strategy+business

Are You Modular or Integral? Be Sure Your Supply Chain Knows

by Charles H. Fine

from **strategy+business** issue 39, Summer 2005

reprint number 05205

booz&co.

Reprint

The hidden source of business model malaise: mismatched architectures.

Are You Modular or Integral?

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Illustration by Dan Page

Two of the most successful automobile companies of the 1990s were Daimler-Benz and Chrysler. Each entered the decade on somewhat shaky ground, each prospered enormously during the decade, and each mastered a very different business model. Unfortunately, when Daimler-Benz acquired Chrysler for $36 billion in 1998, their two business models proved incompatible. The new company, DaimlerChrysler AG, has suffered since then; its share price has dropped nearly in half, and annual profits, more than $7 billion just after the merger, are now around $562 million. There is a critical lesson to learn from the story of this merger: Had Daimler-Benz designed a strategy based on the differences between the two business models, it might be better equipped now to weather the current storms.

Chrysler's business model in the 1990s — as detailed in the book *Collaborative Advantage: Winning Through Extended Enterprise Supplier Networks*, by Jeffrey H. Dyer (Oxford University Press, 2000) — emphasized four elements: rapid, innovative vehicle design; a high degree of outsourcing with a large number of suppliers; high levels of trust among these suppliers, enabling mutual support for interoperability; and extreme focus on cost reduction through supplier innovation. To a significant degree, these elements worked together as a single system, constituting a "modular" approach, with independently developed subsystems manufactured by relatively autonomous suppliers to work well together.

In the Chrysler business model, braking, exhaust, and climate control systems, for example, were each managed autonomously by a supplier who might be

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responsible for developing such systems for multiple Chrysler models. Because they outsourced the development and manufacturing of these modules and gave their suppliers leeway to innovate in ways they saw fit, Chrysler's design teams gained the time they needed to focus on fashioning new vehicles and on updating older ones. Cost reduction among suppliers was encouraged with information sharing, long-term commitments, and contracts that gave these companies a significant portion of the savings. Buoyed by these partnership relationships, enthusiastic suppliers took on additional design and development work for components and subsystems, offering ever more creative cost-reduction efforts and even lower prices, leading to significant savings for Chrysler's manufacturing and engineering operations.

Chrysler management set aggressive cost targets throughout the organization, and the net result was a more efficient, tightly structured, earnings-driven company, especially compared with the Chrysler of the 1980s. Best of all, this strategy allowed the automaker to introduce many timely and innovative new products, particularly highly profitable pickup trucks and sport utility vehicles as well as head-turning "image" vehicles such as the Prowler and Viper. Sales and profits soared.

Mercedes, the primary automobile brand of Daimler-Benz, had entered the 1990s with a very different business model — one based on designing, engineering, and manufacturing its cars in a seamless, "integral" way. Suppliers' engineers were required to work cheek to cheek with Daimler-Benz's engineers to ensure the flawless integration of all vehicle subsystems. Achieving superior rides, performance, and durability required no less. Because of this focus on perfection and handcrafted care, Daimler-Benz had never moved fully from craft to mass production. The company made lovingly built, handcrafted Mercedes cars that were very expensive to produce and own. Labor content per vehicle was high compared with lean and even mass-production plants, and product cycle times were measured in decades. By the early 1990s, when each of the Japanese Big Three had debuted a premium nameplate (Toyota's Lexus, Honda's Acura, and Nissan's Infiniti), many buyers concluded they could get luxury at a lower cost. Mercedes had to change.

The automaker's response to the threat of Japanese luxury vehicles was to finally take lean production seriously. Daimler-Benz embraced the principles of just-in-time manufacturing and *kaizen* (continuous improvement) in its operations, emphasizing faster product development, shorter supply chain lead times, and continuous inventory reduction. In doing this, the Mercedes unit brought factory efficiencies much more in line with worldwide standards, but still retained close relationships among the engineering groups who designed and built each vehicle and its outsourced subsystems. The resulting process improvements enabled the company to leverage its brand-name new vehicles more quickly. These innovations enhanced the company's existing capability for producing flawless luxury automobiles. Like Chrysler, Mercedes saw its sales and profits soar.

