"The Spirit in the Walls:" A Pattern for High Performance at Scania

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Scania, the Swedish maker of heavy-duty trucks, buses and diesel engines, has parlayed a modular product design strategy into a robust formula for low costs and sustained profitability. But modularization has contributed to Scania's high performance for more reasons than just effective design, component standardization, and parts commonality. It also has created a customer-focused mode of thinking among the company's managers that is referred to as "the spirit in the walls." This spirit supports a unique web of relationships with patterns that transmit profit-enhancing behavior among Scania people.

Scania people achieve superior financial performance records by focusing their attention on mastering and executing patterns resembling those found in nature, chiefly the pattern that seems implicit in the process of evolution itself. Their approach to modularization enables them to build increasingly complex varieties of customer-pleasing products and services upon a foundation of exceedingly parsimonious means. More than anything else, their ability to execute results that are "rich in ends, but simple in means" accounts for Scania's remarkable success.

This brief case highlights the pervasive influence of Scania's modular design strategy by starting at the most basic level with a discussion of part-number commonality. The discussion then advances through three successively higher levels of generalization: The first level considers certain interactions between product and process design; the second examines the change in thinking that modularization has generated at Scania; the third level focuses on "the spirit in the walls" that modular thinking creates.

Finally, a concluding section explores resemblances between modularization at Scania and patterns of modularization found in nature.

Part-Number Counts and Low Cost: It's More Than Meets the Eye

Everyone believes that a manufacturer will improve costs and profitability by reducing the number of different parts in its products. And for good reason. With fewer different parts, less effort and resources are required to design, make, and service a product line. Accordingly, activity-based cost management systems routinely use part-number count as a cost driver to estimate how much

Scania at a Glance

With headquarters located in Södertälje, Sweden, about 50 kilometers south of Stockholm, Scania is a world-wide manufacturer and marketer of heavy trucks (16 GVW tons and above), buses for over 40 passengers, and industrial/marine diesel engines. Following a common pattern among European truck builders, Scania is a highly integrated producer, making all critical components that go into its trucks. The company employs around 20,000 people worldwide, with production facilities in five countries — Sweden, the Netherlands, France, Brazil, and Argentina — and assembly plants in more than a dozen additional countries. Scania trucks, buses, and engines are sold in over 100 countries on all continents. Over 95 percent of Scania's output is sold outside Sweden, with about 60 percent going elsewhere in Europe. However, Scania's largest single national market in all its products is Brazil. Alone among truck makers in the world, Scania has been profitable every year for more than 30 years, despite the very cyclical nature of its markets. As of early 1995 Scania's worldwide sales of trucks and buses are at record levels, more than 45,000 units per year. In 1994 the company registered operating income of about SEK 4 billion on revenue of about SEK 22 billion. (7.5 SEK=$1 U.S.)

Figure 1. *Cab transport from Oskarshamn to Scania's chassis-assembly in Angers, France.*

financial performance will improve by reducing the number of different parts.

However, it is not well understood that cost-driver information may capture only a small fraction of the financial improvement that part-number austerity makes possible. This is because such information assumes a linear and essentially static relationship between costs and part-number count. It focuses attention on what work to do — reduce the number of different part numbers — but it implicitly assumes that continuing to pursue business as usual is *how* work is to be done. In other words, activity-based cost-driver information tells managers to reduce costs by eliminating a cost driver (such as part numbers); it does not necessarily provoke inquiry into how a company's *modus operandi* causes part-number count to affect profitability. Managers who are driven by these cost-based targets to economize on part numbers, but who still conduct business as usual, never will know if a different approach to doing business might reduce part numbers and yield even deeper and longer-lasting financial improvement.

Scania offers a fascinating glimpse into the extraordinary gains a company can capture by asking new questions rather than by driving business as usual with cost targets. Like Toyota among auto makers, Scania stands alone among heavy-truck makers for low costs, for high quality, and for an unbroken record of annual profits that stretches back at least 30 years. Also like Toyota, Scania achieves low costs without using cost targets to drive people's work. Scania is an excellently-managed company with a unique approach to business that has enabled them to achieve low costs and robust profitability while manufacturing custom-made trucks and buses that are unrivaled for quality and performance.

