian pasta industry's marketing practices by creating a strong brand name and image for its pasta, selling pasta in a sealed cardboard box with a recognizable color pattern rather than in bulk, and investing in large-scale advertising programs. In 1968, to support the double-digit sales growth the company had experienced during the 1960s, Pietro and Gianni Barilla began construction of a 125-million-square-meter state-of-the-art pasta plant in Pedrignano, a rural town 5 km outside Parma.

The cost of this massive facility—the largest and most technologically advanced pasta plant in the world—drove the Barillas deeply into debt. In 1971 the brothers sold the company to the U.S. multinational firm W. R. Grace, Inc. Grace brought additional capital investment and professional management practices to the company and launched an important new Mulino Bianco ("White Mill") line of bakery products. Throughout the 1970s, facing difficult economic conditions and new Italian legislation that both capped retail pasta prices and increased the cost-of-living allowances for employees, Grace struggled to make its Barilla acquisition pay off. In 1979, Grace sold the company back to Pietro Barilla, who by then had secured the necessary funds to purchase it.

The capital investments and organizational changes that Grace had brought to Barilla, combined with improving market conditions, helped Pietro Barilla launch a successful return to the company. During the 1980s, Barilla enjoyed an annual growth rate of over 21 percent (see Table 4-1). Growth was realized through the expansion of existing businesses, both in Italy and other European countries, as well as through acquisition of new, related businesses.

By 1990 Barilla had become the largest pasta manufacturer in the world, making 35 percent of the pasta sold in Italy and 22 percent of the pasta sold in Europe. Barilla's share in Italy comprised its three brands: The traditional Barilla brand represented 32 percent of the market; the remaining 3 percent of market share was divided between its Voiello brand (a traditional Neapolitan pasta competing in the high-priced segment of the semolina pasta market) and its Braibanti brand (a high-quality, traditional Parmesan pasta made from eggs and semolina). About half of Barilla's pasta was sold in northern Italy and half in the south, where Barilla held a smaller share of the market than in the north but where the market was larger. In addition, Barilla held a 29 percent share of the Italian bakery products market.

TABLE 4-1

BARILLA SALES, 1960–1991

Year	Barilla sales (lire in billions*)	Italian wholesale price index
1960	15	10.8
1970	47	41.5
1980	344	57.5
1981	456	67.6
1982	609	76.9
1983	728	84.4
1984	1,034	93.2
1985	1,204	100.0
1986	1,381	99.0
1987	1,634	102.0
1988	1,775	106.5
1989	2,068	121.7
1990†	2,390	126.0

*In 1990, 1,198 lire = US$1.00.
†1990 figures are estimates.
Source: Based on company documents and *International Financial Statistics Yearbook, International Monetary Fund.*

In 1990 Barilla was organized into seven divisions: three pasta divisions (Barina, Voiello, and Braibanti), the Bakery Products Division (manufacturing medium- to long-shelf-life bakery products), the Fresh Bread Division (manufacturing very-short-shelf-life bakery products), the Catering Division (distributing cakes and frozen croissants to bars and pastry shops), and the International Division. Barilla's corporate headquarters were located adjacent to the Pedrignano pasta plant.

INDUSTRY BACKGROUND

The origins of pasta are unknown. Some believe it originated in China and was first brought to Italy by Marco Polo in the 13th century. Others claim that pasta's origins were rooted in Italy, citing as proof a bas relief on a third-century tomb located near Rome that depicts a pasta roller and cutter. "Regardless of its origins," Barilla marketing literature pronounced, "since time immemorial, Italians have adored pasta." Per capita pasta consumption in Italy averaged nearly 18 kilos per year, greatly exceeding that of other western European countries (see Table 4-2). There was limited seasonality in pasta demand—for example, special pasta types were used for pasta salads in the summer while egg pasta and lasagna were very popular for Easter meals.

TABLE 4-2

PER CAPITA CONSUMPTION OF PASTA AND BAKERY PRODUCTS, IN KILOGRAMS, 1990

Country	Bread	Breakfast cereals	Pasta	Biscuits
Belgium	85.5	1.0	1.7	5.2
Denmark	29.9	3.7	1.6	5.5
France	68.8	0.6	5.9	6.5
Germany (West)	61.3	0.7	5.2	3.1
Greece	70.0		6.2	8.0
Ireland	58.4	7.7		17.9
Italy	130.9	0.2	17.8	5.9
Netherlands	60.5	1.0	1.4	2.8
Portugal	70.0		5.7	4.6
Spain	87.3	0.3	2.8	5.2
United Kingdom	43.6	7.0	3.6	13.0
Average	70.3	2.5	5.2	7.1

Adapted from *European Marketing Data and Statistics* 1992, Euromonitor Plc 1992, p. 323.

In the late 1980s the Italian pasta market as a whole was relatively flat, growing less than 1 percent per year. By 1990 the Italian pasta market was estimated at 3.5 trillion lire. Semolina pasta and fresh pasta were the only growth segments of the Italian pasta market. In contrast, the export market was experiencing record growth; pasta exports from Italy to other European countries were expected to rise as much as 20 to 25 percent per year in the early 1990s. Barilla's management estimated that two-thirds of this increase would be attributed to the new flow of exported pasta to eastern European countries seeking low-priced basic food products. Barilla managers viewed the eastern European market as an excellent export opportunity, with the potential to encompass a full range of pasta products.

PLANT NETWORK

Barilla owned and operated an extensive network of plants located throughout Italy (see Table 4-3 and Figure 4-1), including large flour mills, pasta plants, and fresh bread plants, as well as plants producing specialty products such as panettone (Christmas cake) and croissants. Barilla maintained state-of-the-art research and development (R&D) facilities and a pilot production plant in Pedrignano for developing and testing new products and production processes.

TABLE 4-3

BARILLA PLANT LOCATIONS AND PRODUCTS MANUFACTURED, 1989

Index	Plant location	Products
1	Bribanti	Pasta
2	Cagliari	Pasta
3	Foggia	Pasta
4	Matera	Pasta
5	Pedrignano	Pasta, noodles, biscuits
6	Viale Barilla	Tortellini, noodles, fresh pasta
7	Caserta	Pasta, rusks, breadsticks
8	Grissin Bon	Breadsticks
9	Rubbiano	Rusks, breadsticks
10	Milano	Panettone, cakes, croissants
11	Pomezia	Croissants
12	Mantova	Biscuits, cakes
13	Melfi	Snacks
14	Ascoli	Snacks, sliced loafs
15	Rodolfi	Sauces
16	Altamura	Flour mill
17	Castelplanio	Flour mill
18	Ferrara	Flour mill
19	Matera	Flour mill
20	Termoli	Flour mill
21	Milano	Fresh bread
22	Milano	Fresh bread
23	Altopascio	Fresh bread
24	Padova	Fresh bread
25	Torino	Fresh bread

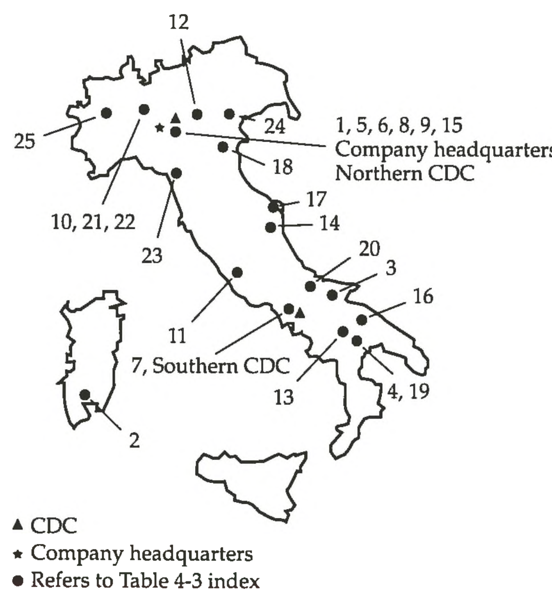


FIGURE 4-1 Map of Barilla plant locations and products manufactured.

