LIFE CYCL

FORECASTING THE RISE AND FALL OF ALMOST

How many more hit movies will Steven Spielberg direct? When will maglev trains or aerospace planes take over as the world's leading transportation system? Answers to many such questions about the future can come from life-cycle research.

BY THEODORE MODIS

My job is to feed my company's strategic decision makers with intelligence. This gives me the opportunity to employ innovative approaches for analyzing data and understanding current concerns. Having been a physicist in a previous career, I find it thrilling to discover practical uses for nuggets of academic knowledge, and I was delighted to discover that the mechanism and pattern of natural growth can illuminate such diverse issues as the shortening of product life cycles, the fall of the Berlin Wall, the unification of the European Economic Community, and the persistent worldwide recession.

Natural Growth in Competition

Survival of the fittest dictates that the filling (or the emptying) of a niche in a competitive environment proceeds along the S-shaped pattern of natural growth. That means that the rate of growth—whether it is world population, the spread of communism, or sales of the latest computer—is greatest in the middle of the life cycle, tapering off as growth reaches saturation level. The niche capacity is assumed to be constant throughout the growth process. A niche in nature rarely remains partially full (or empty), so one should expect a natural-growth process to proceed to completion, thus making the evolution of the process predictable.

There are limits to natural growth, and the *rate* of growth slows down as the population of a product or a species nears its limit. If you put two rabbits in a meadow, you can watch their population go through an exponential-growth pattern at first, but slow down later as it approaches a ceiling—the capacity of the ecological niche. Over time, the rabbit population traces a trajectory that is S-shaped. The *rate* of growth traces a curve that is bell-shaped and peaks when half the niche is filled.

A product's sales follow the same pattern as the product fills its market niche. I became involved in fitting S-curves to populations of computers when I realized that competition in the marketplace is intrinsically the same as in the jungle. The first computer model I tried, one of Digital's early successful minicomputers—the VAX 11/750—illustrated the point. The cumulative number of units sold is shown at the top of Figure 1 (page 22). In the lower graph, we see the product's life cycle, the number of units sold each trimester.

When I produced this graph in 1985, I concluded that the product was phasing out, something that marketers denied vehemently at the time. They told me of plans to advertise and repackage the product in order to boost sales. They also spoke of seasonal effects, which could explain some of the recent low sales.

Sales during the following three years turned out to be in line with my projections. To me, this proved that seasonality, promotional activities, price changes, and competition in general were conditions present *throughout* a product's life cycle and would not change the course of a natural phasing-out process. The

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new programs that marketers put in place were not significantly different from those of the past and therefore did not cause a modification of the established trajectory.

Since that time I have tried to fit S-curves to many products, but using this tool has become complicated by the many new computer models entering the market in rapid succession with little differentiation. The 11/750 I'd originally charted was a long-lived, well-positioned product that had its own market niche. Today's models overlap and often share the market niche with other products. Life cycles are short and behave too irregularly to be fitted by an idealized curve. So rather than modeling single products, we can look at a growth-curve description of a whole family of products (e.g., microwaveable desserts) or a whole generation of technology (electric cars versus gas-driven vehicles).

Fortunately, families are also amenable to a biological description. There is a similarity between the growth of a population and the growth of an individual. A colony of unicellular organisms, regarded as a whole, is much like the body of a multicellular organism. Imagine a cup of soup left on the table for several days. Bacteria will grow in it subject to food limitations. Measurements show that the bacterial growth follows the familiar S-curve pattern and stops growing when the whole surface is covered.

Whether it is bacteria in a bowl of soup, rabbits in a fenced-off meadow, or computers in society, the limited resources available for a resident population are progressively exhausted. If the growth mechanism is a multiplication process—situations in which one unit brings forth another—the overall pattern of growth is *symmetric*. It is this symmetry that endows S-curves with predictive power; when you are halfway through the process, you know how the other half will be. S-curve behavior can be found in a wide range of areas, from the replacement of one transportation system for another to the number of movies a director like Steven Spielberg or Spike Lee might create in a lifetime.

From Chaos to Order

Natural growth is not a uniform process. It consists of successive S-shaped steps, each of which represents a well-defined amount of growth. In Figure 2 (page 22), we can see two distinct time periods: a steeply rising period, when the growth rate is at a maximum, and a flat period, when the overall growth rate drops toward zero. The flat period occurs after an old process has almost finished but before a new one has fully started, such as the decline in sales of vinyl records before compact discs can offer replacement on everything. These two periods—the steep and the flat—are fundamentally different and require individual attention.