In the wake of their separate successes, both Daimler-Benz and Chrysler had ambitions to spread their business models globally. But when Daimler acquired Chrysler in 1998, the two companies encountered a difficult and unexpected hurdle: Their business models were so distinct that they could not readily be combined. Chrysler had cut costs to the bone; Daimler-

Benz was willing to pay whatever was required to achieve its stated goal of unsurpassed luxury. Chrysler outsourced modules and some reliability engineering and systems engineering; the Mercedes engineers worked closely across functional boundaries, designing and building vehicles in which systems meshed seamlessly together to deliver their cars' widely renowned quality of ride and durability. Chrysler relied on relatively autonomous suppliers to perform significant development work; Mercedes meticulously controlled the work of its supply base, tightly clustered around its Stuttgart operations. Chrysler pared its internal technical and innovation capabilities to a minimal core, relying more and more on supplier capability; Mercedes maintained a broad and deep technical infrastructure in pursuit of innovations to load into its cars ahead of its rivals.

Incompatible Models

Chrysler's business model was not capable of building vehicles with the quality, reliability, and luxury typically associated with the Mercedes name. Nor was the Mercedes model able to develop new vehicles with the rapid development speeds and low costs typically linked with Chrysler. The result was organizational gridlock for several years as the gears of the two companies ground into each other, seeking a composite model that could successfully build on the capabilities of the very different partners. First Chrysler faltered, losing $5.8 billion in 2001. The division closed six plants and laid off more than 125,000 employees, but the losses returned in 2003. Then J.D. Power published a survey claiming a rise in quality problems in Mercedes cars. Meanwhile, the most prominent Chrysler-Mercedes joint project, the Crossfire Roadster, was rapidly branded (by *Business Week*, for example) as a one-of-a-kind anomaly. The Daimler truck business, which had been redesigned under DaimlerChrysler to benefit from cross-merger synergies, lost $960 million in two years. The proposed acquisition of the Mitsubishi Motors Corporation, intended to build further supply chain synergy, was rejected by the new company's board in a move seen as a reaction to the failure of Daimler and Chrysler to integrate. By 2005, the Chrysler brand had regained some of its market share and profitability, but Mercedes was posting regular losses.

Lost in the din of press coverage about the DaimlerChrysler debacle is its most instructive point: In a business environment where there is little margin for error in the areas of cost, quality, and customer service, a key predictor of success is the fit between product and supply chain architectures. Alone, Chrysler was a hit because it used a modular vehicle development process with a modular supply chain. Mercedes succeeded with highly integral vehicles backed by a highly integral supply chain. But together, they foundered, because modular and integral architectures are like oil and water. They don't mix.

In this context, the word *architecture* means the arrangement of components and the ways they interrelate. Modular architectures are flexible in structure, with highly standardized interoperability and standard connections for subsystems. A good example of a modular product is a speaker in a stereo sound system. Speakers are differentiated on the basis of their sound quality, which varies widely from one model to another, but they all sport identical connections for attaching to receivers and amplifiers. A modular product system can typically be upgraded by replacement of lesser components with better ones. Many modular systems are also open, meaning that the interfaces between components are not protected by intellectual property that is closely held by the patent holder. Any innovator can create a module for the product as long as it retains the standard interface.

Modular supply chains consist of relatively flexible and interchangeable relationships among suppliers, customers, and partners. In the auto industry, because each supplier in a modular chain develops and retains a great deal of knowledge concerning how to integrate its subsystem with others on the vehicle, this type of integration can take place rapidly for a number of vehicles at once.

By contrast, integral architectures typically link subsystems with tightly coordinated relationships and distinctive or unique features that cannot be easily connected to other systems. Products with integral architecture tend to have complex and nonstandard interfaces, and the subsystems are built (or at least customized) explicitly for a particular product. The distinctive identity of the Apple iPod music player is based on its integral architecture. To be sure, it uses standard interfaces (such as the sound output for headphones or speakers), but the sound source is built into the unit and its internal components and software are relatively nonstandard.