Pasta Manufacturing

The pasta-making process is similar to the process by which paper is made. In Barilla plants, flour and water (and for some products, eggs and/or spinach meal) were mixed to form dough, which was then rolled into a long, thin continuous sheet by sequential pairs of rollers set at increasingly closer tolerances. After being rolled to the desired thickness, the dough sheet was forced through a bronze extruding die screen; the die's design gave the pasta its distinctive shape. After passing through the extruder, Barilla workers cut the pasta to a specified length. The cut pieces were then hung over dowels (or placed onto trays) and moved slowly through a long tunnel kiln that snaked across the factory floor. The temperature and humidity in the kiln were precisely specified for each size and shape of pasta and had to be tightly controlled to ensure a high-quality product. To keep changeover costs low and product quality high, Barilla followed a carefully chosen production sequence that minimized the incremental changes in kiln temperature and humidity between pasta shapes. After completing the four-hour drying process, the pasta was weighed and packaged.

At Barilla, raw ingredients were transformed into packaged pasta on fully automated 120-meter-long production lines. In the Pedrignano plant, the largest and most technologically advanced of Barilla's plants, 11 lines produced 9,000 quintals (900,000 kilos) of pasta each day. Barilla employees used bicycles to travel within this enormous facility.

Barilla's pasta plants were specialized by the type of pasta produced in the plant. The primary distinctions were based on the consumption of the pasta—for example, whether it was made with or without eggs or spinach and whether it was sold as dry or fresh pasta. All of Barilla's pasta was made with flour ground from *grano duro* (high protein "hard" wheat), the highest-quality flour for making traditional pasta products. Semolina, for example, is a finely ground durum wheat flour. Barilla used flours made from *grano tenero* (tender wheat), such as farina, for more delicate products such as egg pasta and bakery products. Barilla's flour mills ground flour from both types of wheat.

Even within the same family of pasta products, individual products were assigned to plants based on the size and shape of the pasta. "Short" pasta products, such as macaroni or fusilli, and "long" products, such as spaghetti or capellini, were made in separate facilities because of the different sizes of equipment required.

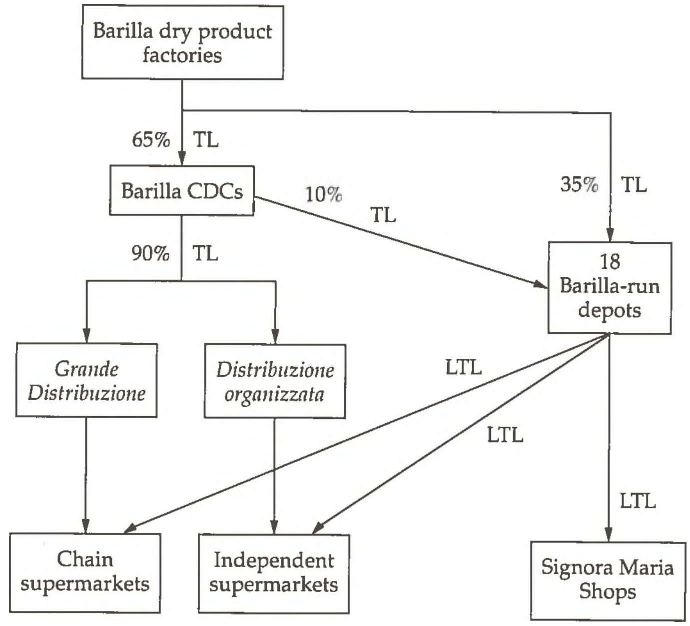
CHANNELS OF DISTRIBUTION

Barilla divided its entire product line into two general categories:

- "Fresh" products, including fresh pasta products, which had 21-day shelf lives, and fresh bread, which had a one-day shelf life.
- "Dry" products, including dry pasta, and longer shelf-life bakery products such as cookies, biscuits, flour, bread sticks, and dry toasts. Dry products represented about 75 percent of Barilla's sales and had either "long" shelf lives of 18 to 24 months (e.g., pasta and dried toasts) or "medium" shelf lives of 10 to 12 weeks (e.g., cookies). In total, Barilla's "dry" products were offered in some 800 different packaged stockkeeping units (SKUs). Pasta was made in 200 different shapes and sizes and was offered in more than 470 different packaged SKUs. The most popular pasta products were offered in a variety of packaging options; for example, at any one time Barilla's #5 spaghetti might be offered in a 5-kg package, a 2-kg package, a 1-kg package with a northern Italian motif, a 2-kg package with a southern Italian motif, a 0.5-kg "northern-motif" package, a 0.5-kg "southern-motif" package, a display pallet, and a special promotional package with a free bottle of Barilla pasta sauce.

Most Barilla products were shipped from the plants in which they were made to one of two Barilla central distribution centers (CDCs): the northern CDC in Pedrignano or the southern CDC on the outskirts of Naples. See Figure 4-2. (Certain products, such as fresh bread, did not flow through the CDCs.) Other fresh products were moved quickly through the distribution system; fresh product inventory was typically held only three days in each of the CDCs. In contrast, each CDC held about a month's worth of dry product inventory.

Barilla maintained separate distribution systems for its fresh and dry products because of their differences in perishability and retail service requirements. Fresh products were purchased from the two CDCs by independent agents (*concessionari*) who then channeled the products through 70 regional



TL = Delivery in truckload quantities.
LTL = Delivery in less-than-truckload quantities.

Note: Shipping percentages are based on product weight.

FIGURE 4-2 Barilla distribution patterns.

warehouses located throughout Italy. Nearly two-thirds of Barilla's dry products were destined for supermarkets; these products were shipped first to one of Barilla's CDCs, where they were purchased by distributors. The distributors in turn shipped the product to supermarkets. Brando Vitali's JITD proposal focused solely on dry products sold through distributors. The remainder of the dry products was distributed through 18 small Barilla-owned warehouses, mostly to small shops.

Barilla products were distributed through three types of retail outlets: small independent grocers, supermarket chains, and independent supermarkets. In sum, Barilla estimated that its products were offered in 100,000 retail outlets in Italy alone.

1. **Small independent shops.** Small shops were more prevalent in Italy than in other western European countries. Through the late 1980s the Italian government had supported small grocers (often referred to as "Signora Maria" shops) by restricting the number of licenses provided to operate large supermarkets. However, in the early 1990s the number of supermarkets began to grow as governmental restrictions abated.

   Approximately 35 percent of Barilla's dry products (30 percent in the north of Italy and 40 percent in the south) were distributed from Barilla's internally owned regional warehouses to small independent shops, which typically held over two weeks of inventory at the store level. Small shop owners purchased products through brokers who dealt with Barilla purchasing and distribution personnel.
2. **Supermarkets.** The remaining dry products were distributed through outside distributors to supermarkets—70 percent to supermarket chains and 30 percent to independent supermarkets. A supermarket typically held from 10 to 12 days of dry product inventory within the stores, and on average carried a total of 4,800 dry product SKUs. Although Barilla offered many pasta products in multiple types of packages, most retailers would carry a product in only one (and at most two) packaging options.