The high-growth period for anything, whether an individual product or a whole company, is a time for conservatism. You do not tamper with something that works well. During this time, top-down forces make companies consolidate, integrate, and centralize their operations. Enterprises fine-tune themselves into a clockwork operation and tend to develop heavy bureauc-

Memorable scene from *E.T.*, one in a collection of hit films by director Steven Spielberg. Can we predict how many more movies Spielberg will create?

FIGURE 1:
Sales of Digital's VAX 11/750 Minicomputer in Europe

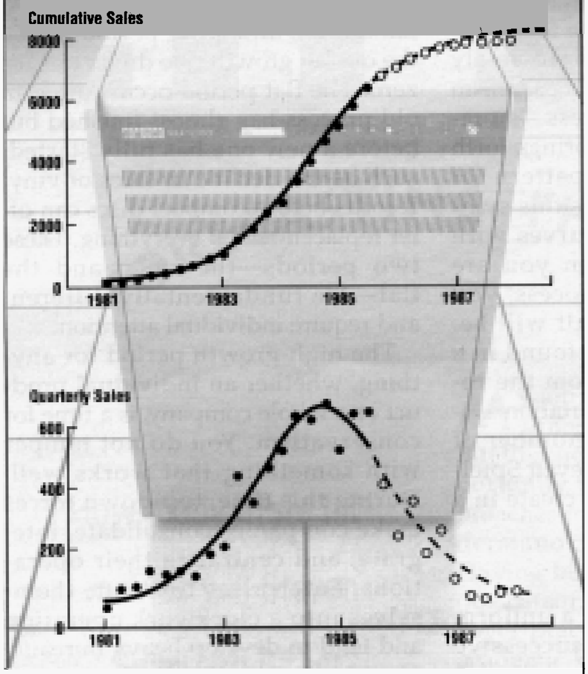


PHOTO COURTESY OF DIGITAL EQUIPMENT CORPORATION

Life cycle of a computer's sales, viewed cumulatively (top) and by quarter (bottom), as predicted in 1985. The dotted line represents author Modis's prediction for the VAX 11/750, and the open circles show its actual sales.

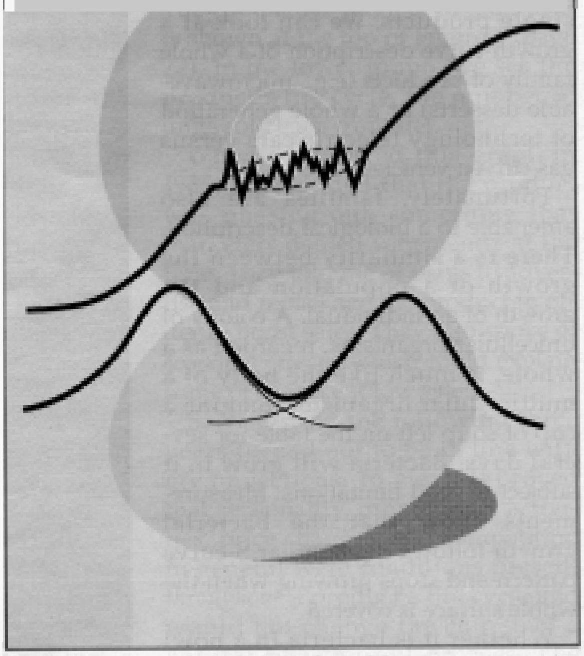
racies. The jargon of management gurus gravitates around terms like leadership, vision-driven, control, continuous improvement, acquisitions, and investments.

As we enter the flat, low-growth period, fluctuations in the rate of growth (of a product's sales record, for example) become progressively more visible, creating an environment of turbulence and chaos. It has been shown that a chaoslike state may precede *as well as* follow the rapid-growth phase. These instabilities can be interpreted as a random search for new directions that will give rise to another growth phase. They are like mutations, which during adverse environmental conditions are given a chance to sprout and compete for survival. The "gifted" mutations—a personal computer with a wireless mouse or voice recognition, for instance—will become the prime movers of the next upturn.