Every truck Scania sells is designed and built to customer order. Nevertheless, they use about half as many different part numbers to produce the same number of trucks as does their nearest competitor, Volvo. Not surprisingly, Scania's profitability exceeds that of Volvo. But other manufacturers should not assume, therefore, that they can match, or even come close to Scania's performance simply by using cost-based targets to drive design engineers to reduce part-number counts. Indeed, low costs and robust profitability do not come to Scania by driving employees and suppliers to achieve cost targets. They come from disciplined attention to mastering design details and from company-wide commitment to goals that transcend local self-interest. In short, Scania excels by focusing on how it does business, not by focusing on eliminating cost drivers, such as part numbers, in order to cut costs.

Modular Product Design: "Rich in Ends, But Simple in Means."[1]

Leif Östling faced a daunting challenge in 1989 when he took over the reins as the youngest general manager (CEO) in Scania's century-long history. For decades Scania had enjoyed a reputation as one of Europe's premier manufacturers of heavy trucks and buses. Moreover, they had turned a profit during every one of the past 30 or so years, a record unmatched anywhere in the world in their highly cyclical industry. The challenge Östling faced was to perpetuate Scania's fine reputation for quality and to continue the company's unbroken profit streak while leading the way to changes that will keep Scania competitive in the global economy of the 1990s, and beyond.

To address this challenge, Östling identified key forces responsible for Scania's past success. His own career with the company, stretching back almost 20 years, certainly made him familiar with the company's current policies and practices. But he felt more should be done to articulate definitively the origins and evolution of those forces that seemed to set Scania apart from the pack. Therefore, he asked two consultants (SAM Samarbetande Konsulter AB, a Swedish consulting firm, and H. Thomas Johnson, an American business author and professor) to conduct interviews with retired and current Scania executives. From those interviews and other research, this consulting team identified several factors responsible for Scania's success (see box on p. 11). Among those factors, however, the one that all parties considered most important was the company's long-

standing modular design strategy.

Modular product design has recently taken hold in many industries, including home building, small tool making, clothing manufacture, and even auto manufacturing. Scania's design engineers began to explore the concept as far back as 1970 and had a full-blown modularization program for trucks in place by 1980. The objectives of this modularization program were to provide custom-built solutions to different transport problems, to fabricate standardized components at mass-production costs, and to make it easier to modify truck designs as new conditions arose. In other words, Scania adopted a modular design strategy in order to provide each customer with a high quality, cost effective, tailor-made truck and *simultaneously* provide itself, Scania, with high long-term profit.

Modular product design addresses a persistent concern in industry; namely, reducing the cost of producing ever greater varieties of a product.[2] The principle behind modularity is to divide a product into independent components, thereby making possible the standardization and interchangeability of these components across a wide range of final product varieties. In principle, modularity permits designers to create a diverse array of final products by varying only those features that affect the end result and holding all other features unchanged. In other words, a modular design precludes having to reinvent the entire wheel every time there is a call for something different.

In designing truck cabs, for example, different dimensions and weights are needed to accommodate various end uses and engine sizes. But it is possible to meet those differences and not vary the driver's station or the windshield, both of which are identical in all Scania cabs. Thus, numerous variations in cab size and weight can be achieved by substituting among some, but not all, the components used to assemble cabs. In that way the number of finished cab varieties can greatly exceed the number of different components used to assemble the cabs — a pattern that might be described as "rich in ends, but simple in means." *In all, Scania makes over 300 standard variants of heavy truck (from 16 to over 35 GVW tons) using no more than 6000 to 7000 parts (from a system total of about 12,000 parts) in over 90 percent of all trucks sold — one-third to one-half as many components and parts as other European truck makers.*

In principle, modular design enables manufacturers to sell diverse varieties of end products, yet produce them at the low costs one associates with mass-produced lines of homogenous products. In practice, it enables low costs usually because component standardization and interchangeability permit reduced numbers of components to be fabricated in large batches and long production runs. Modules built from low-cost standard components can then be assembled-to-order at low cost in many varieties of end product.[3] In fact, that is how Scania explained for many years how it could build customized trucks at competitive costs, even though it does not lead its industry in final product volume.