   Dry products destined for a supermarket chain were distributed through the chain's own distribution organization, known as a *grande distribuzione* ("grand distributor"), or GD; those destined for independent supermarkets were channeled through a different set of distributors known as *distribuzione organizzata* ("organized distributors"), or DOs. A DO acted as a central buying organization for a large number of independent supermarkets. Most DOs had regional operations, and the retailers they served usually got their products from only a single DO.

Due to regional preferences and differences in retail requirements, a typical distributor might distribute 130 of Barilla's 800 dry product SKUs. Most distributors handled products coming from about 200 different suppliers; of these, Barilla typically would be the largest in terms of the physical volume of products purchased. Distributors typically carried from 7,000 to 10,000 SKUs in total. However, their strategies varied. For example, one of Barilla's largest DOs, Cortese, carried only 100 of Barilla's dry products and carried a total of only 5,000 SKUs.

Both GDs and DOs purchased products from the Barilla CDCs, maintained inventory in their own warehouses, and then filled supermarket orders from their warehouse inventory. A distributor's warehouse typically held a two-week supply of Barilla dry products in inventory.

Many supermarkets placed daily orders with distributors; the store manager would walk up and down the store aisles and note each product that needed to be replenished and the number of boxes required (more sophisticated retailers used hand-held computers to record order quantities as they checked the shelves). The order would then be transmitted to the store's distributor; orders were typically received at the store 24 to 48 hours after receipt of the order at the distribution center.

SALES AND MARKETING

Barilla enjoyed a strong brand image in Italy. Its marketing and sales strategy was based upon a combination of advertising and promotions.

Advertising

Barilla brands were heavily advertised. Advertising copy differentiated Barilla pasta from basic commodity "noodles" by positioning the brand as the highest quality, most sophisticated pasta product available. One ad campaign was built on the phrase: "Barilla: a great collection of premium Italian pasta." The "collection" dimension was illustrated by showing individual uncooked pasta shapes against a black background, as though they were jewels, evoking a sense of luxury and sophistication. Unlike other pasta manufacturers, Barilla avoided images of traditional Italian folklore, preferring modern, sophisticated settings in major Italian cities.

Advertising themes were supported by sponsorships of well-known athletes and celebrities. For example, Barilla engaged tennis stars Steffi Graf to promote Barilla products in Germany and Stefan Edberg in the Scandinavian countries. Luminaries such as actor Paul Newman were also used to promote Barilla products. In addition, Barilla advertising focused on developing and strengthening loyal relationships with Italian families by using messages such as "Where there is Barilla, there is a home."

Trade Promotions

Barilla's sales strategy relied on the use of trade promotions to push its products into the grocery distribution network. A Barilla sales executive explained the logic of the promotion-based strategy:

> We sell to a very old-fashioned distribution system. The buyers expect frequent trade promotions, which they then pass along to their own customers. So a store will know right away if another store is buying Barilla pasta at a discount. You have to understand how important pasta is in Italy. Everyone knows the price of pasta. If a store is selling pasta at a discount one week, consumers notice the reduced price immediately.

Barilla divided each year into 10 or 12 "canvass" periods, typically four to five weeks in length, each corresponding to a promotional program. During any canvass period, a Barilla distributor could buy as many products as desired to meet current and future needs. Incentives for Barilla sales representatives were based on achieving the sales targets set for each canvass period. Different product categories were offered during different canvass periods, with the discount depending on the margin structure of the category. Typical promotional discounts were 1.4 percent for semolina pasta, 4 percent for egg pasta, 4 percent for biscuits, 8 percent for sauces, and 10 percent for breadsticks.

Barilla also offered volume discounts. For example, Barilla paid for transportation, thus providing incentives of 2 to 3 percent for orders in full truckload quantities. In addition, a sales representative might offer a buyer a 1,000 lire per carton discount (representing a 4 percent discount) if the buyer purchased a minimum of three truckloads of Barilla egg pasta.

Sales Representatives

Barilla sales representatives serving DOs spent an estimated 90 percent of their time working at the store level. In the store, sales reps helped merchandise Barilla products and set up in-store promotions; took note of competitive information, including competitors' prices, stockouts, and new product introductions; and discussed Barilla products and ordering strategies with store management. In addition, each sales rep spent a half day in a regularly scheduled weekly meeting with the distributor's buyer, helping the distributor place its weekly order, explaining promotions and discounts, and settling problems such as returns and deletions associated with the last delivery. Each rep carried a portable computer for inputting distributor orders. The rep also would spend a few hours a week at the CDC, discussing new products and prices, covering problems concerning the previous week's deliveries, and settling disputes about different discounts and deal structures.

In contrast, a very small sales force served the GDs. The GD sales force rarely visited GD warehouses and usually sent their orders to Barilla via fax.

DISTRIBUTION

Distributor Ordering Procedures

Most distributors—GDs and DOs alike—checked their inventory levels and placed orders with Barilla once a week. Barilla products would then be shipped to the distributor over the course of the week that started 8 days after the order was placed and ended 14 days after the order was placed—the average lead time was 10 days. For example, a large distributor that ordered every Tuesday might order several truckloads to be delivered from the following Wednesday through the following Tuesday (see below). Distributors' sales volumes varied; small distributors might order only one truckload a week, whereas the largest warranted deliveries of as many as five truckloads a week.

Most distributors used simple periodic review inventory systems. For example, a distributor might review inventory levels of Barilla products each Tuesday; the distributor would then place orders for those products whose levels fell below the reorder level. Nearly all of the distributors had computer-supported ordering systems, but few had forecasting systems or sophisticated analytical tools for determining order quantities.

Impetus for the JITD Program

As the 1980s progressed, Barilla increasingly felt the effects of fluctuating demand. Orders for Barilla dry products often swung wildly from week to week (see Figure 4-3). Such extreme demand variability strained

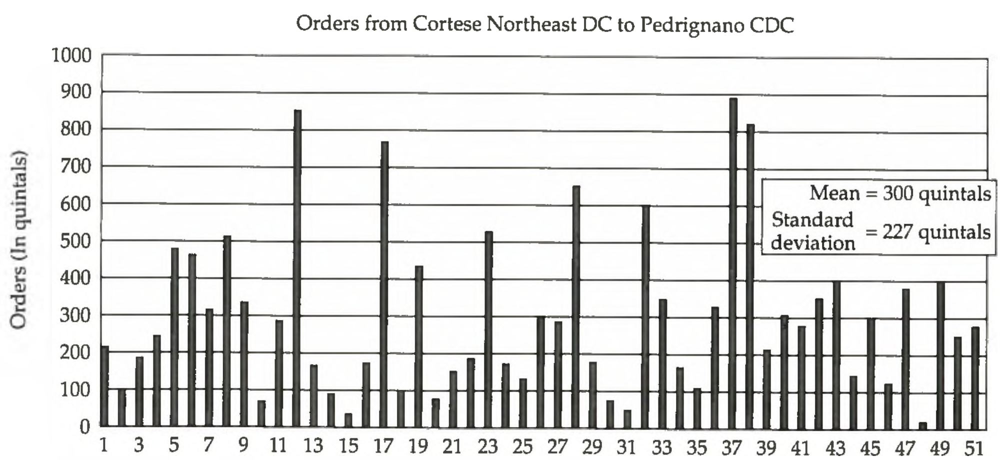


FIGURE 4-3 Weekly demand for Barilla dry products from Cortese's Northeast Distribution Center to the Pedrignano CDC, 1989.

