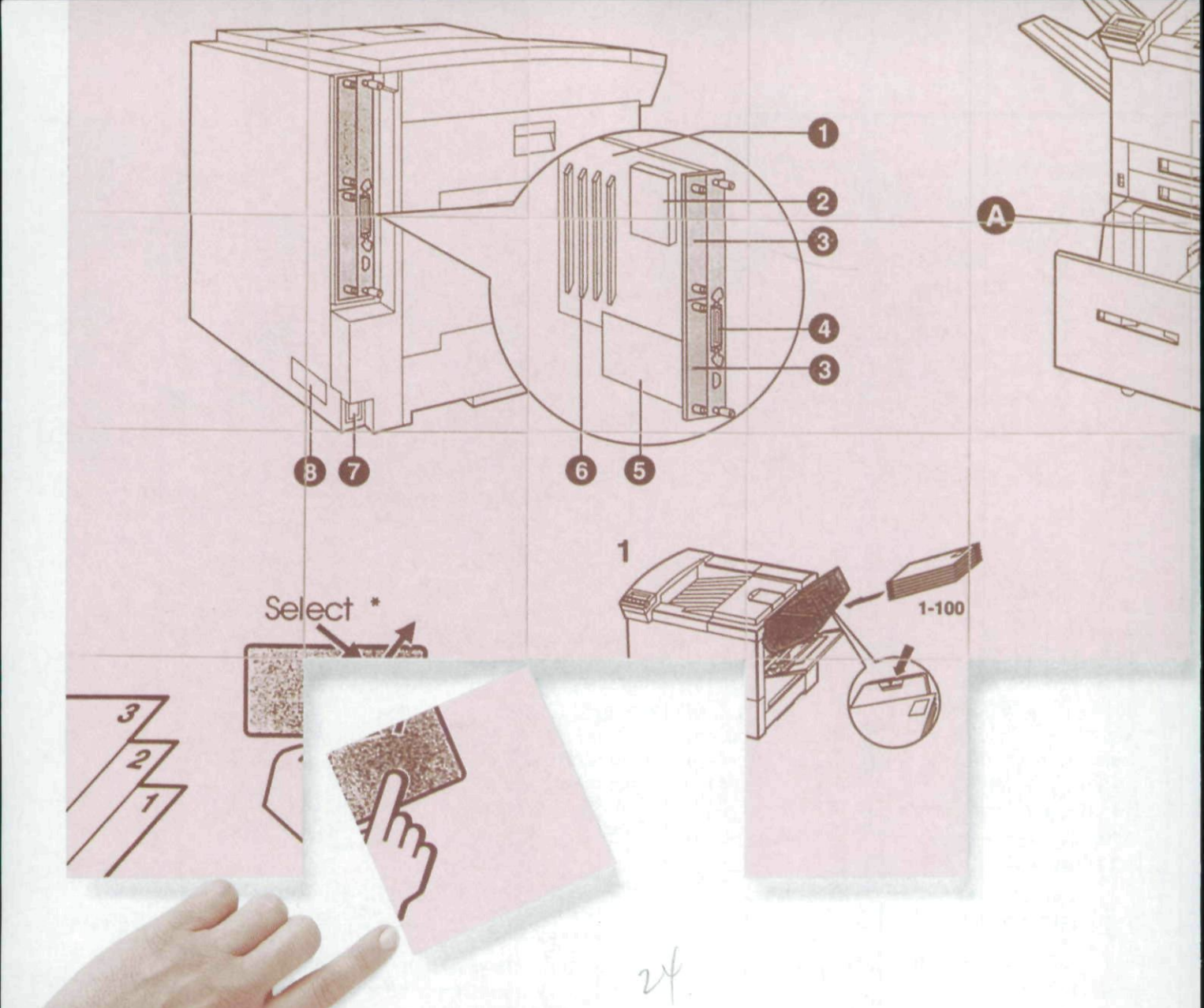



# Mass Customization at

by Edward Feitzinger and Hau L. Lee

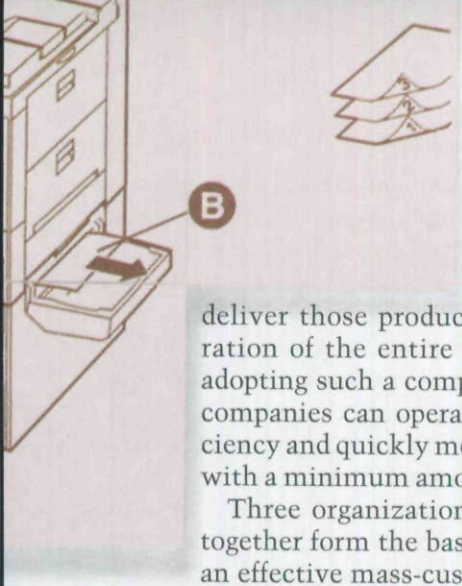
In many mass markets, companies are facing a predicament. On the one hand, customers are demanding that their orders be fulfilled ever more quickly. On the other hand, they are demanding highly customized products and services. Even without trying to customize their products, most companies have found it difficult to fulfill orders swiftly and at an acceptable cost. Is it possible, then, to mass-customize products, deliver them rapidly, and at the same time reduce costs?

The Hewlett-Packard Company has confronted these pressures in many of its businesses, including computers, printers, and medical products. It has proved that companies indeed can deliver customized products quickly and at a low cost. Some companies in such industries as apparel, paint, and consumer electronics have had similar success: they have dramatically increased their product variety, slashed the time they require to fulfill customers' orders, and reduced costs. Other companies have not: they have mass-customized only to see their costs soar out of control.

The key to mass-customizing effectively is postponing the task of differentiating a product for a specific customer until the latest possible point in the supply network (a company's supply, manufacturing, and distribution chain). Instead of taking a piecemeal approach, companies must rethink and



PHOTO BY TONY RINALDO




integrate the designs of their products, the processes used to make and deliver those products, and the configuration of the entire supply network. By adopting such a comprehensive approach, companies can operate at maximum efficiency and quickly meet customers' orders with a minimum amount of inventory.

Three organizational-design principles together form the basic building blocks of an effective mass-customization program:

□ A product should be designed so it consists of independent modules that can be assembled into different forms of the product easily and inexpensively.

□ Manufacturing processes should be designed so that they, too, consist of independent modules that can be moved or rearranged easily to support different distribution-network designs.

□ The supply network – the positioning of inventory and the location, number, and structure of manufacturing and distribution facilities – should be designed to provide two capabilities. First, it must be able to supply the basic product to the facilities performing the customization in a cost-effective manner. Second, it must have the flexibility and the responsiveness to take individual customers' orders and deliver the finished, customized goods quickly.

## Modular Product Design

A product with a modular design provides a supply network with the flexibility that it requires to customize a product quickly and inexpensively. Such a design separates the composition of end products into parts or subassemblies, some of which are common to all product options, others of which are not. A modular product design has three benefits. First, a company can maximize the number of standard components it uses in all forms of the product, assemble those components for all product options in the earlier stages of the assembly process, and postpone the addition of the components that differentiate the product until the later stages of the process. Second, a company can make the modules of the product separately; in fact, it can manufacture different modules at the same time, which significantly shortens the total time required for production. Third, a company can more easily diagnose production problems and isolate potential quality problems.