More recently, however, Leif Östling has begun to argue the merits of make-to-order component fabrication over scale economies of large-batch component fabrication. He also has urged his colleagues to identify other, potentially much larger, sources of benefits from a modular strategy, beyond those already ascribed to component standardization. Consequently, Scania now is embarked on a systematic study of these broader benefits. But before examining those other benefits, consider how modular design practices at Scania have entailed much more than just reducing the number of different parts that go into products.

Managing* Pattern *(How Work is Done), Not* Results *(What Work to Do)

Scania's modular design strategy is not a case of reducing component variety while continuing to pursue business as usual. They achieved a significant reduction

Key Factors Contributing to Scania's Success

When asked to explain their company's remarkable success, current and retired Scania executives of the past 30 years recently listed the following practices:

- expansion into new export markets slowly and deliberately, but continuously
- product range limited to medium and heavy trucks
- trucks assembled from carefully engineered modules built from a parsimonious set of standardized components
- strong in-house design and development capabilities, without ignoring advances made by competitors
- rational production methods to build key components in-house
- saying no to making things that other companies do better
- development of close relationships with suppliers and vendors
- simplification of products and processes; reduction of tasks not associated with the core business; encouragement of close cooperation between marketing and technical people
- knowing the value delivered to customers, holding the line on price and doing everything possible to sustain high residual value for trucks
- top managers must be engineers who grow up with the company, who know the processes and put profit before volume
- every manager must know what it takes to design, produce, and sell the best trucks money can buy.

Figure 2. *Scania's technical management on a test-track with competitors' products.*

...product design and development costs fall more or less in direct proportion to the reduction of part numbers.

in part-number counts by changing their *modus operandi* in the product design area. Indeed, Scania's design engineers worked on their approach to product design for over 15 years before they achieved full-scale modularization and component standardization by 1980. They tested every critical part of a truck under every conceivable driving condition that Scania customers might experience, using static and dynamic tests with resistance-wire strain gauges and modern electronic equipment to simulate driving conditions. The results of these tests provided the mix of components in the modular matrix that now supports Scania's ability to sell and make customized trucks at very low cost.[4]

It is inconceivable that top-down cost-focused pressure to reduce part proliferation could have generated the disciplined and persistent campaign of experimentation and testing that Scania's design engineers carried out in the name of component standardization over the past few decades. That campaign is an indication that the difference in Scania's overall financial performance comes from people attending to patterns in *how* things are done. They do much more than focus, in the name of results-oriented targets, on *what* is done.

Scania abandoned business as usual and adopted a new way of doing business first in the product design area, not the production area as so many other manufacturers — most notably Toyota — have done in the past 20 to 30 years. Starting in the product design area does have advantageous spill-over effects. Indeed, savings from the reduction of part numbers due to modularization and component standardization occur not only in the product design area, but also cascade downstream into other areas such as production and distribution. According to Leif Östling's estimates, product design and development costs fall more or less in direct proportion to the reduction of part numbers. And production costs per unit of a component also fall about ten percent when standardization permits the quantity of a component in production to double. Finally, distribution costs, caused by parts ordering and storage, fall about 30 percent when the number of part numbers is cut in half.

Östling indicates the financial impact of Scania's modularization and component standardization program by comparing the European operations of Scania and Volvo during the 1980s. In Europe the two companies produced and sold approximately the same number of trucks in those years, but Volvo's trucks required about twice as many part numbers.[5] Hence, product development costs at Volvo, averaging about 1.3 billion SEK per year, were nearly double the .7 billion SEK that Scania on average spent on product development each year. In addition, Östling estimates that Scania's more parsimonious parts selection generated average annual savings in production and in distribution amounting to about .4 billion SEK. In total, then, Scania in that period enjoyed around 1 billion SEK more operating income per year than Volvo on account of its attention to modularization and component standardization.