An integral supply chain architecture is characterized by strong cross-company links and a relatively high barrier to entry for newcomers. Members of the chain are close to one another in geography, organization, culture, and/or electronic connectivity. For example, a manufacturer and its principal suppliers are likely to be concentrated in one city or region, have common or interlocking ownership, share a business and social culture, or maintain tight electronic communications links. If a supplier for an integral manufacturer like Mercedes or BMW goes bankrupt, the manufacturing process is seriously impaired until a new supplier can be found and its engineers can build working relationships with their counterparts in the manufacturing company and other key suppliers.

One interesting difference between modular and integral architectures is the way that product features relate to components. Instead of having a clean one-to-one correspondence between a component and its function (as typically occurs in a modular architecture product), integral products tend to have components so interwoven that each may perform more than one function. For example, an automobile sound system is typically modular. The system has one clear, identifiable function: to project sound from the radio and any other audiovisual component. There is typically very little interaction between the sound system designer and the auto body designer for any particular car, and it's straightforward to enable most sound systems to work well in many automobile models. (Very high-end cars for which designers engage in sophisticated acoustics engineering are a notable exception.) You can order automobile sound systems on the Internet if you are willing to install them yourself.

In contrast, consider the integral architecture of a jet. The wing of a jet airplane serves several functions. It provides airlift through its shape, holds jet fuel, helps to control the momentum of takeoff and landing (through its moving wing flaps), and carries the engines. Aircraft fuselage designers work very closely with the designers of the wings. You would not want to ride in an airplane whose wing was ordered on the Web!

Aligning Architectures

At first glance, especially when decisions about their design are made, the supply chain and product architectures seem unrelated. But in practice, the architecture of the supply chain and the architecture of the product have a powerful impact on each other. For example, modular product designs make modular supply chains much easier to implement. The members of the chain can be highly dispersed geographically, organizationally, and culturally, because the interfaces among the subsystems they supply are either standardized or relatively easy to design from a distance. The modular nature of the subsystems also makes it easier for manufacturers to audit them for quality control, which would otherwise be a challenge in a modular supply chain.

To illustrate the importance of aligning product and supply chain architecture, consider three companies renowned for their mastery of supplier relationships: Toyota, Dell, and Nokia. These three companies benefit from a well-matched fit between supply chain and product architectures. Toyota cars, known for their reliability and flawless performance, have an integral supply chain and product design. Dell's renowned modular designs match its standardized multiple-vendor supply chain. Nokia employs a deliberately designed hybrid approach, with a modular semiconductor and software core, highly integrated components for the rest, and a complementary supply chain design.

Toyota products epitomize integral architecture. The company's product development philosophy stresses the importance of cross-functional coordination for the development of most vehicle subsystems. Through close attention to the interplay among automotive subsystems, Toyota has achieved highly responsive acceleration and braking; well-designed climate control, acoustics, and other driver comfort features; efficient use of space; and pleasing interiors.

The architecture of Toyota's supply chain parallels its product architecture. Toyota has historically maintained extremely friendly ties with its suppliers, in some cases taking a financial stake in them. As part of this relationship, many of Toyota's key suppliers are situated near the automaker's engineering and development operations in Toyota City, midway between Tokyo and Osaka. And with this geographic, social, and cultural proximity among Toyota and its suppliers, there is continuous bidirectional feedback on vehicle and subsystem design. One important example of this cozy partnership: Toyota engineers spend a great deal of time working at supplier sites to ensure that subsystems and components deliver the high level of integrality that the Japanese automaker demands for its vehicles.

Toyota's product and supply chain architectures are complementary and mutually reinforcing. The integral product architecture requires a tightly bound, integral supply chain, which, in turn, represents a significant factor in the ongoing development and production of Toyota's vehicles.

Dell Inc., the No. 1 personal computer maker, sits at the other end of the architecture spectrum. A Dell PC

Dell's supply chain, like its PCs, is made up of a series of interchangeable parts.

is an extremely modular product, assembled primarily from off-the-shelf components connected by standard interfaces. Dell built its name as the maker of customer-designed machines, because its modular system architecture can accept a wide range of combinations of monitors, memory chips, hard drives, processors, CD/DVD players, input devices, and numerous other options. But Dell will rarely, if ever, venture into technology development in a way that would require simultaneous, interrelated innovation in multiple subsystems.