Barilla's manufacturing and logistics operations. For example, the specific sequence of pasta production necessitated by the tight heat and humidity specifications in the tunnel kiln made it difficult to quickly produce a particular pasta that had been sold out owing to unexpectedly high demand. On the other hand, holding sufficient finished goods inventories to meet distributors' order requirements was extremely expensive when weekly demand fluctuated so widely and was so unpredictable.

Some manufacturing and logistics personnel favored asking distributors or retailers to carry additional inventory to check the fluctuation in distributors' orders, noting that with their current inventory levels, many distributors' service levels to the retailers were unacceptable (see Figure 4-4 for sample distributor inventory levels and stockout rates). Others felt that the distributors and retailers were already carrying too much inventory. In the late 1980s a Barilla logistics manager discussed retail inventory pressure:

> Our customers are changing. And do you know why they are changing? As I see it, they are realizing they do not have enough room in their stores and warehouses to carry the very large inventories manufacturers would like them to. Think of shelf space in retail outlets. You cannot easily increase it. Yet manufacturers are continuously introducing new products, and they want retailers to display each product on the fronts of their shelves! That would be impossible even if supermarkets were made from rubber![1]

Distributors felt similar pressure to increase the inventory of items they already stocked and to add items they currently did not carry.

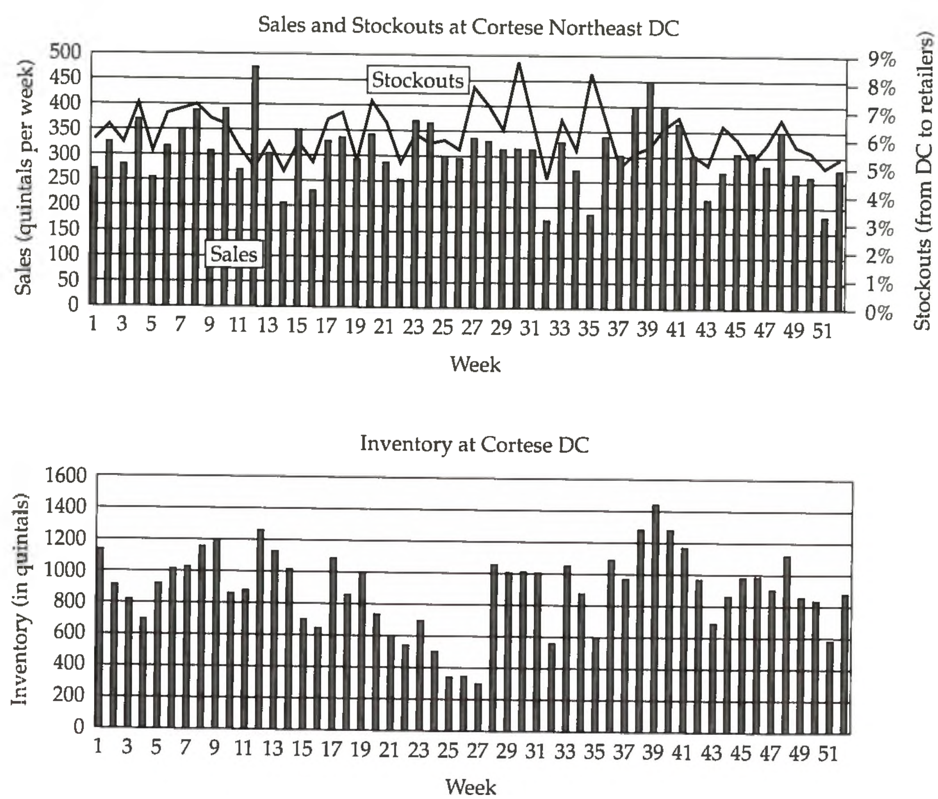


FIGURE 4-4 Sample stockout and inventory levels, Cortese's Northeast Distribution Center, 1989.

[1] Claudia Ferrozzi, *The Pedrignano Warehouse* (Milan: GEA, 1988).

In 1987 Brando Vitali, then Barilla's director of logistics, had expressed strong feelings about finding an alternative approach to order fulfillment. At that time, he noted, "Both manufacturers and retailers are suffering from thinning margins; we must find a way to take costs out of our distribution channel without compromising service." Vitali was seen as a visionary whose ideas stretched beyond the day-to-day details of a logistics organization. He envisioned an approach that would radically change the way in which the logistics organization managed product delivery. In early 1988 Vitali explained his plan:

> I envision a simple approach: rather than send product to the distributors according to their internal planning processes, we should look at all of the distributors' shipment data and send only what is needed at the stores—no more, no less. The way we operate now it's nearly impossible to anticipate demand swings, so we end up having to hold a lot of inventory and do a lot of scrambling in our manufacturing and distribution operations to meet distributor demand. And even so, the distributors don't seem to do such a great job servicing their retailers. Look at the stockouts (see Figure 4-4) these DOs have experienced in the last year. And that's despite their holding a couple of weeks of inventory.
>
> In my opinion, we could improve operations for ourselves and our customers if we were responsible for creating the delivery schedules. We'd be able to ship product only as it is needed, rather than building enormous stocks in both of our facilities. We could try to reduce our own distribution costs, inventory levels, and ultimately our manufacturing costs if we didn't have to respond to the volatile demand patterns of the distributors.
>
> We have always had the mentality that orders were an unchangeable input into our process and therefore that one of the most important capabilities we needed to achieve was flexibility to respond to those inputs. But in reality, demand from the end consumer is the input and I think that we should be able to manage the input filter that produces the orders.
>
> How would this work? Every day each distributor would provide us data on what Barilla products it had shipped out of its warehouse to retailers during the previous day, as well as the current stock level for each Barilla SKU. Then we could look at all of the data and make replenishment decisions based on our own forecasts. It would be similar to using point-of-sale data from retailers—we would just be responding to see-through information one step behind the retailer. Ideally, we would use actual retail sell-through data, but that's hard to come by given the structure of our distribution channel and the fact that most grocers in Italy aren't equipped yet with the necessary bar-code scanners and computer linkages.
>
> Of course, it's not quite as simple as that. We need to improve our own forecasting systems so we can make better use of the data that we receive. We'll also need to develop a set of decision rules that we can use to determine what to send after we've made a new forecast.

Vitali's proposal, "just-in-time distribution," met with significant resistance within Barilla. The sales and marketing organizations were particularly vocal in their opposition to the plan. A number of sales representatives felt their responsibilities would be diminished if such a program were put in place. A range of concerns was expressed from the bottom to the top of the sales organization. The following remarks were heard from Barilla sales and marketing personnel:

- "Our sales levels would flatten if we put this program in place."
- "We run the risk of not being able to adjust our shipments sufficiently quickly to changes in selling patterns or increased promotions."
- "It seems to me that a pretty good part of the distribution organization is not yet ready to handle such a sophisticated relationship."
- "If space is freed up in our distributors' warehouses when inventories of our own product decrease, we run the risk of giving our competitors more distributor shelf space. The distributors would then push our competitors' product more than our own, since once something is bought it must be sold."
- "We increase the risk of having our customers stock out of our product if we have disruption in our supply process. What if we have a strike or some other disturbance?"
- "We wouldn't be able to run trade promotions with JITD. How can we get the trade to push Barilla product to retailers if we don't offer some sort of incentive?"
- "It's not clear that costs would even be reduced. If a DO decreases its stock, we at Barilla may have to increase our own inventory of those products for which we cannot change production schedules due to our lack of manufacturing flexibility."

