Reducing the Potential for Cascade: Recognizing and Mitigating Situations that Threaten Business Viability

Katherine E. Walker, David S. Deary, and David D. Woods

The Ohio State University, 1971 Neil Avenue, Columbus OH 43210, USA
walker.891@osu.edu, deary.1@osu.edu, woods.2@osu.edu

Abstract. In today's rapidly changing, highly interconnected global business environment, small disturbances can quickly produce a cascade of further disruptions that challenge an organization's plans and ability to respond. The disturbance cascade can lead to an adaptive system failure as the system's capacity to keep up with the pace of events becomes exhausted. As the capacity to handle the demands of the cascading difficulties is consumed, mobilizing or generating additional capacity requires time and effort and must be begun early in order to match the pace and tempo of cascading disturbances. As a result, a key property of adaptive systems is the ability to forestall, cope with, and break disturbance cascades. This paper reports results on the strategies used by one organization to recognize where cascades may develop, to build a readiness to respond effectively in the face of cascading disturbances prior to actual events, and to respond effectively when cascades begin to develop. The results come from an on-going study with the operations center of a transportation firm that conducts continuous operations with hundreds of movements per day.

1 INTRODUCTION

In today's highly interconnected, rapidly paced global business environment, firms are facing challenging events with effects that propagate and cascade in surprising ways to disrupt business operations. Both large-scale events, such as "Superstorm" Sandy or Japan's 2011 tsunami, and small-scale events, such as the recent fake Associated Press tweet about explosions at the White House, have impacted businesses by affecting vital infrastructure, supply chains, and the decisions of other firms. To maintain continuity, resilient businesses must manage disturbances not only reactively but also proactively; they must look ahead to anticipate bottlenecks and challenges ahead.

This paper is the result of an on-going study with the operations center of a transportation firm. The company conducts continuous operations, performing hundreds of movements per day. The firm provides an excellent natural laboratory for resilience research due to its scale and complexity; up to sixty percent of the schedule

may change on a typical day and many of its operations are performed on short notice or with last-minute changes. The organization to be successful has to maintain a continuous ability to adjust to new events and disruptions for long term economic success and to conduct operations extremely safely at the same time. As a result, all parts of the operation are working to balance short term costs and productivity with the two chronic goals of long term economic viability and ultra-high safety.

The research team began by conducting a study of routine operations, then returned to observe operations when challenges occurred, some of which were known well in advance (e.g., associated with holidays or special events) and some with short notice (e.g., extreme weather; Deary et al., 2013). The team also conducted interviews with both management and operations personnel to understand how they prepared for and responded to these disturbances. An important aspect of this analysis was to understand how goals, trade-off management, and communication strategies changed in the face of disruptions.

Observing how management and operations personnel adapted their work in the face of challenge events revealed what the organization had learned about how to be prepared to handle surprises (readiness to respond) and how these mechanisms had become part of the organization's repertoire. Some of the specific activities we observed before and during challenge events included the establishment of senior management planning groups, weather impact analysis teams, and temporary local command centers.

The field research revealed that many of the mechanisms the organization had developed to handle surprise were tailored to deal with the potential for disturbances and challenges to cascade following a triggering event. The potential for cascade is a critical demand factor in both joint cognitive systems and complex adaptive systems (e.g., Woods, 1994). The *potential for cascade* refers to how a triggering event produces a set of disturbances which can propagate and interact over lines of interdependency. As a cascade of disturbances grows, the difficulties associated with responding also grow (Woods and Patterson, 2000), resulting in a positive feedback loop that reinforces and adds to the cascade of demands (Woods and Hollnagel, 2006). For complex systems under pressure to improve performance relative to acute goals, as changes produce more extensive interdependencies in a system and its interconnections, (higher coupling), the potential for cascade increases. As a result, the risk of falling into one of the basic patterns of adaptive system breakdown increase a great deal, particularly the risk of decompensation and working at cross purposes (Woods and Branlat, 2011). To be able to respond effectively in highly coupled networks, organizations need to be able to act to mitigate the spread of disturbances and break disturbance propagation. Again there is a tight interplay between demands and responses -- it is particularly difficult to try to cope with the challenges of cascades while in the middle of a cascade. This risk -- poor or delayed responses which then exacerbate the cascade, producing more demands on operational units and for coordination across units -- means that preparation is essential. Organizations that

confront the potential for cascade develop mechanisms in advance that can be brought to bear to cope with the general demand properties of cascades.