Undoubtedly any company can capture these financial gains by using cost-driver targets to manipulate *what* people do, even if *how* they do business stays unchanged. Simply reducing part-number proliferation, for example, will cut costs across several areas, including product development, production, and distribution. However, *if traditional methods of product design continue to be used, reduced part-number variety will most likely lead to reduced varieties of end products.* In a sense, that results in "lean ends from simple means," not the "rich ends from simple means" that Scania achieved as a result of its disciplined approach to modular product design. By changing how the company did design work, Scania's modular design strategy not only reduced part-number variety. It also, at no extra cost, *increased* the variety of end products the company could deliver to customers. That increased end-product variety was, of course, the main objective of Scania's modular design strategy. No one can say for sure how much this added product variety improved Scania's financial performance, but it undoubtedly generated substantial extra revenue, quite apart from the costs saved by part-number reduction.

Component Sourcing

Scania makes about half the components and parts (in value) going into its trucks — especially those that critically affect the performance of the truck — and purchases the other half from outside suppliers. Making critical components in-house eliminates the need to coordinate outside suppliers, thus reducing cost and improving quality. For example, an in-house effort to improve fuel efficiency by increasing engine torque affected the design of the gear box and rear axle. In-house design and production of the entire powertrain and rear end permitted quick and efficient handling of these interactions, resulting in a distinct competitive advantage.

Scania does not, however, make something when an outsider clearly does it better, as with brake systems from Bendix, radios and mobile telecommunication systems made by Ericsson, electrical components made by Philips, or injection pumps made by Bosch. Moreover, they purchase commodity parts such as microchips, wire harnesses, screws, bolts, and so forth "off the shelf" as much as possible, to eliminate the costs of custom specifications. For example, interior cab lights and fasteners are standard off the shelf items in a Scania truck. Other truck makers' cabs, by contrast, often contain uniquely designed light bulbs and customized fasteners. Custom specifications for such items cost the OEM more to order and cost the customer more to replace.

Building a Web of Relationships: "The Spirit in the Walls"

Östling and his executive team at Scania have set out to identify and strengthen additional sources of strength in their modular strategy, beyond component standardization itself. In particular, they are discovering that modular thinking has helped Scania generate a web of relationships among people that reinforces and transmits profit-enhancing patterns of behavior throughout all parts of the company. A goal of the company now is to build and strengthen those relationships.

Remarkably, the Scania organization resembles less a collection of separable parts that coexist for the purpose of generating profit than it resembles an interrelated web of relationships that energizes people's ability to serve people. The modular design strategy contributes to this web by engendering in Scania people a customer-focused spirit — referred to in Scania as "the spirit in the walls" — that subordinates local, functional priorities to systemic goals. It is this spirit that connects Scania's managers, employees, customers, and suppliers in a web of relationships that seems to generate profit naturally. The concept of modularization undergirds that web with a pattern that emphasizes people serving people. Managers, employees, and suppliers build each other's competencies to serve customers and the community. With everyone in Scania focused on mastering and executing the pattern, the result — profit — appears to take care of itself.

Two recent examples, one from a supplier and one from a customer, show how this people-focused pattern affects long-run performance. First, an English parts supplier that has worked with Scania for over 40 years recently explained why Scania was able to secure parts and materials with relative ease even while sharply increasing its annual output rate this past year (from about 30,000 units to more than 45,000 units). They attribute this absence of supply bottlenecks largely to Scania's efforts to build its suppliers to "best in the class" status. Over the years, this particular supplier had come to regard Scania as their best customer — "the most trustworthy, the best paying, and the most innovative source of new ideas." Consequently, they gave Scania's orders the priority that enabled Scania to smoothly ramp up production to record levels in a short period. The second example of people-focused performance comes from a customer, a hauler located in northern Sweden. This hauler appreciated Scania's long-standing policy of designing new components and parts so that they are interchangeable with the part they supercede in existing vehicles. One reason this customer has stayed with Scania trucks for many years is that he knows he can readily swap parts from old Scania trucks to his new ones, something that no other make of truck permits him to do. These examples demonstrate why Scania enjoys a higher customer retention rate — 80 percent — than do either of its two main European rivals: about 70 percent at Volvo and about 60 percent at Mercedes-Benz.