Vitali countered the concerns of the sales organization:

> I think JITD should be considered a selling tool, rather than a threat to sales. We're offering the customer additional service at no extra cost. In addition, the program will improve Barilla's visibility with the trade and make distributors more dependent on us—it should improve the relationships

between Barilla and the distributors rather than harm them. And what's more, the information regarding the supply at the distributors' warehouses provides us with objective data that would permit us to improve our own planning procedures.

Giorgio Maggiali, head of materials management for Barilla's fresh products group, was appointed director of logistics in late 1988 when Vitali was promoted to head one of the company's new divisions. Maggiali was a hands-on manager, known for his orientation to action. Shortly after his appointment, Maggiali appointed a recent college graduate, Vincenzo Battistini, to help him develop and implement the JITD program.

Maggiali recounted his frustrations in implementing the JITD program:

In 1988 we developed the basic ideas for the approach we wanted to use and tried to convince several of our distributors to sign on. They weren't even interested in talking about it; the manager of one of our largest distributors pretty much summed up a lot of the responses we had when he cut off a conversation saying, "Managing stock is my job; I don't need you to see my warehouse or my figures. I could improve my inventory and service levels myself if you would deliver my orders more quickly. I'll make you a proposal—I'll place the order and you deliver within 36 hours." He didn't understand that we just can't respond to wildly changing orders without more notice than that. Another distributor expressed concerns about becoming too closely linked to Barilla. "We would be giving Barilla the power to push product into our warehouses just so Barilla can reduce its costs." Still another asked, "What makes you think that you could manage my inventories any better than I can?"

We were finally able to convince a couple of our distributors to have in-depth discussions about the JITD proposal. Our first discussion was with Marconi, a large, fairly old-fashioned GD. First Battistini and I visited Marconi's logistics department and presented our plan. We made it clear that we planned to provide them with such good service that they could both decrease their inventories and improve their fill rate to their stores. The logistics group thought it sounded great and was interested in conducting an experimental run of the program. But as soon as Marconi's buyers heard about it, all hell broke loose. First the buyers started to voice their own concerns; then, after talking to their Barilla sales reps, they started to repeat some of our own sales department's objections as well. Marconi finally agreed to sell us the data we wanted, but otherwise things would continue as before with Marconi making decisions about replenishment quantities and timing. This clearly wasn't the type of relationship we were looking for, so we talked to other distributors, but they weren't much more responsive.

We need to regroup now and decide where to go with JITD. Is this type of program feasible in our environment? If so, what kind of customer should we target? And how do we convince them to sign up?

The Barilla case raises two important issues:

- Variations in distributors' order patterns have caused severe operational inefficiencies and cost penalties for Barilla. The extreme variability in orders that Barilla receives is surprising considering the distribution of demand for pasta in Italy. Indeed, while variability in aggregate demand for pasta is quite small, orders placed by the distributors have a huge variability.
- In the proposed JITD strategy, Barilla will be in charge of the channel between the CDCs and the distributors and decide on the timing and size of shipments to its distributors. Thus, unlike traditional supply chains in which distributors place orders and manufacturers try to satisfy these orders as much as possible, in JITD "Barilla's own logistics organization would specify the appropriate delivery quantities—those that would more effectively meet the end consumer's needs yet would also more evenly distribute the workload on Barilla's manufacturing and logistics systems." In the last few years, such a strategy has been referred to as *vendor managed inventory* (*VMI*).

By the end of this chapter, you should be able to answer the following questions:

- What are the reasons for the increase in variability in Barilla's supply chain?
- How can the firm cope with the increase in variability?
- What is the impact of transferring demand information across the supply chain?

- Can the VMI strategy solve the operational problems faced by Barilla?
- How can the supply chain meet conflicting goals of different partners and facilities?

4.1 INTRODUCTION

We live in the "Information Age." Data warehouses, web services, XML, wireless, the Internet, and portals are just a few of the technologies dominating the business page of the daily newspaper. In Chapter 11, we examine these technologies in detail and look at the issues surrounding their implementation. In this chapter, we consider the value of using any type of information technology; we deal specifically with the potential availability of more and more information throughout the supply chain and the implications this availability has on effective design and management of the integrated supply chain.

The implications of this abundance of available information are enormous. The supply chain pundits and consultants like to use the phrase, *In modern supply chains, information replaces inventory.* We don't dispute this idea, but its meaning is vague. After all, at some point the customer needs products, not just information! Nevertheless, information changes the way supply chains can and should be effectively managed, and these changes may lead to, among other things, lower inventories. Indeed, our objective in this chapter is to characterize how information affects the design and operation of the supply chain. We show that by effectively harnessing the information now available, one can design and operate the supply chain much more efficiently and effectively than ever before.

It should be apparent to the reader that having accurate information about inventory levels, orders, production, and delivery status throughout the supply chain should not make the managers of a supply chain less effective than if this information were not available. After all, they could choose to ignore it. As we will see, however, this information provides a tremendous opportunity to improve the way the supply chain is designed and managed. Unfortunately, using this information effectively does make the design and management of the supply chain more complex because many more issues must be considered.

We argue here that this abundant information

- Helps reduce variability in the supply chain.
- Helps suppliers make better forecasts, accounting for promotions and market changes.
- Enables the coordination of manufacturing and distribution systems and strategies.
- Enables retailers to better serve their customers by offering tools for locating desired items.
- Enables retailers to react and adapt to supply problems more rapidly.
- Enables lead time reductions.

The chapter is based on the seminal work in [90] and [91] as well as the recent work in [28] and [30]. In the next section, we follow the review article [29].

4.2 THE BULLWHIP EFFECT

In recent years many suppliers and retailers have observed that while customer demand for specific products does not vary much, inventory and back-order levels fluctuate considerably across their supply chain. For instance, in examining the demand for Pampers disposal diapers, executives at Procter & Gamble noticed an interesting phenomenon.

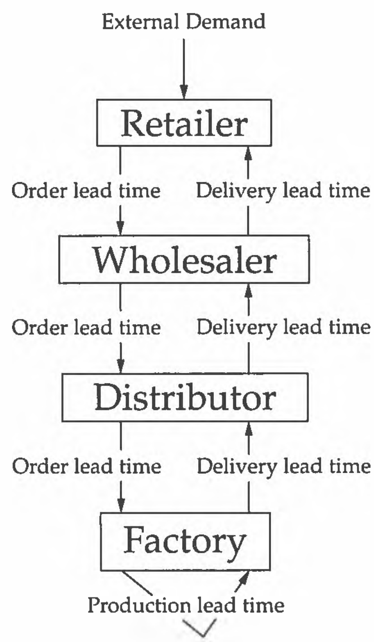


FIGURE 4-5 **The supply chain.**

As expected, retail sales of the product were fairly uniform; there is no particular day or month in which the demand is significantly higher or lower than any other. However, the executives noticed that distributors' orders placed to the factory fluctuated much more than retail sales. In addition, P&G's orders to its suppliers fluctuated even more. This increase in variability as we travel up in the supply chain is referred to as the *bullwhip effect.*

Figure 4-5 illustrates a simple four-stage supply chain: a single retailer, a single wholesaler, a single distributor, and a single factory. The retailer observes customer demand and places orders to the wholesaler. The wholesaler receives products from the distributor, who places orders to the factory. Figure 4-6 provides a graphical representation of orders, as a function of time, placed by different facilities. The figure clearly shows the increase in variability across the supply chain.

