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Systems failure

Arnold M Howitt and **Herman B 'Dutch' Leonard** say that the threat of large-scale systems failure requires emergency managers to take bold steps to avert or mitigate damage and to be ready for more complex and extensive emergency responses

THE DIRECT IMPACTS OF JAPAN'S March 11 earthquake and tsunami were horrific: tens of thousands of people killed or missing and presumed dead, immense property damage, and an evacuation zone around the crippled TEPCO nuclear reactors.

As severe as these immediate effects of the disaster were, they were compounded by other effects – one thing after another, each affecting the others negatively. Within a wide area of Japan, particularly where the tsunami struck, the tightly interconnected systems of modern life virtually collapsed. Utilities (power, water, transport, communications), economic activity (manufacturing, power generation, food distribution, local businesses), social and community networks, and government services (sanitation, policing, emergency response, healthcare) were drastically disrupted or destroyed.

But the effects of the disaster spread much further than the areas physically affected by the earthquake and tsunami. People with relatives or friends in the impact zone desperately sought to make contact. National or regional companies with local operations sought word about their employees and property, and tried to avert disruptions to their businesses. The Japanese tourism industry shuddered. Non-governmental organisations outside of the disaster area sprang into action, with concern for members or networks of contacts affected by the earthquake and its aftermath. National political leaders and numerous national and provincial government agencies mobilised to cope with many new demands.

Outside Japan, companies that do business with affected companies in the disaster zone worked to patch together immediate or anticipated gaps in their supply chains.

A firefighter from Tokyo Fire Department measuring radiation and discharging water at the stricken Fukushima nuclear power plant

TFD

Meanwhile, the nuclear industry worldwide began assessing the impacts that TEPCO's reactor failures would have on their own political and regulatory environments.

Interconnectedness

Under normal conditions, interconnected systems of modern life operate in reasonable harmony with one another. Overall, they exhibit substantial resilience, absorbing small shocks to a system element without creating major discontinuities in services or activity. By contrast, in large-scale disasters, two or more circumstances may interact with cascading negative consequences.

This can be caused by an external shock like the earthquake/tsunami or by a spontaneous internal 'error' – a breakdown of one or more components of a system that take it outside the range in which it is supposed to operate. A

simple example illustrates the point: a rainstorm may bring down power lines, thus shutting down pumps needed to avoid flooding. The resulting flood may damage the electrical grid and pumping capacity further, making it more difficult to restart and harmonise the overall flood-prevention system.

A system accident or collapse occurs if one or more elements of the overall system are pushed beyond their design limits, resulting in a severe breakdown with reverberating impacts. When the earthquake and tsunami affected a wide range of interconnected components of Japan's economic, social, and government systems simultaneously, the resulting consequences fed on one another, and the effects pyramided – eventually pushing past the capacity of the system as a whole to absorb the sharp deviations from normal operating ranges.

System failures seem to be occurring more frequently and we believe this is a pronounced and important trend. For example, Pakistan's severe floods and the earthquakes in Chile and Haiti in 2010, both the blizzards and the Wenchuan earthquake in China in 2008, Hurricane Katrina in the United States in 2005, the Asian tsunami in 2004 – each of these disasters had similarly drastic effects on numerous aspects of modern life.

Such impacts don't occur by chance. Strong forces in the ways that economic, financial, natural, and man-made physical systems co-evolve in the modern world create, in turn, conditions that lead to system-level failures when disasters strike.

If the risk of system accidents is increasing, the implications are deep and wide. System collapse as a form of large-scale social hazard should be understood as a profoundly important phenomenon that needs to be addressed through changes in system designs, through policy, and – since it constitutes a risk – arguably through new approaches to defining and insuring the risks.

System accidents result when self-organised systems evolve towards a point of super-criticality. Their components, so tightly connected, become highly vulnerable to breakdowns

Where do these vulnerable systems – and system vulnerabilities – that characterise modern societies come from? Many of the systems we use (and inhabit) were not designed – they 'formed'. The interlocking destinies of their component subsystems developed gradually as a result of natural or human forces that brought or pushed them together – becoming what theorists call 'self-organising systems'. System accidents result when self-organised systems evolve towards a point of super-criticality. Their components are so tightly connected that they become highly vulnerable to breakdowns – small or large – if one or more are disrupted by natural or man-made disasters.