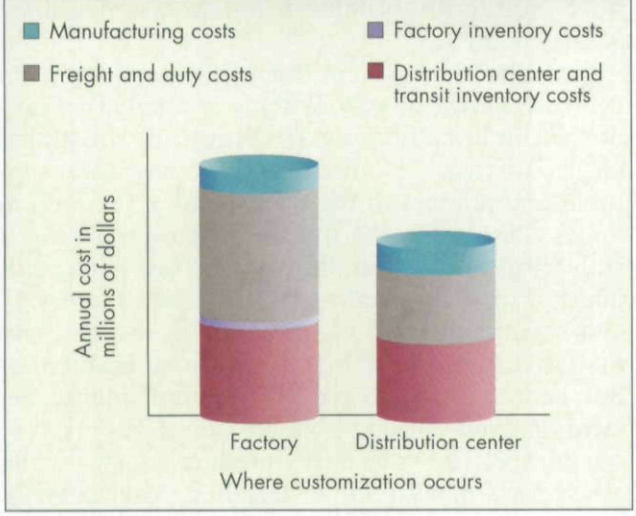
Consider a component that is not standardized: a dedicated power supply, or a power supply that cannot automatically convert voltage. In the global electronics market, building a dedicated power supply into a product in the first stages of production forces a manufacturer to commit to the product's country of destination. If a company has a long production process or delivery time from factory to end consumer, having this kind of power supply makes it difficult to mass-customize efficiently. But a company could standardize components, designing or purchasing a single power supply that would work across an entire product family or, ideally, across many product families. Alternatively, the company could postpone the assembly of the power supply until a later point in the production process. Either approach would result in greater flexibility and lower costs.

HP has successfully implemented a standardization strategy for the LaserJet printer that it sells in Europe and North America. A partner in Japan makes the printer's core engine, which then is shipped by sea to the two markets. Before HP and its partner designed the LaserJet for mass customization, the printer had a dedicated power supply of 110 volts and 220 volts, which forced the company to differentiate it by end-customer market as soon as production began in Japan. Under the improved design, a power supply that works in all countries is built into the product. This universal power supply allows HP to ship products from one continent to another when a significant imbalance of supply and demand exists between the two regions. As a result of standardizing the LaserJet, HP was able to reduce the total costs of manufacturing, stocking, and delivering the finished product to the customer by 5% per year.

# Hewlett-Packard: The Power of Postponement

*Edward Feitzinger is a process-technology manager at the Hewlett-Packard Company's strategic planning and modeling unit in Palo Alto, California. Hau L. Lee is a professor of industrial engineering and engineering management and the director of the Stanford Global Supply Chain Management Center at Stanford University in Palo Alto.*

## Customization Costs Drop with the Generic DeskJet Printer




HP decided to take a different approach to customizing its DeskJet printers for the European and Asian markets. The company opted to customize the printers at its local distribution centers rather than at its factories. For example, instead of customizing the DeskJets at its factory in Singapore before shipping them to Europe, HP has its European distribution center near Stuttgart, Germany, perform this job. The company therefore designed the printer with a country-specific external power supply that the customer plugs in when setting up the printer. The distribution center not only customizes the product but also purchases the materials that differentiate it (the power supplies, packaging, and manuals). As a result of this redesign, manufacturing costs are slightly higher than when the factories customized the printers, but the total manufacturing, shipping, and inventory costs dropped by 25%. (See the chart "Customization Costs Drop with the Generic DeskJet Printer.")

Because the use of standardized components to support mass customization may increase the cost of materials, companies must carefully assess whether the benefits of standardization outweigh the added costs. HP learned that the value of common components depends on the uncertainty in product demand across its geographical markets, the lead time to replenish its stocks of parts, the length of the product's life cycle, and the cost of shipping the finished product. As uncertainty, lead time, and inventory and stock-out costs increase, so do the benefits of standardization. HP found that forecasting the mix of options that customers want is most difficult at the beginning and end of a product's life cycle. Shorter life cycles, in particular, increase uncertainty and thus the benefits of standardization.

Making decisions like these is not easy. It involves people from at least five areas of a company: marketing, research and development, manufacturing, distribution, and finance. These five groups must play the following roles to support an effective mass-customization program:

☐ Marketing must determine the extent to which mass customization is needed to fulfill customers' requirements.

☐ Research and development must redesign the product so that it can be customized at the most efficient point in the supply network.

☐ Manufacturing and distribution must coordinate both the supply and the redesign of materials and situate manufacturing processes in the most efficient locations.

☐ Finance must provide activity-based cost information and financial analyses of the alternatives.

Each group at any company has its own measures of performance. At HP, marketing is evaluated on revenue growth, R&D on a product's functionality and the cost of its components, and manufacturing and distribution on the cost of assembling and delivering a product to the customer. The different measures focus the groups on different objectives: marketing wants to offer as many product options as possible to attract more customers, R&D wants to offer the product with the greatest possible functionality at the lowest possible cost, and manufacturing and distribution want to make one product at a stable volume.