The spirit of disciplined service engendered in Scania's management by its modular thinking is quite different from the spirit that finance-oriented manage-by-results thinking has engendered in most businesses in America and Europe during the past three to four decades. Most European and American companies, in contrast to Scania, manage by results, not by pattern (or process).[6] They leave the determination of *how* things are done to the whim of each individual worker or manager. Employees are told to pursue cost or profit targets by manipulating people and processes, not by mastering the discipline of a standardized pattern of work. In other words, the *means* is subordinated to the *end*. To manage by pattern, however, implies giving priority to the means. This makes every act valuable in its own right, not just something to finish while racing mindlessly to reach an end result down the road. How something gets done becomes as important as what is done — a sentiment expressed by the late Dr. W. Edwards Deming and implicit in every ancient religious tradition; namely, do things the right way and the results you are capable of achieving will happen. It should surprise no one that the absence of disciplined attention to pattern makes profitability more elusive, more erratic, and more difficult to sustain over the long run in fragmented companies that

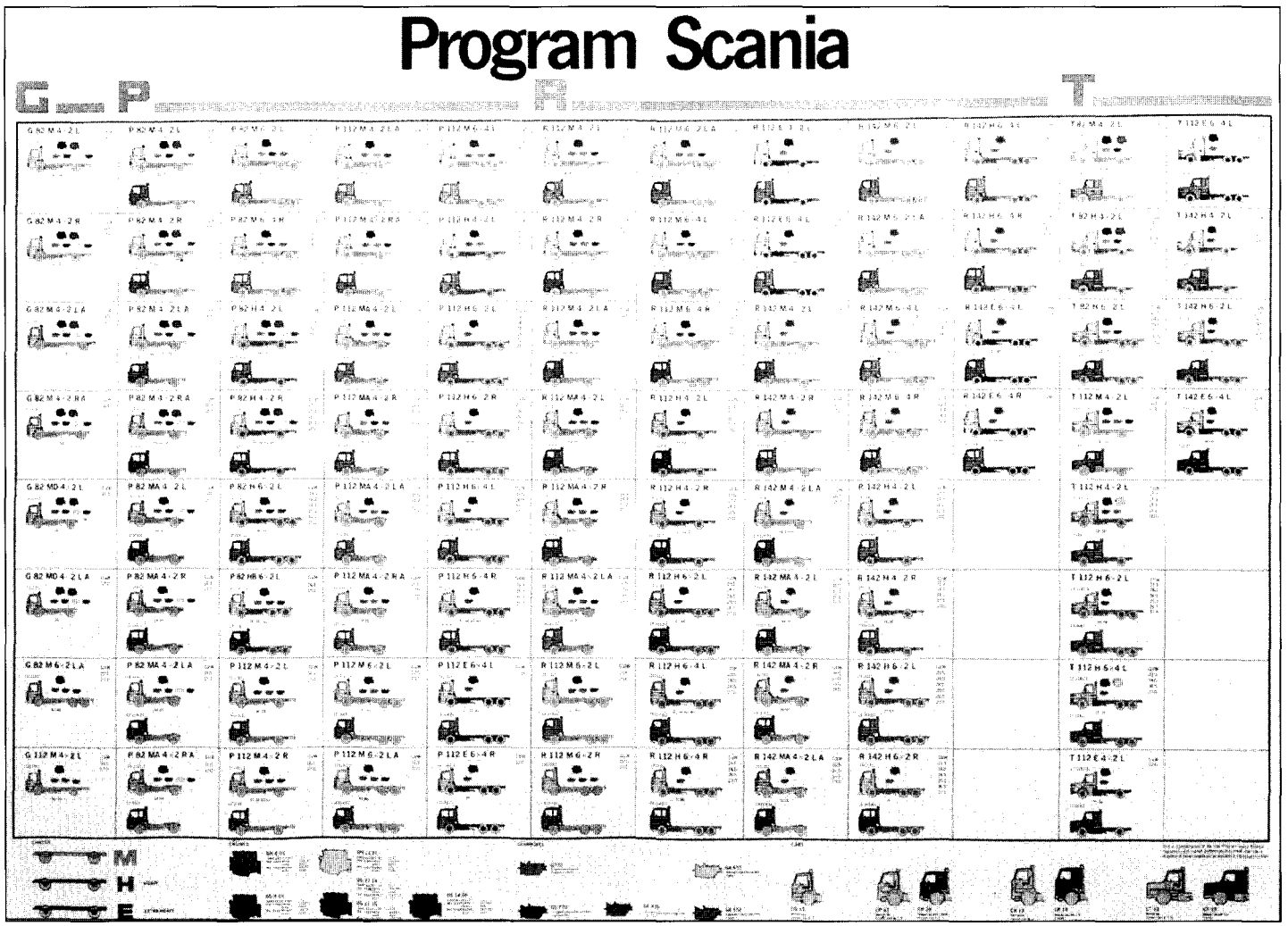

Figure 3. *This figure portrays 168 out of more than 250 different trucks that Scania could produce from different combinations of frame, engine, gearbox, axle, and cab modules in 1980, the year the company launched its modular design concept. Silhouettes across the bottom of the figure show varieties of the different frames (medium, heavy, and extra heavy), engine sizes (9, 11, and 14 litre), gearboxes (5-speed, 10-speed, and automatic), and cabs (three forward-control and two bonneted). (Not shown here are axles, driveshafts, and other components.) Scania uses this parsimonious array of standardized component modules to offer buyers custom-built trucks that serve myriad individual requirements, including urban delivery, local haulage, long-distance work, heavy-duty work, and more. As of 1995, Scania's range includes two forward-control types (P and R), and one bonneted type (T) in over 300 different varieties.*

manage by results than in Scania, where mastery of customer-focused thinking connects people and their work in a holistic pattern.

Using modular thinking as a template, Scania's executive team is working to reinforce attention to that holistic pattern — to *how* things are done — throughout the entire organization, from product design to after-sale service. Modular thinking will provide a warp thread that holds together the pieces of the company, energizing each part with a common devotion to the goal of developing the organization's competencies to serve customer wants. That purpose already is evident from the role of modularization in the product design area, where modular design principles create a systemic view of reality that says parts derive meaning from the whole, not that the whole is defined by the sum of its parts. In this case the whole is something more than just a product — the truck. It also is more than either the company or the customer. *It is both at the same time.* The essential thrust of the modular design concept, as employed in product design at Scania, is that the financial success of each — company and customer — depends on the mutual success of both (that is, the whole system).