The low-growth period is a fertile time for taking risks and initiating profound changes; innovations and discoveries abound and enterprises segment, decentralize, and encourage entrepreneurship. The seasonal jargon of management gurus during this period revolves around such terms as re-engineering, empowerment, culture-driven, downsizing, and self-organizing units.

A typical succession of growth steps is shown in Figure 3, with the case of energy consumption worldwide. Expectedly, the two chaotic states are centered around the mid-1930s and 1990, periods of low economic growth but also of discovery and innovation. It was in the decade of the 1930s that a host of important innovations were launched (power steering, wrinkle-free fabrics, diesel locomotives, radar, rockets, helicopters, fluorescent lighting, Kodachrome, television, and magnetic tape recording, to name a few), which set the stage for a recovery that led to the high-growth period of the 1950s and 1960s.

FIGURE 2:
Chaos in Natural Growth



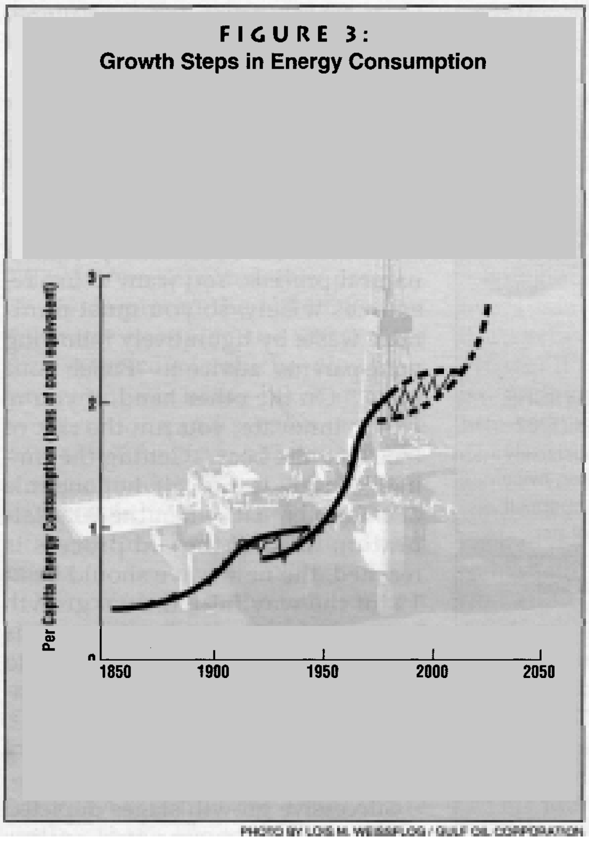
Typical succession of growth processes. The graph at the top shows the amount of growth achieved, and the graph at the bottom shows the rate of growth. During low-growth periods, chaotic oscillations become evident, as during the transition from vinyl recordings to compact discs.

By analogy, one could expect the decade around 1990 to witness the birth of a multitude of industry-generating innovations that will trigger a recovery leading to another high-growth period early in the next century. Some drivers include portable computers, cellular phones, optical disks, high-bandwidth communication networks, intelligent microprocessors, space shuttles, and probably mass supersonic transport via air and/or magnetic levitation.

Cascading growth processes can be encountered in a variety of human affairs. Chains of S-curves with different ceilings and time constants proceed independently at all times. While the world economy goes through a long wave, ethnopolitical blocs, individual nations, industries, companies, and people are tracing their own distinct life cycles.

The Collapse of the Communist Empire

The ultimate sin of a forecaster is to predict something *after* it has happened. Well, my work revolves around innovative forecasting techniques, and here I am about to pre-



Energy consumed per capita annually worldwide. The smooth lines represent fits to natural-growth processes.