Dell's supply chain, like its PCs, is made up of a series of interchangeable parts. Because Dell's products are modular, its suppliers are not typically indispensable — except for Intel and Microsoft, which provide the two integrally designed components, the microprocessor and the operating system. Numerous companies supply each of the other components for Dell's PCs, and Dell (like other PC makers) frequently pressures suppliers to improve cost, quality, and technology with the implicit threat of replacing any company that falls behind the curve. Dell's suppliers can be located thousands of miles apart because the design and development of components requires little direct coordination or interaction.

The alignment of Dell's production and supply chain architectures is critical to the company's ability to build products to order and, simultaneously, use pricing decisions (at a component level) to manage supply and demand balances in the supply chain.

A more complex example of the value of architectural alignment can be seen in Nokia's Mobile Phones group. The product architecture of a mobile phone is somewhat integral. Partly because of size and power constraints, a mobile phone is designed as a very tightly integrated package of electronic and radio frequency components. Customers cannot mix and match features like memory, display size, processors, and keypads as they may with a personal computer. Nokia has thus maintained close, long-term relationships with key suppliers, exhibiting a high degree of mutual interdependence for such components as memory chipsets, LCDs, and antennas.

The company has also, however, designed modularity into two key aspects of its phone products: software and engines. Nokia's software, including the operating system that provides its popular user interface, can be ported across many of the company's hardware platforms, allowing reuse and continuous upgrading of the software "module." Within the mobile phone value chain, Nokia has spun out significant aspects of its operating system development into a freestanding industry consortium called Symbian, thus developing a more modular supply chain structure to go with the modular technical relationship. In June 1998, Nokia was instrumental in establishing Symbian as a private independent company, co-owned by Ericsson, Motorola, and Psion. As a result, the supply chain architecture for the Nokia operating system has been made much more modular; some Nokia phones use operating systems from Symbian, but others use a proprietary operating system developed and used solely by Nokia.

The mobile phone's engine, or hardware "core" — the integrated electronics subsystem, produced primarily on automated circuit board assembly lines — is similarly modular for strategic reasons. Nokia's engine platforms can be used across its product lines, allowing the development of new products without the need to design engines from scratch. Moreover, engine assembly can be separated in location and time from final product assem-

There are three lines of business at Cisco: consumer (modular), enterprise (hybrid), and telephone company (integral).

bly because the architectural relationship between the engine and the rest of the phone can be made reasonably modular. The combination of modular product and modular supply chain in the same subsystems allows Nokia the option to outsource engine assembly to contract electronic manufacturers. That lets Nokia focus the bulk of its cell phone innovation efforts on integrating fashion and function — key elements of customer satisfaction.

Costs of Mismatch

Companies with mismatched architectures, like DaimlerChrysler, nearly always find themselves on the wrong side of cost structures, pricing, customer demand, and quality. They typically try to reduce costs by outsourcing elements of their value chain, and then find themselves facing unexpected coordination costs, extended development times, and even project failure brought on by the unanticipated complexities of misaligned architectures.

That's what seems to have happened at Chrysler after the Daimler-Benz acquisition. One strength of Chrysler's modular system was the ability to rapidly turn out new models. Executives coming to Chrysler from the Mercedes unit, accustomed to much longer car launch cycle times, must have found it quite disconcerting to find "the pipeline was empty." Why were there so few models under development at Chrysler? They set out to "fix" the problem by introducing Mercedes engineering methods. They spent two years trying to adapt Chrysler's modular processes to an integral model, without rethinking the combined architectures of product and supply chain. They gradually discovered that Chrysler's suppliers were unfamiliar with the kind of partnership role that Mercedes's suppliers were well versed in; thus, the new engineering processes could not yield vehicles that would meet Chrysler's historical customer and price targets. Moreover, during this time, new car development at Chrysler stagnated — with a far more severe effect on Chrysler (which was accustomed to a three- or four-year car development cycle) than it would have had on Mercedes.

