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CHASING THE INNOVATION "BUTTERFLY" WITH SYSTEMS THINKING

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"Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?"
—Eduardo Lorenz

Product development is a complex dynamic system buffeted by numerous uncertainties. Seemingly small changes in product features or a slight repositioning of a firm's skill sets can drive market standards and expectations. Sometimes these initially subtle changes can even move whole industries into unexpected places. These are characteristics commonly found in what physicists term "complex systems." But is the system connecting markets, product features, and firms' skill sets truly a complex system as a physicist or systems thinker would define it, and if so, what are the implications of that complexity for product development and marketing managers?

Strange Shifts

It may help to consider the following case study in the automotive industry. Beginning in the 1970s, various U.S. Clean Air Acts passed by Congress combined with rising gasoline prices created a demand for vehicles that emitted few pollutants and had high fuel efficiency. The mechanically based automotive engine control systems of the time could not attain sufficient precision to meet the new legislative requirements, let alone provide the customer with acceptable performance in terms of vehicle acceleration.

To fix this problem, the automotive companies eventually shifted to using electronic controls so complex that, by 1990, the engines, transmissions, and many other components in their vehicles were controlled by a number of small microcomputers. However, electrical engineers with sufficient automotive industry expertise to design the control systems simply did not exist prior to 1970. To train and develop these engineers in sufficient numbers took the automotive firms more than a decade. By 1990, legions of these engineers existed in all the major companies.

Once this capability was developed, strange shifts began to occur in the industry. Firms started introducing new features enabled by electronic controls such as anti-lock brakes to prevent skidding in poor weather, all-wheel drive to improve traction, active suspension controls to help prevent roll-over accidents, and vehicle diagnostics systems to detect critical parts failures before they occur. Over time, the market not only embraced these features but began to consider many of them standard, reinforcing the need for more electronic controls capability within the automotive industry.

As is well documented, without assistance, the human minds' inherently linear nature cannot adequately cope with managing such non-linear, path-dependent behavior. However, systems thinking can help us describe the dynamics of this kind of system and its implications. For example, consider the set of causal loops in "The Capability-Innovation-Market System," which describes the behavior of the automotive industry case just described. When "Product Performance" deteriorated with respect to the market's "Desired Product Performance" owing to the legislative shock of the Clean Air Acts, the "Performance Gap" increased. This gap created a need for "Investment" in new "Capabilities," that is, the hiring and training of a group of skilled personnel capable of creating and designing automotive electronic control systems. Over time, this new capability improved "Product Performance," and in the process, the firm learned even more about automotive systems, thus creating and enhancing its own "Capabilities" in a reinforcing loop, which we will term the "Capability Development" loop.

Eventually, this improving product performance also reduced the "Performance Gap" with respect to engine performance and fuel economy, completing the "Product Portfolio Improvement" balancing loop. However, with time, as some "Market Wants" were satisfied, others increased. The market first began to express "Market Wants" for improved "Desired Product Performance" in areas such as safety, increasing the "Performance Gap" in other areas. This gap completed a reinforcing loop by driving further "Investment" in electronics "Capabilities" that improved "Product Performance."

This last loop, which we term the "Market Co-Evolution" loop, creates a ratcheting effect that enables complex behavior. We use the word "complex" here in the literal mathematical sense that a small change or deviation in any variable within this

TEAM TIP

Drawing lessons from the product development example, explore what capabilities your organization should develop with respect to your most likely future scenarios.

non-linear system with feedback loops and delays will lead to unpredictable results over the long term. Managing this complexity, by itself, is challenging enough. However, there are other aspects of the Capability-Innovation-Market system that complicate managerial decision-making even further.

The Innovation Butterfly

Like the weather system alluded to by Lorenz in the quote at the beginning of the article, the Capability-Innovation-Market system has a number of potential butterflies that can create unforeseeable, permanent shifts in the future behavior of the system. Legislative shocks such as the impending increase in the required average fuel economy for automotives can arise at any time in response to world and national events. The market's wants often change in notoriously unpredictable ways. (For example, why our children take the trouble of tapping out on a cell phone's 12-button keyboard "Hi, how R U?" to their friends when they could just call those same friends with less effort remains a mystery to the authors.) Technological innovation is a creative endeavor and thus is inherently uncertain, particularly in the context of executing projects with tight deadlines. Establishing desired product performance targets to respond to market wants is fraught with uncertainty as well. (To use one last automotive example, when Ford introduced the Windstar in 1993, executives simply could not believe that consumers would ever want a fourth door in their minivans. One morning in 2007, at a coffee shop in Austin at which one of the authors frequently writes, he counted no fewer than 14 minivans, *all of which had four doors*.)

Further, while we have bundled a number of variables—such as market wants for safety and engine performance—together, there are really numerous separate but interconnected wants. Similarly, most firms have not just one product but rather a portfolio of products to offer the market, and each product takes many skill sets (or capabilities, as business strategists refer to them). Hence, each firm has a portfolio of such creative capabilities as well as a portfolio of products.

Researcher Kathy Eisenhardt tells us that these capabilities recombine in a creative and continuous manner. Because the innovations introduced by product development are creative, the technological route to such crucial products and services such as clean energy or miniaturized medical devices is essentially unpredictable. Research and development—as recently described in a *Business Week* article on the 3M corporation—is not simply process improvement and therefore cannot be enhanced by techniques such as Six Sigma quality control. Such techniques assume that a process is repeatable over time, which creativity most manifestly is not. To complicate matters still further, few firms exist without competitors, each laden with their own potential butterflies that might create tornados for themselves or their competitors.