Most technology or financial systems have been constructed deliberately to anticipate and avoid the spiralling negative interactions that produce system accidents. But advances in technology have allowed these systems to become ever more complex. Theorists have argued – and experience seems to demonstrate – that we will observe critical events of all scales with a random, but probabilistically predictable frequency, in such systems. If we define a system accident as a critical event beyond a specified scale, system accidents will be inevitably recurring phenomena in deliberately-designed, as well as self-organising, systems.

Unfortunately, there is good reason to believe that neither individuals or organisations, nor governments, are sufficiently aware of or are designed to manage these risks in

advance – or to cope with the consequences.

Participants often don't realise that they are involved in systems; they do not recognise the interdependencies and risks as they generally have transactions with only one or a few components of the system. Consumers of food, for example, interact almost exclusively with the retail end of the distribution system, having little contact with the wholesale system or any of the other components that stand behind it. Farmers, who deal with the other end of the chain, only see in part the wholesale commodities purchasing and transport systems which buy and carry their products away.

Since many of the systems that create large-scale social vulnerabilities are at least partly self-organising, no natural regulatory process encompasses them. There is no comprehensive design or overall supervisor of the world's food production and distribution, manufacturing, or financial systems. Even at national level, no single institution is responsible for thinking about or regulating such systems comprehensively.

There is also a widespread lack of understanding of the nature of system accidents, their risks, and the conditions that create vulnerability. Large regulatory institutions – ie governments – frequently seem unaware of the conditions that generate vulnerability, and often lack the policy tools or political will which are necessary to mitigate hazards. While the safety systems of a nuclear power plant should be carefully designed and operate under a well-defined regulatory regime, Japan's experience illustrates shortcomings in both the range of plausible threats for which the nuclear industry was prepared, along with the ways in which government regulated these before the disaster and their response in its aftermath.

As globalisation increases competitive pressures in many domains of human life, there are strong forces pushing managers to achieve economies and efficiencies – often by decreasing safety buffers in their operations. For example, we have cut back significantly on warehouses and inventories, substituting just in time supply chains. These buffers provide some insulation if adjacent systems malfunction – and allow time for the system malfunction to be corrected before it causes problems elsewhere. But that insulation diminishes or disappears if we create more tightly coupled systems through just in time delivery.

Many of the systems that exhibit the characteristics of vulnerability outlined here are of a scale that transcends existing government structures. Consider the piecemeal and incompletely co-ordinated attempts to manage the recent – and ongoing – financial crisis and the attempts to co-ordinate system reforms. The financial system is global, self-organising, and driven by economic forces that tend to push systems toward super-criticality. It was not designed and therefore can easily develop difficult-to-notice linkages that generate significant potential for instability and system-level failure. Its current evolution and the development of new linkages is undertaken by self-interested agents who can't or don't see the larger system as a whole (and might not care if they could or did). It is not owned or overseen by any single regulatory overseer. It should be no great wonder, then, that it may have been (and may still be) self-organising itself into a supercritical state which is subject to system accidents.

US Marines pick up debris during humanitarian assistance at Oshima Island, Japan. The increasing frequency of system failures, exemplified by Japan's earthquake / tsunami / nuclear accident, also has important implications for response preparedness

US Marine Corps / Lance Cpl Brennan O'Lowney

The emergency response community is clearly not in a position – either in terms of authority or resources – to manage the risks of system accidents. Yet, as Japan's experience demonstrates, emergency responders must cope with the physical manifestations of many potential types of system accidents. What should the emergency management community be doing in regard to this social risk – both through professional organisations and the actions of senior leaders?