Among many examples of cascades that challenged organizations or industry sectors, consider the 2010 European Ash Cloud crisis. While that cascade triggered by the volcanic eruption in Iceland was handled quite poorly, this paper reports the results on an organization that has developed a variety of mechanisms to be prepared to respond to cascades. The observations of the transportation firm before and during challenge events showed utilization of explicit and implicit means to build common understanding about interactions among roles, mechanisms for planning that address goal trade-offs and resource allocation, initiative regarding the exercise of authority at all levels, and the reconfiguration of information flows to accommodate new channels, uncertainties, noise, and increased volume.

2 UNDERSTANDING SYSTEM TRADE-OFFS

All work systems must balance trade-offs; multi-role systems as a rule have goal conflicts and finite resources with which to manage goals (Woods & Hollnagel, 2006). Situations with a high potential for cascade force businesses to confront and change the way they manage trade-offs in order to maintain operations. The trade-offs of particular concern for this paper are acute-chronic trade-offs. Examples of these include balancing the acute need for production versus the chronic need to maximize safety, and the acute need for production versus the chronic need to protect and maintain equipment. These trade-off decisions can be remarkably difficult. They must be made quickly in disruptive situations and mismanaging them can result in losses relative to business viability over the long term. This challenge is compounded by a tendency to sacrifice long-term objectives when there is an increased pressure to meet short-term targets. Work systems must devote resources to ensure that chronic goals are protected and that various roles are not working at cross purposes, which can be quite difficult during a challenge event in which resources are necessary elsewhere (Hoffman & Woods, 2011).

3 MANAGING CASCADES

Woods and Branlat (2011) describe decompensation, or the exhaustion of adaptive capacity in the face of growing disruption, as one of the basic patterns in adaptive system failure. Breakdown occurs when disturbances grow and cascade faster than responses can be formed and deployed. Initially, the system is able to act and compensate for the disruption, but as new challenges arrive, there is no longer capacity to keep up with the escalating situation (Woods, 1994; Woods and Patterson, 2000). Woods and Wreathall (2008) developed the stress-strain model to represent how an organization is able to adapt and match response capabilities to meet changing demands factors that arise to challenge the organization's ability to stay in control and

meet a range of goals. Figure 1 shows the stress-strain adaptive landscape annotated for the challenges presented by the potential for cascade.