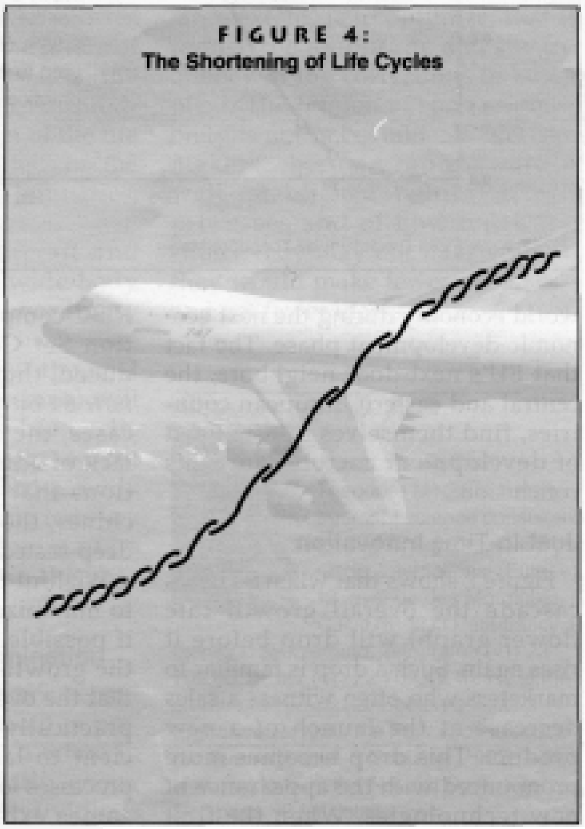
sent arguments that demonstrate that the collapse of communism could have been predicted with devilish precision as early as the 1960s. What makes me indulge in such an unprofessional exercise is the fact that recently one more person threw at me the now classic remark, "Who could have ever predicted the fall of the Berlin Wall?"

As Figure 2 shows, the chaotic period starts as we approach the saturation. At the same time, the life cycle of any growth process is generally *symmetric*. Communism started in 1917. It peaked 40 years later, in the mid-1950s, when the Soviet Union successfully competed and often surpassed the United States (to wit, Sputnik, 1957). A symmetric life cycle would position the end of communism another 40 years later, in the mid-1990s. The headline transition, the collapse of the Berlin Wall, took place in a sharp, discontinuous way, reflecting the first large fluctuation of the chaotic state that sets in as the end of a natural-growth process is approached. With the end of the process expected in the mid-1990s, the onset of the chaotic state should be expected several years earlier.

This is a *rather accurate* prediction for the collapse of communism and could have been made as early as the 1960s when it became clear that the Soviet Union had already gone over its peak. The Soviets had begun losing ground against the United States in 1963 with the Cuban Missile Crisis, then in 1969 with the moon race that was doomed for lack of funds. They had not been able to afford an adequate testing of their super rocket ahead of time, and it exploded during the critical launch.

The fall of the Berlin Wall punctuated the end of the communist growth curve, but the beginning of a free-market society was not imminent. The new politicization process was not ready to grow, and Eastern-bloc countries found themselves drifting into a state of chaos. Predictably, they are being torn apart by bottom-up forces, decentralizing, segmenting, subdividing, searching for identity and a political system, and in general exploring all directions, including extreme ones such as private police units in Moscow and murderous belligerencies in the former Yugoslavia. Exceptional leaders such as Mikhail Gorbachev, Eduard Shevardnadze, and Boris Yeltsin are incapable of controlling the strong and turbulent cultural forces. Their only chance is to align themselves with the most promising trend and hope they survive until the "sprouting" of the upcoming growth phase.

In contrast, western European countries have so far undergone a considerable political development and are now reaching a phase of maturity in their politicization process. Mediocre leaders have no difficulty surviving here. The name of the political game is unity—e.g., the European Union. Such actions are timely and portend a dominant role in the



An overall S-curve pattern may consist of a long series of smaller S-curves. Note that the life cycles indicated by the smaller S-curves become longer in the middle of the overall curve, then become shorter again. A successful technology, such as Boeing's 747, will have a longer life cycle within the natural growth curve of a family of technologies, such as wide-body jets. Toward the end of that family's natural growth, new products will come and go quickly.

