LEARNING FROM *NORMAL ACCIDENTS*

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Normal Accidents' *growing influence since 1984 on social science scholarship and across academic, business and governmental disciplines was not accidental. Author Charles Perrow intended to shake up the study of safety and bring organization theory into the forefront. This article examines ongoing debates about the management of technological systems, reviews the book's important seeds of theory, and discusses the theoretical and practical issues related to a world growing more complex and technologically hazardous.*

Keywords: *hazardous technology; organizational learning; reliability; redundancy; Perrow*

Charles Perrow and his 1984 book *Normal Accidents* have had a profound influence on the way we think about complex organizations that use hazardous technology. Such influence is neither normal nor accidental. It is not normal in that it is exceedingly rare for social science scholarship to become widely read by scholars across disciplines, by managers and operators in business and in government, and by the general public alike. Perrow's influence was not accidental, however, in that he deliberately set out to shake up the study of safety with hazardous technologies. In a field that had been dominated by engineers and by economists, Perrow sought to bring organization theory loudly and boldly into the debate. Heated debates continue about how to manage virtually all the technological systems Perrow examined, of course, but these debates have been improved by his work and by the literature inspired by *Normal Accidents*.

In this article, I will do three things. First, I will present some data to give readers a sense of the breadth of the influence of the book since it was published in 1984. Second, I will review the main themes of *Normal Accidents*, highlighting some of the important seeds of theory that were planted throughout the book and that have grown since then. Finally, I will discuss some theoretical and practical issues about which we still know little. That is the most serious part of this exercise, for the world is not becoming smaller; it is becoming more complex and interconnected. And we still have a long way to go to understand how best to live with hazardous technologies.

THE RANGE OF PERROW'S INFLUENCE

Normal Accidents is an extremely widely cited book, with 1,115 citations between 1984 and July 2003 in the combined Social Science Citation Index (738), Science Search Index (334), and Arts And Humanities Citation Index (33). A the-

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ory has major impact when it moves outside its own subfield to illuminate new sets of problems traditionally addressed by scholars from other academic disciplines. That is clearly the case with Perrow's book, as can be seen by even a cursory survey of the subjects to which normal accidents theory has been applied and the diversity of disciplinary journals in which the work is cited. With respect to the subject matter, because Perrow discussed a broad set of hazardous technical systems in his book, we would expect specialists on those technologies to use his ideas. But subsequent scholars have applied or further developed the ideas to a much wider range of organizational, personal, and national activities. These include (to give just a partial list), hospital emergency room procedures (Pate-Cornell, Lakats, Murphy, & Gaba, 1997), the origins of the Franco-Prussian War (Nickles, 1999), the social construction of Pacific Ocean salmon (Scarce, 1997), glitches in computer software development (MacKenzie, 1996, chap. 9), U.S. Air Force friendly fire incidents (Snook, 2000), the poetry of thermodynamics (Funtowicz & Ravetz, 1997), and the representation of risk in contemporary American novels (Heise, 2002). With respect to diversity of disciplines influenced by the book, it is worth noting the range of journals in which *Normal Accidents* is cited. Organization theorists would easily recognize many of the journals in which citations to Perrow's book appear—the major sociology, management, organizations, and political science journals—but how many other organization theorists have been cited recently in the *Journal of Animal Science* (Thompson, 1999), *Pediatrics* (Merritt, Palmer, Bergman, & Shiono, 1997), the *Review of Religious Research* (Harper & Schutte-Murray, 1998), *Heart Surgery Forum* (Dain, 2002), or the *Journal of Hazardous Materials* (Reams & Templet, 1996)? (This last article, "Political and Environmental Equity Issues Related to Municipal Waste Incineration Siting," also provides new evidence of Perrow's influence on garbage can theory.)

It is more difficult to measure how much influence Perrow's work has on how leaders of organizations that manage hazardous technologies think about safety and accidents. Citations can be easily counted, but impact on ideas cannot. Still, evidence of influence can be discerned. Perrow has never been invited to speak at NASA headquarters, for example (Beam, 2003), but normal accidents theory has nevertheless been prominently featured in internal NASA briefings on space shuttle safety (Greenfield, 1997; Stamatelatos, 2002). Furthermore, he and I have both discussed normal accidents theory at length with senior officials of the U.S. and the Russian nuclear weapons laboratories (Sagan & Valentino, 1994). *Normal Accidents* has even been used to support a judge's opinion in a federal appellate court case concerning a Mississippi River bridge accident (*I&M Rail Link v. Northstar Navigation*, 2000). This kind of evidence does not, of course, mean that managers of hazardous technological systems have learned the right lessons from Perrow's work; but it does suggest that they cannot easily ignore his ideas.

REDUNDANCY AND RISK

Normal Accidents issued a warning: Catastrophic accidents with high-risk technology systems are inevitable over time if the systems are complex and tightly coupled. This warning is what got Perrow so much initial attention, but that is not what ultimately made the book so important. Many other journalists, scholars, and politicians had, after all, argued against the development or widespread use of many of the technologies discussed in Perrow's book. Moreover, although some critics called Perrow a Luddite, this was an unfair criticism; he actually called for the

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abandonment of only two of the risky technologies he analyzed—nuclear pov
and nuclear weapons. The sudden emergence of a large number of dramatic ac
dents soon after the book's publication—Bhopal in 1984, Chernobyl in 1986, t
Exxon Valdez in 1989, and the Challenger in 1986—also gave Perrow a reputati
as a sociological soothsayer with a clear crystal ball. But that is unfair prai
because not all of these accidents fit into the *Normal Accidents* theoretical fram
work. Many of the most well-known catastrophes (I would only include Chernob
and, possibly, the Challenger accident) may have been normal accidents, produce
by baffling complexity and by tight coupling, but others were caused by more tra
ditional, prosaic problems such as single component failures, sloppy operation
drinking on the job, or failure to invest in even the most simple of precautionar
safety systems in some developing countries.