To understand the impact of the increase in variability on the supply chain, consider the second stage in our example, the wholesaler. The wholesaler receives orders from the retailer and places orders to his supplier, the distributor. To determine these order quantities, the wholesaler must forecast the retailer's demand. If the wholesaler does not have access to the customer's demand data, he must use orders placed by the retailer to perform his forecasting.

Since variability in orders placed by the retailer is significantly higher than variability in customer demand, as Figure 4-6 shows, the wholesaler is forced to carry more safety stock than the retailer or else to maintain higher capacity than the retailer in order to meet the same service level as the retailer.

This analysis can be carried over to the distributor as well as the factory, resulting in even higher inventory levels and therefore higher costs at these facilities.

Consider, for example, a simple widget supply chain. A single factory, Widget-Makers Inc., supplies a single retailer, the WidgetStore. Average annual widget demand at the WidgetStore is 5,200 units, and shipments are made from WidgetMakers to the

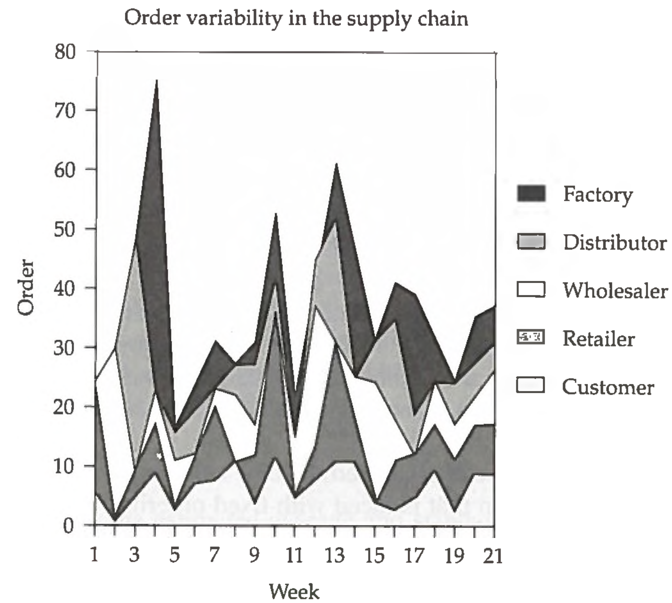


FIGURE 4-6 The increase in variability in the supply chain.

store each week. If the variability in orders placed by the WidgetStore is low, so that the shipment every week is about 100 units, WidgetMakers' production capacity and weekly shipping capacity need be only about 100 units. If weekly variability is very high, so that during certain weeks WidgetMakers must make and ship 400 units and some weeks no units at all, it is easy to see that production and shipping capacity must be much higher and that some weeks this capacity will be idle. Alternatively, WidgetMakers could build up inventory during weeks with low demand and supply these items during weeks with high demand, thus increasing inventory holding costs.

Thus, it is important to identify techniques and tools that will allow us to control the bullwhip effect; that is, to control the increase in variability in the supply chain. For this purpose, we need to first understand the main factors contributing to the increase in variability in the supply chain.

1. *Demand forecasting.* Traditional inventory management techniques (see Chapter 3) practiced at each level in the supply chain lead to the bullwhip effect. To explain the connection between forecasting and the bullwhip effect, we need to revisit inventory control strategies in supply chains. As discussed in Chapter 3, an attractive policy used in practice by each stage of the supply chain is the *min-max inventory policy.* Here, whenever the inventory position at a facility is less than a given number, referred to as the *reorder point*, the facility raises its inventory level up to a given target level, called the *order-up-to level.*

   The reorder point is typically set equal to the average demand during lead time plus a multiple of the standard deviation of demand during lead time. The latter quantity is referred to as *safety stock.* Typically, managers use *standard forecast smoothing techniques* to estimate average demand and demand variability. An important characteristic of all forecasting techniques is that as more data are observed, the more we modify the estimates of the mean and the standard deviation (or variability) in customer demands. Since safety stock, as well as the order-up-to level, strongly depends on these estimates, the user is forced to change order quantities, thus increasing variability.

2. *Lead time*. It is easy to see that the increase in variability is magnified with increasing lead time. For this purpose, recall from Chapter 3 that to calculate safety stock levels and reorder points, we in effect multiply estimates of the average and standard deviation of the daily customer demands by the lead time. Thus, with longer lead times, a small change in the estimate of demand variability implies a significant change in safety stock and reorder level, leading to a significant change in order quantities. This of course leads to an increase in variability.
3. *Batch ordering*. The impact of batch ordering is quite simple to understand. If the retailer uses batch ordering, as happens when using a min-max inventory policy, then the wholesaler will observe a large order, followed by several periods of no orders, followed by another large order, and so on. Thus, the wholesaler sees a distorted and highly variable pattern of orders.

   It is useful to remind the reader that firms use batch ordering for a number of reasons. First, as pointed out in Chapter 3, a firm that is faced with fixed ordering costs needs to apply the min-max inventory policy, which leads to batch ordering. Second, as transportation costs become more significant, retailers may order quantities that allow them to take advantage of transportation discounts (e.g., full truckload quantities). This may lead to some weeks with large orders, and some with no orders at all. Finally, the quarterly or yearly sales quotas or incentives observed in many businesses can also result in unusually large orders observed on a periodic basis.
4. *Price fluctuation*. Price fluctuation can also lead to the bullwhip effect. If prices fluctuate, retailers often attempt to *stock up* when prices are lower. This is accentuated by the prevailing practice in many industries of offering promotions and discounts at certain times or for certain quantities.
5. *Inflated orders*. Inflated orders placed by retailers during shortage periods tend to magnify the bullwhip effect. Such orders are common when retailers and distributors suspect that a product will be in short supply, and therefore anticipate receiving supply proportional to the amount ordered. When the period of shortage is over, the retailer goes back to its standard orders, leading to all kinds of distortions and variations in demand estimates.

4.2.1 Quantifying the Bullwhip Effect[2]

So far, we have discussed factors contributing to the increase in variability in the supply chain. To better understand and control the bullwhip effect, we also would find it useful to *quantify* the bullwhip effect; that is, quantify the increase in variability that occurs at every stage of the supply chain. This would be useful not only to demonstrate the magnitude of the increase in variability, but also to show the relationship between the forecasting technique, the lead time, and the increase in variability.

To quantify the increase in variability for a simple supply chain, consider a two-stage supply chain with a retailer who observes customer demand and places an order to a manufacturer. Suppose that the retailer faces a fixed lead time, so that an order placed by the retailer at the end of period t is received at the start of period $t+L$. Also, suppose the retailer follows a simple periodic review policy (see Chapter 3) in which the retailer reviews inventory every period and places an order to bring its inventory level up to a target level. Observe that in this case the review period is one.

[2]This section can be skipped without loss of continuity.

Hence, as discussed in Chapter 3, Section 3.2.7, the order-up-to point is calculated as

$$L \times AVG + z \times STD \times \sqrt{L}$$

where *AVG* and *STD* are the average and standard deviation of daily (or weekly) customer demand. The constant z is the safety factor and is chosen from statistical tables to ensure that the probability of stockouts during lead time is equal to the specified level of service.

To implement this inventory policy, the retailer must estimate the average and standard deviation of demand based on its observed customer demand. Thus, in practice, the order-up-to point may change from day to day according to changes in the current estimate of the average and the standard deviation.

Specifically, the order-up-to point in period t, y_t, is estimated from the observed demand as

$$y_t = \hat{\mu}_t L + z\sqrt{L}S_t$$

where $\hat{\mu}_t$ and S_t are the estimated average and standard deviation of daily customer demand at time t.