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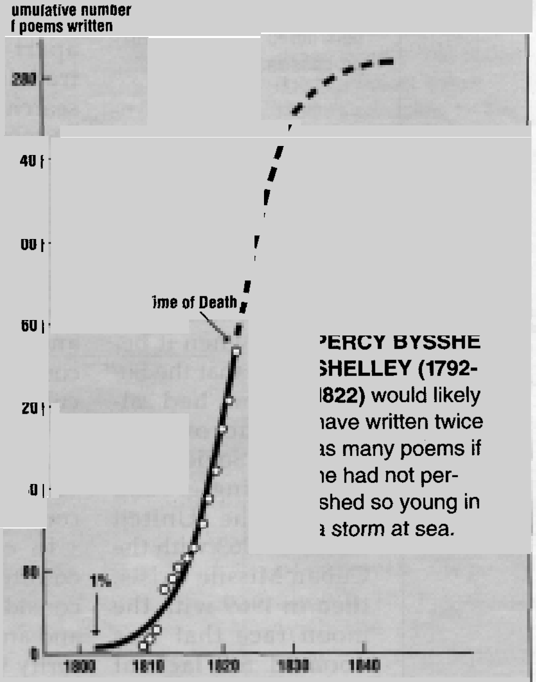
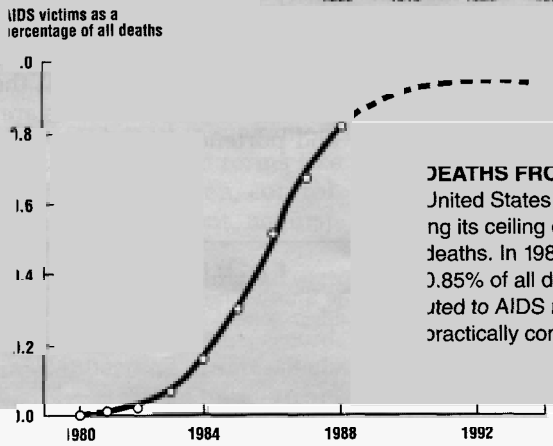
Whether it's to forecast how quickly a disease may spread before disappearing or how many masterpieces a creative genius may produce in a lifetime, life-cycle research is a useful predictive tool, as these two charts illustrate.



PERCY BYSSHE SHELLEY (1792-1822) would likely have written twice as many poems if he had not perished so young in a storm at sea.



DEATHS FROM AIDS in the United States may be approaching its ceiling of 0.95% of all deaths. In 1988, the fact that 0.85% of all deaths were attributed to AIDS makes this "niche" practically complete.

Source: From *Predictions* by Theodore Modis.

world economy during the next economic-development phase. The fact that EU's next-door neighbors, the central and eastern European countries, find themselves in dire need of development corroborates this conclusion.

Just-in-Time Innovation

Figure 2 shows that when S-curves cascade the overall growth rate (lower graph) will drop before it rises again. Such a drop is familiar to marketers who often witness a sales decrease at the launch of a new product. This drop becomes more pronounced with the appearance of new technologies. When the first RISC computers (Reduced Instruction Set Computing) were introduced, they sold poorly, as do the new 64-bit processors today. In both cases, the easy explanation is the lack of adequate software applications that run on these new machines, though there may be more deep-seated reasons for the drop.

Wishful-thinking marketers hope to minimize the low-growth period, if possible, for example by having the growth steps so close together that the overall growth rate remains practically *constant*. But it's inefficient to launch new products or processes long before the old one becomes exhausted. For example, a book publisher does not normally release a paperback version of a best-selling novel until the hardcover version has sold about as well as it can—or until the author finishes the next manuscript for a new hardcover book to "replace" the old one.

A constant growth rate is not realistic because it does not represent a natural process. You want to use resources wisely, so you must minimize waste by figuratively following your parents' advice to "Finish your plate." On the other hand, if you're late to innovate, you run the risk of "missing the boat." Getting the timing just right is difficult, but one rule of thumb is that, when the 90% saturation level of the old process is reached, the new wave should be at 1% of the way into its own growth process. Another rule of thumb is that the duration of chaos is likely to be comparable in length to the duration of the boom.

Cascading S-Curves

Successive growth stages depicted by cascading S-curves may outline an overall growth process itself amenable to an S-curve description. The discovery of stable chemical elements, for example, spanned three centuries but occurred in clusters of four distinct, regularly spaced growth phases representing S-curves within S-curves, suggesting a fractal nature for natural growth. This cascading effect is illustrated in Figure 4 (page 23). As you will note, life cycles are longer during the steep-rising, high-growth period and shorter during the flat, low-growth periods.

The phenomenon of shrinking life cycles is an important concern of today's manufacturers. For a family of products, shrinking life cycles reflect how close to exhaustion a technology may be. On a larger scale, shrinking life cycles of families of products (e.g., mainframe computers) reflect changing social patterns (such as a trend toward demand for more portable and personalized products). On an even larger scale, lots of products with shrinking life cycles may reflect a global economic recession.

Monitoring the drift of the width of life cycles over time will tell us either how close we are to full saturation (life cycles getting shorter), or how far we are from a future rapid-growth phase (life cycles are getting longer).