After a great deal of effort and substantial financial losses, the Chrysler business model has found a new, very productive equilibrium, but seemingly at a cost to the Mercedes unit and its ability to maintain its traditional integrated model. The resulting quality problems at Mercedes, which, as noted earlier, were quantified by J.D. Power and widely reported in the press, have yet to yield a solution in the merged DaimlerChrysler organization.

Something similar happened at Polaroid in the 1980s. Developed by an independent inventor named Edwin Land more than 50 years ago, Polaroid's instant photography process was markedly different from conventional photography. It employed a highly integral product architecture and supply chain. No parts, not even the lenses, could be adapted from other cameras, and all the supply facilities were located in the Boston area near Mr. Land's headquarters; many of them were owned by Polaroid and run by a tightly knit team of managers and technical experts.

Then, during the 1980s, Polaroid outsourced its camera assembly facilities — first to Scotland, then to China. But because the product design remained integral, the interfaces among parts remained distinctive and complex. Polaroid engineers shuttled constantly between the U.S., Scotland, and China. This slowed down their ability to launch new products, perhaps distracting their attention from the upcoming challenges posed by digital photography. The Polaroid Corporation filed for bankruptcy in 2001 and was acquired in 2002.

Because most commercial fields contain success stories of companies with both modular and integral architectures, decision makers in companies with well-aligned architectures are often tempted to change them. Both Lucent and Nortel, telecommunications equipment manufacturers, fell prey to this temptation in the 1990s, and both for the same reason: competition from Cisco Systems Inc. in their analog and digital switch businesses. For some products, Cisco's prices were lower than the manufacturing costs of the equivalent Lucent or Nortel product. Perceiving that Cisco achieved these low costs through a modular architecture, Lucent and Nortel decided to outsource much of their supply, selling off internal factories and facilities that made components for their switches. Because they did not concurrently modularize the product architecture, however, the design task (and the costs) remained with Lucent and Nortel. They could not quickly realize the savings they had hoped for. This increased the difficulty that both companies faced in recovering from the collapse of the telecom market in 2000.

Cisco itself, by most accounts, had an easier time after the bust. One reason may well have been the company's deliberate strategy for aligning supply chain and product architectures. In effect, there are three lines of business at Cisco. Consumer home products (under the Linksys brand) are designed and outsourced in modular fashion, like Dell computers. "We don't even touch the boxes," one Cisco executive told me. Enterprise routers, which account for 65 percent of the company's sales, are like Nokia telephones: integral in many respects, with some modular components. And then there is the equipment manufactured for telephone companies, "like hand-built Ferraris," said the executive, "with in-house custom design and lots of Cisco touch."

Aligned Design

How then can a company design its product and supply architectures to make sure that they are aligned? An apt answer can be found in a concept I call "three-dimensional concurrent engineering," in which engineering, operations, and procurement participate together simultaneously in product development, process development, and supply chain development. The goal is to ensure that the components can be procured and the product manufactured in a timely fashion; to reduce the number of design changes and product redesigns; and to avoid quality problems by involving cross-functional teams at the beginning of the project.

When key systems are outsourced — in either a modular or an integral fashion — it is critical to bring supply chain experts together at the initial stages of product development. This three-dimensional concurrent engineering, involving manufacturing engineers, design engineers, and engineers from suppliers and key partners, ensures that the product design will dovetail with the constraints and needs of the total supply chain.

Alignment allows companies to be resilient while maintaining a coherent business model. As the product architecture evolves during the design process, the supply chain architecture evolves along with it. For product subsystems with complex interfaces and interactions, close supplier relations must be designed into the supply chain. For supplied components that are standard with well-defined interfaces, modular relationships can be fashioned at arm's length. The success of Toyota, Dell, Nokia, and Cisco can be attributed to a well-executed alignment strategy. The difficulties of DaimlerChrysler, Polaroid, Nortel, and Lucent illustrate how challenging it can be to cope with separate product and supply chain architectures that are shoehorned together after each of them has evolved in a distinctly different way. +

Reprint No. 05205

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