All top managers in Scania have given careful

attention to that concept for the last 15 years, mastering the details of how standardized component modules serve both customer and company at the same time. Scania's design engineers articulate the full array of finished truck variants in a matrix of 300 or so cab and frame combinations known as the "PRT range" (see Figure 3). Everyone in top management is mindful of the combinations and patterns inherent in that matrix and everyone understands that selling trucks designed within that range simultaneously serves the needs of both customer and company. In dealing with customers or in making a sale, no one would depart from design specifications in the matrix either to cut costs by skimping on components or to drive a sale by overloading components. Either way, the gain to company or customer would be offset by a loss to the other. Both customer and company gain when trucks are sold that combine modules within the pattern of the matrix.

Top management at Scania is now taking steps to insure that this systemic, customer-driven style of modular thinking extends to every person and every activity in the company, not just to product design. This effort rests on the growing awareness that the company can do much more to increase the customer's *total* satisfaction — and Scania's own long-term profitability — than simply design a better truck. While a truck's physical design features embody much that a customer wants, those features themselves may directly satisfy only a small part of any customer's total wants over the economic life of the truck. A customer's total satisfaction from owning a truck comes from *everything* that ownership does to make the customer's business more enjoyable and more profitable. To serve the customers' needs in this total sense means enlisting and focusing the talents of every person in the organization, including outside suppliers.

Product design is just the first step along an endless pathway a company can follow, if it chooses, to lock in each customer for life. Results-focused companies too often see the pathway to profitability extending no further than the sale itself. However, Scania is already far down the road to understanding that the pathway to sustained long-run profitability begins at the time of sale. Thus, a major focus of future corporate communications and training efforts will be to impress on everyone in the organization the difference between profitably satisfying customers with a superior product and profitably locking in customers for life. In part, Scania's dedication to this difference explains its long-standing commitment to vertical integration that has deterred the company, so far, from venturing into the North American market (see box above).