If the groups are not properly coordinated, their attempts to optimize their own performance may hurt the company's ability to create the most efficient supply network that can deliver a customized product at the lowest cost. Therefore, negotiations among these groups are critical. At HP, the basis for negotiations is an analysis of the supply network that numerically represents all of the groups' perspectives and comes up with the best result for the company. In one instance, designers initially balked at creating a generic DeskJet printer for both Mac

**Clashing priorities make it hard to create the most efficient supply network.**

and DOS users, because doing so would add to the cost of materials needed to make the product. (The other option was continuing to produce two distinct ink-jet printers.) The division conducted an analysis that compared a generic printer's higher cost of materials with its lower inventory costs. It found that although the cost of materials would increase, required inventories would drop by 50%. (See the chart "Required Inventories Drop with the Generic DeskJet Printer.") In addition, the generic printer would enable computer resellers and retailers to stock one model instead of two. This last benefit had a significant impact: a major retailer elected to sell HP's generic DeskJet in large part because servicing both Mac and DOS customers with the same stock of printers would reduce inventory costs, shelf space, and associated overhead.

## Modular Process Design

Breaking down the production process into independent subprocesses provides companies with the kind of flexibility that effective mass customization requires. Such an approach is based on three principles: process postponement, process resequencing, and process standardization.

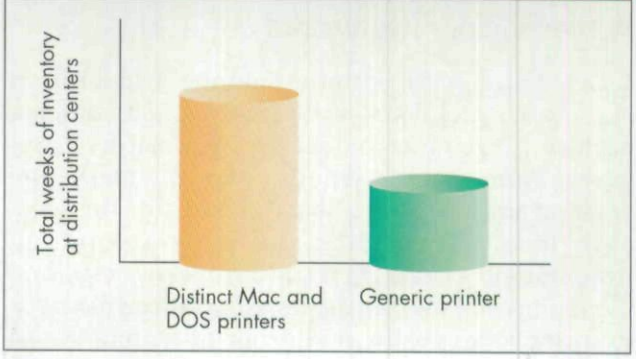
The way neighborhood hardware and paint stores match paint colors on their premises is a good example of process postponement. Instead of making a broad range of different paints to meet customers' specific requirements, factories make generic paint and a variety of color pigments, which hardware and paint stores stock. The stores use a chromatograph to analyze a customer's paint sample and to determine the paint-and-pigment mixture that will match it. This innovative process provides customers with a virtually unlimited number of consistent choices and, at the same time, significantly reduces the inventory of paint that stores need to stock in order to match every customer's desired color on demand. The key to postponement was separating the paint-production process into two subprocesses – the production of the paint and the mixing of the pigment and paint – and creating a low-cost chromatograph.

A modular process design also offers advantages in the retail apparel industry. Most department-store outlets sell finished clothing with little or no provision for customizing it to fit the customer's body and taste. Most cloth is dyed, cut, and sewn to predetermined dimensions, making low-cost mass customization difficult if not impossible. (Tailored clothing is usually quite expensive.) An emerging technology in the fashion industry, however, effectively splits the production process into two modular subprocesses: the body-measurement process and the cut-and-sew process. A device uses computer and optical technology to take a customer's measurements at the store, much as a tailor does. The computer then sends the measurements to the clothing vendor, which cuts and sews the garment within 48 hours. The result is a completely customized garment that costs about the same as an off-the-shelf item.

Although the retail outlet has to buy and maintain the measuring device, it can significantly improve sales per square foot with the purchase. The outlet needs to hold only samples of a specific garment instead of stock in all sizes and colors. And end-of-season discounts that retailers have to offer to clear out unsold goods become unnecessary. Given the fact that a clothing retailer typically obtains full price for only 50% to 60% of its clothing inventory, eliminating such discounts can lead to a substantial improvement in profits. In addition, the modular process design greatly reduces clothing manufacturers' inventory risks. Instead of stocking high-cost finished goods that may or may not sell, manufacturers can stock relatively low-cost raw fabrics that are turned into finished products only in response to actual orders.