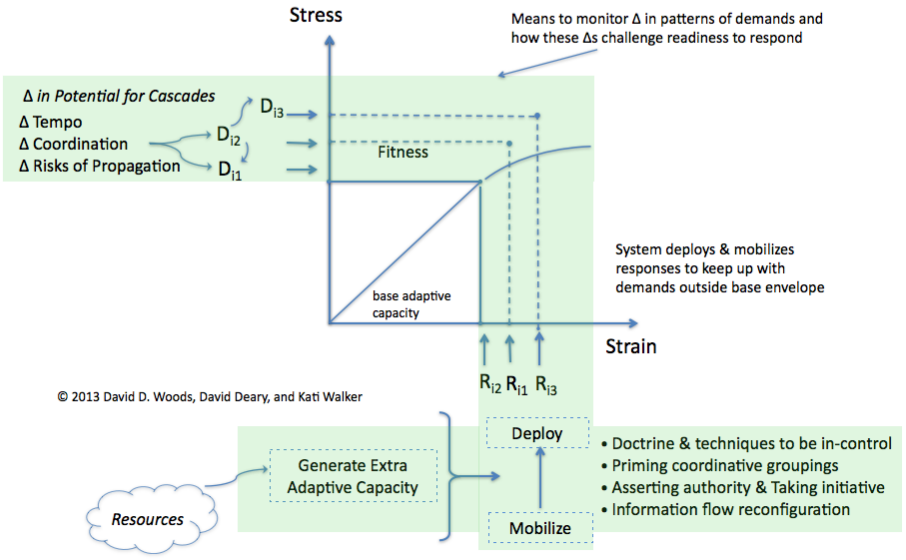

Fig. 1. The stress-strain adaptive landscape annotated for the potential for cascade. Fitness is represented by the match of responses (x-axis) to demands (y-axis). Cascades challenge the boundary of the system's base adaptive capacity, and require the system to mobilize and deploy extra adaptive capacity to handle the demands. This study examined how an organization prepared to deal with high potential for cascade situations, that is, what the organization learned about how to be able to mobilize and deploy responses in the face of the special properties of cascading situations.

In a cascade sequence, demands increase rapidly and unpredictably as new difficulties arise and interact. Cascade sequences are particularly interesting because of the increase and changes in tempo, the coordination links across units change, and new risks arise about how planned responses can break down (i.e., the risk of failing to mitigate or break the disturbance cascade). During cascade events, the system must monitor for changes in the pattern of demands and understand how the cascade could

propagate. This gives rise to a need for adapting coordinative activity, which can introduce more demands into the system as management and personnel are consumed by new tasks, new data flows, and new forms of uncertainty. As difficulties propagate, the tempo of the situation will increase and squeezing the time available to analyze, replan, and execute new courses of action.

In response to these difficulties, an organization must be prepared to generate, mobilize, and deploy additional adaptive capacity to keep pace with or block cascading demands. In our observation, we identified four types of responses tailored to cope with the potential for cascade.

3.1 Doctrine and techniques to be in-control

Businesses may use past experience, their knowledge of resources available, and projections of future resource use to predict which events will pose challenges to adaptive capacity. Once the business recognizes a known or emergent disruption, it will begin to behave in accordance with its doctrine for dealing with the class of event at hand. While it will begin to execute explicit standing policies, in behaving along doctrinal lines individuals and functions will interact based on a shared frame of reference shaped by implicit expectations as well as explicit directives. In organizations with low turnover in key positions, such as our example firm, these implicit expectations are formed through years of shared practice in coping with disruptions. A challenge outside the bounds of the firm's doctrinal experience may constitute a surprise that impairs the group's ability to assess and respond to the risk of propagation associated with a cascade.

During the challenge event, operators must work to make detailed decisions and deploy resources to match the tempo of the disturbance. As time pressure grows, there is less time to evaluate different options; waiting to make a decision may cause the disturbance to worsen. Operators often use previously developed techniques to make the best possible decision as quickly as possible to prevent further disruption. As one senior operator noted while preparing for Hurricane Sandy, "The key is giving a quick response to a new request, otherwise it snowballs."

Management may help determine these heuristics when they directly affect the business goals, but working-level personnel will often develop their own techniques for working at a faster pace. In the example, while an operator may typically have the time to determine the best and least-expensive option to move an asset from place to place, in an event with high potential for cascade, they might simply use the fastest available alternative without regards to cost in order to maintain maximum adaptive capacity.

3.2 Priming coordinative groupings

When a major disruption can be seen years in advance (e.g., holidays) or just days ahead of time (e.g., a hurricane), management forms priming coordinative groupings to prepare for the event. While established doctrine is an invaluable starting point for responding to an emergent situation, a group convened to deal with a particular event is essential in addressing the unique circumstances of the new challenge. The group's

success hinges in many ways on its ability to apply lessons from similar past events while recognizing potential differences.