To lock in each customer for life, Scania people must do more than merely follow and listen to the customer. They also must lead and anticipate the customers' needs. As a former director of design once said, "The company always must be looking around the corner and be ahead of the customer with new developments. By the time customers see a new idea, it is too late for the company to react." It is in this spirit that Scania for the past 40 years has led in development of new technologies associated with turbocharging and turbocompounding, with synchromesh gearboxes, and with environmentally sound engines and trucks. Scania has led the industry since the early 1980s in achieving improved fuel economy (20 percent less fuel with 30 percent more power), engine emissions (NO_x [the pollutant is generally referred to as nitrogen oxide] per ton-km down 50 to 65 percent), exterior noise levels (down 85 percent), hours for service and maintenance per year (down from about 100 to 10), and vehicle safety (better structural design and improved electronic braking and gear changing).

To a large degree, Scania's top managers already demonstrate the capacities needed to profitably lock in customers. For example, each executive has a deep understanding of issues and concerns outside his own immediate area of expertise. This shared understanding is explicit in position titles such as "development and production" or "production and control." Evidence of this sharing appears when discussions with almost any executive in the company reveal a deep familiarity with design engineering and manufacturing engineering issues and often a working knowledge of problems encountered in mar-

European Versus American Strategies

Historically, European heavy truck manufacturers have been more highly integrated than their counterparts in the United States. American truck makers tend to focus on assembly of engines, gearboxes, axles, and other components purchased from outside suppliers, whereas European builders generally develop and produce their own components. The European way gives customers a well-matched vehicle in which all components work as a smooth system. Moreover, the manufacturer generally assumes responsibility for servicing and maintaining the entire vehicle. The American way, in contrast, gives customers greater freedom of choice in specifying the design of the vehicle. However, after-sale service and maintenance must be entrusted to the various component suppliers.

This difference in strategies creates customer expectations in the United States that make it very difficult for European truck manufacturers to operate in their accustomed manner. Consequently, European makers who have ventured into the U.S. market — in all cases by acquiring domestic truck companies — have found it necessary to adopt the American way. Scania is alone among the world's leading truck makers to have chosen not to grow by acquisition. So far, their devotion to producing the entire truck has caused them to bypass the American market.

Figure 4. *Scania chassis in front of the Scania factory in Angers, France.*

keting, distribution, and after-sales service. This knowledge is not surprising since turnover in the executive ranks is very low and most executives with ten years or more experience have worked in at least two areas of the company. Moreover, almost all have formal training in engineering. Because managers possess highly-developed cross-functional competencies, they communicate easily. In fact, rapid, informal, and *informed* communication among members of Scania's management team creates subtle linkages whereby design, production, and marketing all make an enormous contribution to Scania's "leanness," flexibility, and customer responsiveness. This communication surely contributes enormously to the company's superior financial record.

Another shared capacity among Scania's top managers is a desire to walk directly in the customer's shoes as often as possible. To that end virtually all members of the top executive team are licensed to drive all the company's products. Moreover, they frequently make overnight trips driving trucks with their own and competitors' customers to experience firsthand the customer's point of view. Because of this direct contact with customers and their particular expertise, all Scania executives understand and can knowledgeably discuss the broadest possible implications of any problem that may arise. Their communication and interaction is not unlike that of a cross-functional design team that never stops designing and improving, rather than disbanding at the end of a project. For example, a production manager driving overnight with a customer may discover a nagging inconvenience that can be rectified by shifting the location of a dashboard instrument. Probably the production manager already has a good sense of the modular design implications of the shift. He is therefore able to profitably discuss the issue with design engineers and then determine himself the manufacturing implications of any proposed change. When each executive understands product development, production, and customer awareness, they see these as forming an organic whole and recognize how one member affects the others. Thus, building on a web of relationships generated by widely shared modular thinking, Scania has achieved quite naturally and without upheaval the responsiveness and flexibility that countless corporations around the world today are trying to achieve by artificially reengineering themselves into "flat" or "horizontal" organizations.