Once a company has divided the overall operational process into modular subprocesses, it can consider resequencing the subprocesses. Benetton did just that in its sweater-manufacturing operations. Instead of first dyeing the yarn into different colors and then knitting it into finished garments, Benetton changed the order of the dyeing and knitting subprocesses. The company dyed the uncolored sweaters either when it received an order or when it had a better idea of consumers' color tastes for that season. By rearranging the subprocesses, Benetton effectively postponed the point of product differentiation and thereby saved millions of dollars in charges for obsolete inventory.

**Required Inventories Drop with the Generic DeskJet Printer**



Standardizing earlier portions of the production process and postponing differentiation help improve the flexibility of the supply network. Consider HP's disk-drive division, which supplied AT&T, NeXT, and HP with disk drives. It originally had trouble matching supply with demand because its customers often revised their orders at the last minute, and its processes for testing disk drives made it difficult to accommodate those revisions. Under the old approach, the division inserted a printed circuit board prior to the lengthy test process. Each customer, however, usually required a distinct circuit board. As a result, once a board was inserted, the disk drive could be sold only to that customer.

The division then found a way to conduct most of the test process without inserting the final customer-specific board. It separated the test process into two subprocesses: the standard tests required for all end products and the customized tests specific to individual end products. The division ran all its disk drives through the standardized test process, then stocked the generic units until an order arrived. When it received an order, it added the circuit board that the customer required, performed the customized tests, and shipped the product. By successfully postponing the point of product differentiation, this approach greatly enhanced the division's flexibility and substantially lowered its inventory costs. HP recently closed the division for other business reasons, but it still considers the division's use of postponement a best practice.

**Hewlett-Packard's distribution centers can deliver highly customized PCs more quickly and cheaply than competitors can.**

## Agile Supply Networks

Determining the optimum number and location of factories and distribution centers is a complex decision. It requires balancing such factors as response time to a customer's order, the marketing value of maintaining a local manufacturing presence, local-content rules, duties, transportation time and costs, local labor and occupancy costs, and the replication of fixed assets. Centralized distribution networks – using one depot or warehouse to serve multiple regions – typically offer the advantage of low costs. Decentralized networks, however, often allow a business to offer customers improved service. By rethinking the design of the supply network when redesigning products and processes for mass customization, a company can optimize costs and provide fast, effective service.

For example, a company with many product options benefits little from having many distribution centers around the world if those centers perform only the tasks of warehousing and distribution. The investments in inventory required to support all the options would be enormous. The economics change radically, however, if a company redesigns its products and processes into modules so that the final customization steps take place on receipt of a customer's order. It then becomes cost effective to have more distribution centers, each of which stocks basic products and performs the final steps in the customization process.

In addition, having distribution centers perform such light manufacturing can help a company both comply with the local-content rules that are prevalent in emerging markets and respond to customers who are unwilling to wait six weeks for a customized product to be shipped from a factory in another region. In this way, a company enjoys the best of both worlds: on the one hand, it can concentrate its manufacturing of critical parts in a few sites around the world so that it can achieve economies of scale; on the other hand, it can maintain a local manufacturing presence.