First, leaders of this community should use the 'bully pulpit' of their positions to call attention to system-accident hazards. They can do this as confidential advisers to elected leaders and senior policy officials, in public testimony to legislative bodies, in press conferences, media interviews and in public speaking to community audiences. There are obstacles. These include lobbying for more financial resources to deal with threats whose immediacy or necessity is debatable and which are competing with other societal needs. Although not likely to be sufficient to mobilise society, creating increased awareness of the risks may, over time, lead to the development of political will to address these hazards.

Second, the emergency response community needs to expand its focus in several dimensions of disaster preparedness: prevention/mitigation, response and recovery.

The response community knows the difficulty in mobilising societal resources for mitigating or preventing low-probability/high-consequence hazards like earthquakes or nuclear accidents. But major events like the tragedy in Japan offer a window of opportunity to grab the attention of policymakers and the public and may help build political and governmental support for protective measures. It is worth the effort to frame and promote strategies to prevent or mitigate the consequences of system accidents.

The increasing frequency of system failures, exemplified by Japan's earthquake/tsunami/nuclear accident, also has important implications for response preparedness. System failures are likely to have broader geographic impacts than 'ordinary' disasters, affect larger numbers of people, involve a wider range of social/economic damage, and last far longer than the events most response organisations typically encounter. As a result, they will require an extraordinary amount of surge capacity, including: A greater number of response organisations and responders; a vast array of responders from outside the normal first response community; involvement of multiple jurisdictions, levels of government, and even countries; and the need to orchestrate more varied resources of expertise and numbers of response personnel – even though authority over these responders is likely to be widely dispersed and imperfectly defined.

To respond effectively to such events, response organisations need to develop methods and comfort in functioning alongside allies from many fields of expertise, jurisdictions, levels of government, as well as non-governmental and business organisations. Prior relationships, outreach to potential partners, and co-ordinated planning will help.

But because system accidents inevitably involve people who have never met or worked together – requiring them to assemble sudden teams or hastily formed networks – it will be crucial to have a template of operations (like the National Incident Management System and the National Response Framework in the US or similar systems in other countries) that can be scaled up under catastrophic conditions. Having these common systems on paper will only be an initial step; they have to be trained and exercised effectively and used whenever possible, even in smaller events, so that they will be truly operational when a system accident occurs.

Public finances

Finally, we need to take advance steps to prepare for recovery, anticipating the difficult tasks of reconstruction that will follow a systems failure like Japan's. In a variety of ways, we can take low- or moderate-cost steps that have potentially high value in making recovery more effective or faster or both.

For example, we know that in the wake of a major disaster the public finances of affected areas will be in turmoil – revenues will decline precipitously, while creditworthiness will plummet. This will make it very difficult for a government to marshal funds for service resumption and replacement of infrastructure – steps which, in turn, could create sufficient confidence for individuals and businesses to return and invest their own resources in recovery. Before a disaster, however, local jurisdictions could prepare for this contingency (through some combination of insurance, reserve funds, and mutual assistance pacts with other areas), so that they could access loans in a time of crisis.

We know that after a disaster, a government will need to reconfigure its budget and restructure its institutions in response to the vastly different tasks of reconstruction that are suddenly necessary. Thinking through how that reorientation of government would look – and getting contingent authority on the books if a major emergency were declared – would allow a government to act more quickly in the wake of disaster.

Similarly, a government will want to ready streamlined procedures for building permits, environmental reviews, inspections, and other components of the reconstruction process so that action can be taken swiftly. It will also need to prepare plans to staff the huge surge of demand for these regulatory actions as an affected area seeks to revive after disaster.

Overall, the threat of large-scale system failure following events like Japan's earthquake requires the emergency management community to take bold steps in preparation – to avert or mitigate at least some of the damage that might occur from catastrophic threats; to prepare for a more complex and extensive emergency response; and to take steps in advance that will make recovery more rapid and effective.

None of this is easy; the challenges are enormous. But the potential for future system collapses like Japan's should spur our efforts to be ready. CRJ

■ *A more extended statement of this general argument can be found in an article by the authors published in* Swiss Re, Centre for Global Dialogue, Integrative Risk Management: Advance Disaster Recovery

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