Wrap-up

A pressing concern among businesses today is to find dependable measures of performance. Indicative of this concern is the attention companies pay to new ideas for "balanced scorecards," "vital signs," "profit pyramids," and other measurement nostrums. Scania's experience suggests, however, that a better indicator of a company's ability to generate sustained high performance than traditional measurements is the similarity of the company's practices and behavior to patterns found in nature.

Among the patterns that scientists observe in nature, none seems more pervasive than endless fractalization — that is the infinite repetition of a pattern at successive orders of magnification that occurs in nonlinear mathematical forms (such as Benoit Mandelbrot's "Julia sets"), in cloud formations, in rock formations, in river systems, in coastlines, and much more. In a sense, fractalization is another way of saying "repetition with modularity." Therefore, we can say that with modularization businesses use one of nature 's fundamental patterns to address the chronic problems they face when trying to provide customers with variety at low cost.

One place in nature where the pattern of modularization is particularly evident is in evolution — the pattern of life itself. Evolution reflects continuous change that builds to greater and greater complexity upon a foundation of very simple means. A business is probably on the pathway to sustained profitability if "rich in ends, but simple in means" is a basic pattern underlying its thinking and behavior. But those businesses that try to finesse the issue by engaging in mass production techniques implicitly follow a pattern opposite to what we see in nature. What we see in nature is *the creative unfold-*

ing of life toward forms of ever increasing complexity. Indeed, the essence of life is the unfolding of diversity. The opposite of life is described by words such as eternal sameness, entropy, and homogeneity. Homogeneous mass production is, therefore, the pattern of death. It should not be surprising, therefore, that companies that have attempted to achieve variety and diversity by following batch-oriented patterns of mass-production usually end up suffocating in quagmires of complication, not flourishing in the power of complexity.[7]

Nature suggests that modularity is a way to achieve diversity efficiently, because nature seems to follow modular principles in generating the evolving diversity of species on earth. This is evident in the profound similarities in bone structure among wide classes of animal life, and similarities in circulatory structure in plant and animal life. Modularity is a key pillar underlying the process of life itself — the continual and efficient unfolding of newness and diversity. Businesses invite problems if they pursue profit targets without regard for such a modular pattern.

Thus, the patterns inherent in evolution — in nature's modular design strategy — probably give a business an excellent means of assessing the potential for success or failure of any program it embarks on. Three such thought patterns summarize the essential messages contained in Scania's modular philosophy:

- Focus every act on serving the richest possible array of customer needs by the simplest means, as though profitability depended on it
- How something is done is inseparable from what is done
- Don't pursue an action for the "result" it supposedly achieves if it fails to serve customers and does not build the organization's human competencies.

Although it will not be a foolproof technique, gauging any proposed policy or action against these patterns will do much to insure that a company's financial performance will be on a pathway to sustained profitability. In other words, a business may do better to appraise the merits of a proposed action by "mapping" the action onto nature's patterns of growth and change, not by attempting to "measure" the action's eventual consequences.

1. A phrase coined originally by the late Norwegian philosopher/ecologist Arne Naess.
2. Ulrich, Karl T.and Karen Tung, "Fundamentals of Product Modularity," MIT Working Paper #335-91-MSA, September 1991.

Figure 5. *A Scania T113H4x2 tipper at a gravel pit at Autopista del Sol in Buenos Aires.*

3. Linking mass production of standardized components with assemble-to-order in final assembly has sometimes been referred to as "mass customization." A step beyond that, achieved only partially and by only a handful of relatively small manufacturers to date, is to fabricate engineer-to-order components that flow on a pull basis into final assemble-to-order. In other words, assemble-to-order from non-standard parts that are fabricated with nearly zero setup time, including design time as well as machine setup time.
4. Sjöström, Sverker, "The Modular System in Truck Manufacturing," *The Saab-Scania Griffin*, 1990/91, pp. 2-12.
5. Volvo sold 10-15 percent more trucks.
6. For more on the concept of remote-control management by results, see H. Thomas Johnson, *Relevance Regained: From Top-Down Control to Bottom-Up Empowerment*, New York: The Free Press, 1992.
7. For more on this, see the discussion of "spaghetti junction" in Johnson, *Relevance Regained*, pp. 37-41.

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