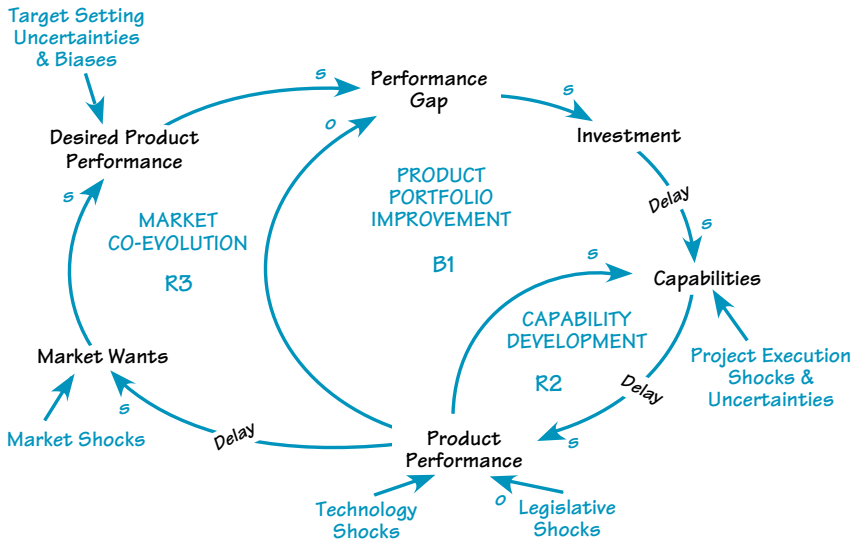
The Weather Analogy

So as systems thinkers, what are we to do? Give up on the innovation butterfly? Of course not. To make an analogy, consider weather. Because weather is a complex system, meteorologists will probably never be able to make point predictions for a given day more than a week into the future. On the other hand, they have made great strides in recent decades in improving the prediction of long-run patterns of behavior, such as the average precipitation in a region over the next year.

In the same way, by using systems thinking to better understand the Capability-Innovation-Market system, product development managers can improve their ability to predict the long-term average risks and rewards resulting from a particular policy or management structure. Moreover, because managers actually control a significant portion of the Capability-Innovation-Market system, they should be able to exert some leverage over these expected results, something that meteorologists simply cannot do within their own system. By embracing the power of systems thinking, product development managers may not be able to make point predictions about their firm's future, but they can at least shape the probable outlines of that future.

Our understanding of how exactly to do so remains immature. However, we can begin by taking a couple of lessons from how the boy and girl scouts plan camping trips. First off, as

THE CAPABILITY-INNOVATION-MARKET SYSTEM



This loop has a number of potential "butterflies" that can create unforeseeable, permanent shifts in the future behavior of the system. But by using systems thinking, managers can improve their ability to predict the long-term average risks and rewards resulting from a particular policy or management structure.

maligned as weather forecasters are, they do much better than laypeople in predicting weather in the short term (Simmons and Hollingsworth, 2002). As the time of the campout approaches, scouts can adjust what they will stow in their backpacks with respect to clothing, rain gear, etc. in response to the forecast the night before the campout begins. Doing so is analogous to a firm's decision to choose what capabilities it should develop with respect to the most likely anticipated market scenarios.

Of course, such guesses by managers and scouts can prove incorrect. So, second, we can actually do as all girl and boy scouts do, and be prepared. We can stow a lightweight poncho in case it does rain or, if it is winter, perhaps a pair of mittens in case it snows. Taking this precaution allows the campers to react quickly, if perhaps not perfectly, to unanticipated developments in the weather. In a similar manner, managers can maintain some additional capabilities in-house or alternately link with outside firms that can quickly provide additional capabilities if the market turns out to evolve in an unanticipated manner.

Still, there is much work to do before the innovation butterfly can be chased as effectively as possible so that product development managers can shape their own future. Some suggestions and questions are below:

- The ability of meteorologists to predict short-term weather probabilities has improved in recent decades. Can the use of systems simulation methodologies such as those pioneered by system dynamicists improve the scenario planning for market forecasts in reaction to various management policies?
- Is there a way to control some of the shocks affecting product development such as modularizing risk within project execution and hence reducing the number of innovation butterflies?
- What is the role of organization and culture in coping with the complex Capability-Innovation-Market system? Are some organizational structures or organizational cultures (such as open-source solutions, networked arrangements, distributed product development, or something else) better suited to some Capability-Innovation-Market scenarios than others?
- Decentralization of authority—as shown by Adam Smith and many of his successors—often works well in complex systems. If that is the case, as many routine leadership tasks move toward the periphery, what duties constitute the leader's new work in the complex world of product development? ◘

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For Further Reading

Edward G. Anderson Jr. and Mary Ann Anderson (2000). "Are Your Decisions Today Creating Your Future Competitors? Avoiding the Outsourcing Trap." *The Systems Thinker*, September 2000

Edward G. Anderson and Nitin Joglekar (2005). "A Hierarchical Modeling Framework for Product Development Planning." *Production and Operations Management*, 14 (3): 344-361

Parker, Geoffrey G., and Edward G. Anderson Jr. (2002) "From Buyer to Integrator: The Transformation of the Supply Chain Manager in the Vertically Disintegrating Firm." *Production and Operations Management* 11 (1): 75-91

A. Simmons and A. Hollingsworth, *Quarterly Journal of the Royal Meteorological Society* 2002, pp. 647–677