Examples from Industry

In 1985, Digital Equipment Corporation introduced a line of microcomputers called MicroVAX. When MicroVAXes appeared, they progressively displaced the old PDPs that formerly occupied the $20,000- to $50,000-price microniche. Now, this price range is being taken over by workstations and servers, and the MicroVAX family is phasing out like a single product. Yet, a dozen different models have been sold, and most of them followed a distinct growth curve.

MicroVAX I was the family's first entrant; it had a short life cycle, and it was generally considered an unsuccessful product—unfairly so. It should rather be seen as an exploratory attempt that paved the way for products that followed. MicroVAX II had the longest life cycle—three times as long as its predecessor. The life-cycle duration started decreasing already with the follow-up product, M2000, which lasted for a little more than half as long as MicroVAX II. Recent models, such as M3100/20/30, have life cycles that are more than four times smaller than that of MicroVAX II. By my calculations, the MicroVAX technology should be more than 90% exhausted. I obtained a confirmation of this conclusion (87% of the level of the ceiling) by checking on the evolution of MicroVAX's market share and treating the whole family as a single "product."

Another example of S-curves within S-curves can be found with the aviation industry. Wide-body aircraft can be considered as a family with about 10 members, each having its own life cycle. Early versions, such as the DC10 and Lockheed Tristar, were shorter-lived than Boeing 747. On the other hand, the recent rapid appearance of the 767s, a series of Airbuses, MD 11s, and 777s implies that these aircraft will have shorter life cycles than the 747s. The S-curve of the wide-body family of aircraft is approaching a ceiling, with the 747 as the central long-lived product. The picture suggests that there must be a new upcoming family, probably consisting of supersonic aircraft with relatively high carrying capacity but narrower fuselage (single corridors) than today's wide bodies.

Showing Off at the Dock

Being able to estimate the level of overall saturation from observing life-cycle trends is a powerful approach. It implies that a nonspecialist, such as a laborer loading boxes into trucks off the manufacturing dock, may notice that the label names on the boxes change three times as frequently as they used to back in the good old days, and boast to his fellow workers that he *knows* that the technology behind these products is more than 80% exhausted. He may go further, arguing that if things were done right the next-technology products should be probably showing up at the dock with the next shipment.

This image may sound naive, but the approach offers valuable insights for those situations where the tracking of the overall life cycle of products, families of technologies, and even social trends is imponderable. Examining the smaller subprocesses can give us a glimpse of the future of the outer "envelope"—that is, the evolution of the life cycles of products tells on the evolution of the life cycles of families, which tells on the evolution of companies, industries, and the whole economy.

In the example of aircraft and transatlantic transport, wide-body jets replaced *and outlived* ordinary jets. Since the life cycle is increasing, one may then expect that the next family of aircraft (supersonic) will feature an even longer life cycle. Such a conclusion is in agreement with a prediction published recently that aviation is still a young industry that will reach the midpoint of its diffusion process only in the year 2002.

Prediction vs. Predetermination

Predictability of a system's behavior implies a certain amount of predetermination, which is a taboo in Western society, particularly among forceful, strong-willed individuals who like to plan out the future. Their scenarios, however, are often biased toward flattering their egos with notions of possessing the power of free will. For instance, a marketer's long-term forecasts tend to be systematically biased in favor of their new products and against the old ones, ignoring the natural progression of well-established processes such as substitutions, phasing-ins, and phasing-outs.

What good decision makers do more often than not is *optimize*. Optimization reduces free choice. From the moment you choose to strive to win a race, there is not much freedom left: You must follow the list of optimized course actions as closely as possible. You must try to stay on the course and to make corrections as needed, just as natural systems do. Thus, the winner's actions and decisions are rather predictable compared with the "free will" of a Sunday driver who stops for no predictable reason—to gaze at a rare bird, perhaps.

Highway driving is not necessarily anxiety provoking (the occasional Sunday driver notwithstanding). Most of the time there is little choice. Similarly, a leader's job, to a large extent, is to optimize; that is, reduce the amplitude and the frequency of the corrections to be applied. The burden of such responsibility is not unbearable. If "decision makers" became more aware of well-established natural-growth processes and of how much free choice they may not have after all, they would make fewer mistakes—and get fewer ulcers. □

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