Suppose the retailer uses one of the simplest forecasting techniques: the moving average. In other words, in each period the retailer estimates the mean demand as an average of the previous p observations of demand. The retailer estimates the standard deviation of demand in a similar manner. That is, if D_i represents customer demand in period i, then

$$\hat{\mu}_t = \frac{\sum_{i=t-p}^{t-1} D_i}{p}$$

and

$$S_t^2 = \frac{\sum_{i=t-p}^{t-1} (D_i - \hat{\mu}_t)^2}{p-1}$$

Note that the expressions above imply that in every period the retailer calculates a new mean and standard deviation based on the p most recent observations of demand. Then, since the estimates of the mean and standard deviation change every period, the target inventory level will also change in every period.

In this case, we can quantify the increase in variability; that is, we can calculate the variability faced by the manufacturer and compare it to the variability faced by the retailer. If the variance of the customer demand seen by the retailer is $Var(D)$, then the variance of the orders placed by that retailer to the manufacturer, $Var(Q)$, relative to the variance of customer demand satisfies

$$\frac{Var(Q)}{Var(D)} \geq 1 + \frac{2L}{p} + \frac{2L^2}{p^2}$$

Figure 4-7 shows the lower bound on the increase in variability as a function of p for various values of the lead time, L. In particular, when p is large and L is small, the bullwhip effect due to forecasting error is negligible. The bullwhip effect is magnified as we increase the lead time and decrease p.

For instance, suppose the retailer estimates the mean demand based on the last five demand observations, that is, $p = 5$. Suppose also that an order placed by the retailer at the end of period t is received at the start of period $t + 1$. This implies that the lead time (more precisely the lead time plus the review period) equals 1, that is, $L = 1$. In

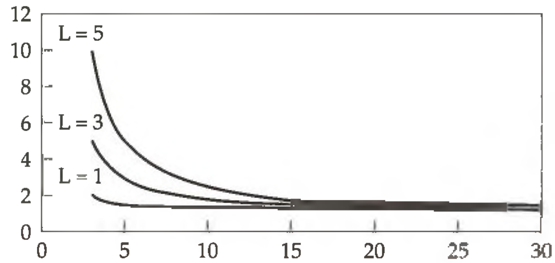


FIGURE 4-7 A lower bound on the increase in variability given as a function of *p*.

this case the variance of the orders placed by the retailer to the manufacturer will be at least 40 percent larger than the variance of the customer demand seen by the retailer, that is,

$$\frac{Var(Q)}{Var(D)} \geq 1.4$$

Next consider the same retailer, but now assume, as is the case in the retail industry, that the retailer uses 10 demand observations (i.e., $p = 10$) to estimate the mean and standard deviation of demand. Then the variance of the orders placed by the retailer to the manufacturer will be at least 1.2 times the variance of the customer demand seen by the retailer. In other words, by increasing the number of observations used in the moving average, the retailer can significantly reduce the variability of the orders it places to the manufacturer.

4.2.2 The Impact of Centralized Information on the Bullwhip Effect

One of the most frequent suggestions for reducing the bullwhip effect is to centralize demand information within a supply chain, that is, to provide each stage of the supply chain with complete information on the actual customer demand. To understand why centralized demand information can reduce the bullwhip effect, note that if demand information is centralized, each stage of the supply chain can use the actual customer demand data to create more accurate forecasts, rather than relying on the orders received from the previous stage, which can vary significantly more than the actual customer demand.

In this subsection, we consider the value of sharing customer demand information within a supply chain. For this purpose, consider again the initial four-stage supply chain, described in Figure 4-5, with a single retailer, wholesaler, distributor, and factory. To determine the impact of centralized demand information on the bullwhip effect, we distinguish between two types of supply chains: one with centralized demand information and a second with decentralized demand information. These systems are described below.

Supply Chain with Centralized Demand Information In the first type of supply chain, the *centralized supply chain*, the retailer, or the first stage in the supply chain, observes customer demand, forecasts the mean demand using a moving average with p demand observations, finds his target inventory level based on the forecast mean demand, and places an order to the wholesaler. The wholesaler, or the second stage of the supply chain, receives the order along with the retailer's forecast mean demand, uses this forecast to determine its target inventory level, and places an order to the distributor. Similarly, the distributor, or the third stage of the supply chain, receives the order along with the retailer's forecast mean demand, uses this forecast to determine its target inventory level, and places an order to the fourth stage of the supply chain, the factory.

In this centralized supply chain, each stage of the supply chain receives the retailer's forecast mean demand and follows an order-up-to inventory policy based on this mean demand. Therefore, in this case we have centralized the demand information, the forecasting technique, and the inventory policy.

Following the analysis above, it is not difficult to show that the variance of the orders placed by the kth stage of the supply chain, $Var(Q^k)$, relative to the variance of the customer demand, $Var(D)$, is just

$$\frac{Var(Q^k)}{Var(D)} \geq 1 + \frac{2\sum_{i=1}^{k} L_i}{p} + \frac{2\left(\sum_{i=1}^{k} L_i\right)^2}{p^2}$$

where L_i is the lead time between stage i and stage $i + 1$. That is, the lead time L_i implies that an order placed by facility i at the end of period t arrives at that facility at the beginning of period $t + L_i$. For example, if an order placed by the retailer to the wholesaler at the end of period t arrives at the beginning of period $t + 2$, then $L_1 = 2$. Similarly, if the lead time from the wholesaler to the distributor is two periods, then $L_2 = 2$, and if the lead time from the distributor to the factory is also two periods, then $L_3 = 2$. In this case, the total lead time from the retailer to the factory is

$$L_1 + L_2 + L_3 = 6 \text{ periods}$$

This expression for the variance of the orders placed by the kth stage of the supply chain is very similar to the expression for the variability of the orders placed by the retailer given in the previous section, with the single stage lead time L replaced by the k stage lead time $\sum_{i=1}^{k} L_i$. Thus, we see that *the variance of the orders placed by a given stage of a supply chain is an increasing function of the total lead time between that stage and the retailer.* This implies that the variance of the orders becomes larger as we move up the supply chain, so that the orders placed by the second stage of the supply chain are more variable than the orders placed by the retailer (the first stage) and the orders placed by the third stage will be more variable than the orders placed by the second stage, and so on.

Decentralized Demand Information The second type of supply chain that we consider is the *decentralized supply chain*. In this case the retailer does not make its forecast mean demand available to the remainder of the supply chain. Instead, the wholesaler must estimate the mean demand based on the orders received from the retailer.

Again we assume that the wholesaler uses a moving average with p observations—these are the latest p orders placed by the retailer—to forecast the mean demand. It then uses this forecast to determine the target inventory level and places an order to the supplier, the distributor. Similarly, the distributor uses a moving average with p observations of the orders placed by the wholesaler to forecast the mean and standard deviation of demand and uses these forecasts to determine the target inventory level. The distributor's target level is used to place orders to the fourth stage of the supply chain.

It turns out that in this system the variance of the orders placed by the kth stage of the supply chain, $Var(Q^k)$, relative to the variance of the customer demand, $Var(D)$ satisfies

$$\frac{Var(Q^k)}{Var(D)} \geq \prod_{i=1}^{k} \left[1 + \frac{2L_i}{p} + \frac{2L_i^2}{p^2}\right]$$

where, as before, L_i is the lead time between stages i and $i+1$.

Note that this expression for the variance of the orders placed by the kth stage of the supply chain is very similar to the expression for the variability of orders placed by the retailer in the centralized case, but now the variance increases multiplicatively at each stage of the supply chain. Again the variance of the orders becomes larger as we move up the supply chain so that the orders placed by the wholesaler are more variable than the orders placed by the retailer.