Instead, I would argue that the importance of *Normal Accidents* was Perrow'
willingness to follow his instinct, as an organizational sociologist, that new dan
gers were rooted in the structure of organizations. Perrow's focus on two structura
characteristics of accident-prone organizations—interactive complexity and tigh
coupling—was both simple and profound. For it is the combination of complexity
and tight coupling that confounds even smart and dedicated organizational efforts
to produce perfect safety.

No individual component, human or mechanical, is perfect, of course. "We know this," Perrow notes, "so we load our complex systems with safety devices in the form of buffers, redundancies, circuit breakers, alarms, bells, and whistles" (Perrow, 1999, p. 356). In complex and in tightly coupled systems, however, these redundant safety devices are not independent of one another: The alarm rattles the bell; the bell shatters the whistle; the whistle explodes; and suddenly the whole system collapses.

Subsequent scholarship has focused on how this lack of independence among components in complex systems, and not simply the possibility of multiple simultaneous failures, produces normal accidents. Redundancy theory in engineering shows how even unreliable components, if independent and connected in a parallel manner, can lead to rapid increases in overall system reliability. This is the beauty of redundancy—it enables individuals, in Martin Landau's phrase, to "build an organization that is more reliable than any of its parts." (Landau, 1969). But can redundant components in real-world organizations truly be independent of one another? The difficulty of maintaining complete independence produces what I have called "the problem of redundancy problem" in organizations that manage hazardous technologies (Sagan, in press).

There are three pathways by which the use of redundancy can backfire and produce less, not more, reliability. First, redundant safety devices make the system more complex and can produce hidden common-mode errors. The paradigmatic technical example is the 1966 Fermi reactor accident in Michigan, which was caused when a piece of zirconium, placed in the reactor as a last minute safety device, broke off and blocked the coolant pipe. A similar case in security organizations is Indira Gandhi's 1984 assassination in which an extra Sikh guard, added to her security detail because of a crisis in the Punjab, conspired with an existing guard to murder the Indian prime minister.

Second, redundancy can backfire when it leads to social shirking among humans in organizations. Unlike technical devices, humans are aware of one another and the addition of an extra guard, or pilot, or radar watcher can lead others to be less observant or responsible. Scott Snook's *Friendly Fire* (2000) contains an excellent case in point: 19 crew members aboard an Airborne Warning and Control Systems (AWACS) aircraft in Iraq knew that two U.S. helicopters were flying through the so-called no-fly zone, but not one of them intervened when an F-15 pilot below them announced that he was going to shoot down two supposedly hostile helicopters. Diffusion of responsibility meant that everyone, and therefore no one, was responsible for doing the job.

The third problem with redundancy is that it often leads organizational leaders to increase production pressures, making the system perform at higher tempos or in less safe conditions. This overcompensation problem appears to be the reason that the increased use of helmets by skiers has led to a rise in the number of head injuries: Helmeted skiers feel safer and thus zoomed faster and more often skied between trees, with deadly results. This phenomenon lay at the center of the 1986 Challenger accident. When the safety engineers feared that the critical O-Ring would fail because of the unprecedented cold temperature at launch time, they were comforted by the (false) belief that the secondary O-ring would work if the primary did not. Like overconfident skiers, the Challenger decision makers zoomed forward thinking that redundant safety devices made their actions safe even in more hazardous conditions.

CONCLUSIONS

Scholars have clearly benefited greatly from the intellectual seeds planted by Charles Perrow. Yet I doubt whether the improvement in understanding has kept pace with the increased numbers of complex, tightly coupled systems and the spread of high-risk technologies to new places around the globe. There is clearly much intellectual work left to do.

First, we need more studies that contrast success stories with organizations that have suffered catastrophic accidents. Too often, accident scholars select on the dependent variable in their work—they study a serious accident and find, not surprisingly, that the system was complex and tightly coupled. Very little progress has been made toward the goal of measuring complexity and tight coupling ahead of time, however, which will be necessary to compare the safety records of hazardous organizations with similar structures (Wolf, 2001). More and better studies of that sort will be necessary to determine whether, or for how long, hazardous organizations with these structural conditions can exist without suffering serious accidents.

Second, we need much more work on organizational learning. Because trial-and-error learning is so dangerous in accident-prone systems, what alternatives exist? Many scholars (like the organizations themselves) have turned to studying simulations, experiments, and modeling exercises. This can be helpful, but we know relatively little about how accurate the lessons are from such artificial exercises and little about whether organizations discount them more easily than those based on historical experience. In addition, we know relatively little about how to use opportunities for organizations to learn from each other's errors. Can different institutional arrangements help overcome such impediments, as some claim has occurred in the nuclear power industry and civil aviation?

Finally, we need more (dare I say, redundant) work on the advantages and the disadvantages of different forms of redundancy on organizational reliability. Engineers have gone to great lengths to understand how to improve the independence of components in complex technical systems and how to configure them to reduce common-mode errors. Similar intellectual efforts are needed from organization

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theorists in the future. Otherwise, calls for more safety with hazardous techno gies could lead to counterproductive results, as organizational leaders simply p more bells and whistles onto their alarms and mistakenly think they have there placed us securely beyond the reach of accidents.

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