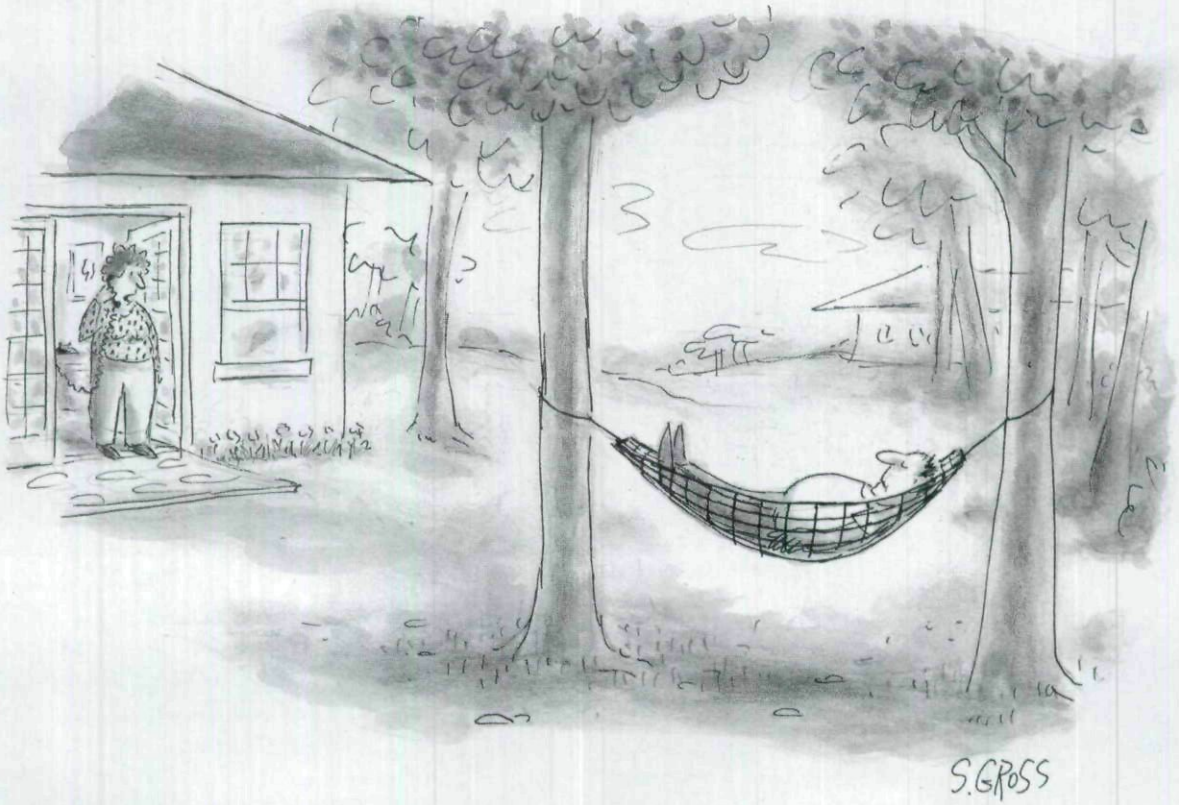
HP's success in personal computers demonstrates the power of integrating the designs of products, processes, and supply networks. Today's desktop personal computer is a highly customized product – some manufacturers offer thousands of different permutations to their customers. The PC consists of industry-standard, pretested components. Its product design is among the most modular in the electronics industry. Its production process also is extremely modular: a manufacturer has many different choices of how and where to build PCs.

Following the assembly and distribution models that prevailed in the PC industry in 1994, most manufacturers built product to stock. Problems associated with stocking the right mix of products to match customers' demands plagued the system; inventory write-offs and clearance sales to get rid of products at the end of their model lives occurred frequently.

In early 1994, HP conducted an analysis of its PC manufacturing and distribution strategies. Analysts discovered that the modular structure of the product and the production process would allow the company to postpone all steps of the PC's final assembly (integrating the PC board, processor, chassis, power supply, storage devices, and software). HP's distribution network then could build the product in locations close to customers only in response to their orders. In this way, the company would save on transportation and duty costs and greatly increase its return on assets. Abandoning its previous practice of stocking finished goods or partially completed units, HP implemented a build-to-order approach at all its distribution centers in early 1995. A Compaq executive lamented in the trade press that HP was "light-years ahead of the competition" in its ability to deliver products quickly and at a low cost. As a result of its new strategy, HP did in fact deliver a highly customized product more quickly and cheaply than its competitors could.

Many of the success stories we have described resulted from the collaborative efforts of manufacturing, engineering, distribution, and marketing organizations within and, in some cases, outside HP. These successes show that mass customization does not have to be a financially risky strategy. By carefully applying the set of design principles we have outlined, companies can mass-customize at a low cost. They no longer have to choose between satisfying their customers and increasing their profit margins. ▽

Reprint 97101 To order reprints, see the last page of this issue.




*"I'll go get him. He's on the net."*

CARTOON BY S. GROSS