Managerial Insights on the Value of Centralized Information We have already seen that for either type of supply chain, centralized or decentralized, the variance of the order quantities becomes larger as we move up the supply chain so that the orders placed by the wholesaler are more variable than the orders placed by the retailer, and so on. The difference in the two types of supply chains is in terms of how much the variability grows as we move from stage to stage.

The results above indicate that the variance of the orders grows additively in the total lead time for the centralized supply chain, while the increase is multiplicative for the decentralized supply chain. In other words, a decentralized supply chain, in which only the retailer knows the customer demand, can lead to significantly higher variability than a centralized supply chain, in which customer demand information is available at each stage of the supply chain, particularly when lead times are large. We therefore conclude that *centralizing demand information can significantly reduce the bullwhip effect.*

This reduction is illustrated nicely in Figure 4-8, which shows the ratio between variability of orders placed by stage k, for $k = 3$ and $k = 5$, and variability of customers' demands for the centralized and decentralized systems when $L_i = 1$ for each i. It also shows the ratio between variability in orders placed by the retailer and variability in customers' demands ($k = 1$).

Thus, it is now clear that by sharing demand information with each stage of the supply chain, we can significantly reduce the bullwhip effect. Indeed, when demand information is centralized, each stage of the supply chain can use the actual customer

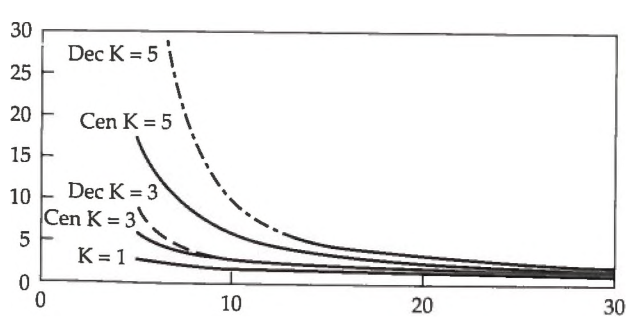


FIGURE 4-8 Increase in variability for centralized and decentralized systems.

demand data to estimate the average demand. On the other hand, when demand information is not shared, each stage must use the orders placed by the previous stage to estimate the average demand. As we have already seen, these orders are more variable than the actual customer demand data, and thus the forecasts created using these orders are more variable, leading to more variable orders.

Finally, it is important to point out that the bullwhip effect exists even when demand information is completely centralized and all stages of the supply chain use the same forecasting technique and inventory policy. In other words, if every stage of the supply chain follows a simple order-up-to policy and if each stage uses the same customer demand data and forecasting technique to predict the expected demand, then we will still see the bullwhip effect. However, the analysis indicates that if information is not centralized—that is, if each stage of the supply chain is not provided with customer demand information—then the increase in variability can be significantly larger. Thus, we conclude that *centralizing demand information can significantly reduce, but will not eliminate, the bullwhip effect.*

4.2.3 Methods for Coping with the Bullwhip Effect

Our ability to identify and quantify the causes of the bullwhip effect lead to a number of suggestions for reducing the bullwhip effect or for eliminating its impact. These include reducing uncertainty, reducing the variability of the customer demand process, reducing lead times, and engaging in strategic partnerships. These issues are discussed briefly below.

1. *Reducing uncertainty.* One of the most frequent suggestions for decreasing or eliminating the bullwhip effect is to reduce uncertainty throughout the supply chain by centralizing demand information, that is, by providing each stage of the supply chain with complete information on actual customer demand. The results presented in the previous subsection demonstrate that centralizing demand information can reduce the bullwhip effect.

   Note, however, that even if each stage uses the same demand data, each may still employ different forecasting methods and different buying practices, both of which may contribute to the bullwhip effect. In addition, the results presented in the previous subsection indicate that even when each stage uses the same demand data, the same forecasting method, and the same ordering policy, the bullwhip effect will continue to exist.
2. *Reducing variability.* The bullwhip effect can be diminished by reducing the variability inherent in the customer demand process. For example, if we can reduce the variability of the customer demand seen by the retailer, then even if the bullwhip effect occurs, the variability of the demand seen by the wholesaler will also be reduced.

   We can reduce the variability of customer demand through, for example, the use of an "everyday low pricing" (EDLP) strategy. When a retailer uses EDLP, it offers a product at a single consistent price, rather than offering a regular price with periodic price promotions. By eliminating price promotions, a retailer can eliminate many of the dramatic shifts in demand that occur along with these promotions. Therefore, everyday low pricing strategies can lead to much more stable—that is, less variable—customer demand patterns.
3. *Lead-time reduction.* The results presented in the previous subsections clearly indicate that lead times serve to magnify the increase in variability due to demand

forecasting. We have demonstrated the dramatic effect that increasing lead times can have on the variability at each stage of the supply chain. Therefore, lead-time reduction can significantly reduce the bullwhip effect throughout a supply chain.

Observe that lead times typically include two components: order lead times (i.e., the time it takes to produce and ship the item) and information lead times (i.e., the time it takes to process an order). This distinction is important since order lead times can be reduced through the use of cross-docking while information lead time can be reduced through the use of electronic data interchange (EDI).

4. *Strategic partnerships.* The bullwhip effect can be eliminated by engaging in any of a number of strategic partnerships. These strategic partnerships change the way information is shared and inventory is managed within a supply chain, possibly eliminating the impact of the bullwhip effect. For example, in vendor managed inventory (VMI, see Chapter 6), the manufacturer manages the inventory of its product at the retailer outlet, and therefore determines for itself how much inventory to keep on hand and how much to ship to the retailer in every period. Therefore, in VMI the manufacturer does not rely on the orders placed by a retailer, thus avoiding the bullwhip effect entirely.

   Other types of partnerships are also applied to reduce the bullwhip effect. The previous analysis indicates, for example, that centralizing demand information can dramatically reduce the variability seen by the upstream stages in a supply chain. Therefore, it is clear that these upstream stages would benefit from a strategic partnership that provides an incentive for the retailer to make customer demand data available to the rest of the supply chain. See Chapter 6 for a detailed discussion.

4.3 EFFECTIVE FORECASTS

Information leads to more effective forecasts. The more factors that predictions of future demand can take into account, the more accurate these predictions can be. See Chapter 3 for a more detailed discussion of forecasts.

For example, consider retailer forecasts. These are typically based on an analysis of previous sales at the retailer. However, future customer demand is clearly influenced by such issues as pricing, promotions, and the release of new products. Some of these issues are controlled by the retailer, but some are controlled by the distributor, wholesaler, manufacturer, or competitors. If this information is available to the retailer's forecasters, the forecasts obviously will be more accurate.

Similarly, distributor and manufacturer forecasts are influenced by factors under retailer control. For example, the retailer may design promotions or set pricing. Also, the retailer may introduce new products into the stores, altering demand patterns.

In addition, because a manufacturer or distributor has fewer products to consider than the retailer, he may have more information about these products. For example, sales may be closely tied to some event. If a retailer is aware of this, he can increase inventories or raise prices to take advantage of this fact.

For all of these reasons, many supply chains are moving toward cooperative forecasting systems. In these supply chains, sophisticated information systems enable an iterative forecasting process, in which all of the participants in the supply chain collaborate to arrive at an agreed-upon forecast. This implies that all components of the supply chain share and use the same forecasting tool, leading to a decrease in the bullwhip effect (see Chapter 11, Section 11.4.6).