In our observation, one of the most important specific activities performed by such groups is to alter resource allocation plans prior to the event to ensure maximum adaptive capacity is available to respond to disturbances. This is not always easy to do; difficulties may cascade in surprising ways, and the highly interconnected economy of the modern world means events that seem distant can still have strong effects. Nonetheless, it is vital to secure resources prior to the event because there are time and work costs to obtaining additional adaptive capacity that challenging situations typically do not allow, and waiting to obtain these resources often means they will arrive too late in the situation to be useful. This requires the firm to focus on chronic goals such as safety and business viability. It is common for these additional resources to be cut if they have not been used in previous events for the acute goal of saving money. In the example, the firm may employ additional operators or assets to deal with increasing demand on the system, or contract with additional businesses outside of the affected area if partner businesses in the area will be non-operational due to the weather system. When dealing with events known well in advance, in particular one that affects operations in only one or a few locations, it is helpful to deploy personnel with the authority and expertise needed to anticipate and ease production bottlenecks to the location. This arrangement has the advantage of enabling the central operations center to gain insight from the on-site team, and by transferring decisions to the local team it frees headquarters personnel to address system-wide issues.

3.3 Asserting authority and taking initiative

In preparing for a disruption, priming coordinative groups of senior managers assert authority that they do not often need to exercise during routine operations. In our observation, many of their most important decisions address acute-chronic trade-offs in the system and ensure that chronic goals such as safety are maintained during challenge events. The example firm might make decisions about when or if they should cease operations in the severe weather area to protect the safety of operators and assets. The firm might also direct working level personnel to secure added resources such as a new supplier just in case it is needed. While the exercise of authority from senior management provides appropriate and necessary guidance to working level personnel, it also creates increased demands, in particular for additional reporting on operational details not normally of interest during routine operations. This behavior is typical of an organization grappling with a difficult technical situation, a circumstance known in the nuclear power industry as “going solid’ (Cook & Rasmussen, 2005).

In typical business operations, individual roles take the initiative to balance local goals, including their own, to create the best possible solution for all roles. However, in an event with high potential for cascade, they may ignore localized goals in favor of chronic, system-oriented goals to best maintain system control. To accomplish this, it is important for working-level operations personnel to understand how their actions impact the system as a whole and their responsibility in maintaining the system’s

chronic goals. Armed with this knowledge, they may take initiative to fulfill the intent of top-level direction in advance of specific guidance from senior management, such as pursuing additional asset protection measures in areas on the edge of a nominal weather impact zone.

3.4 Information flow reconfiguration

It is not enough for management to develop strategies to deal with a potential disruption; operations personnel must be informed of changing priorities so those new strategies can be successfully carried out. Ideally, this communication process occurs continuously prior to and throughout the event. In our weather example, this information would be updated and revised as the storm path changes—an area previously assumed to be in the path might be completely safe, while another area might need to be evacuated much earlier than assumed. While this is happening, the changing strategies of partner businesses must also be observed so the firm can update its movements relative to theirs. This process is resource-intensive, but extremely useful in assisting resilient businesses with making decisions that compensate for system disturbances and are in pace with the tempo of disturbances.

During periods of extremely high tempo operations, personnel facing clogged communication channels must change their communication strategies to direct attention to important disturbances. Most roles will have little capacity to monitor all sources of communication during a disruption, especially if there are multiple, simultaneous electronic channels to be monitored. Operations personnel must work to find the most effective communication methods to ensure vital information is seen and understood. This may frequently take the form of communicating face-to-face. Operators seated near each other may elect to speak (or shout) to their colleagues, or personally visit more distant partners. This physical presence is a clearly recognizable sign of the importance and time-critical nature of the information being delivered.

4 CONCLUSION

Resilient businesses manage disruptive events by effectively shifting priorities to support chronic goals and maintain business viability. Within a business, goal conflicts between roles are inevitable; a resilient business must devote resources to understanding these conflicts and how they should be managed to avoid damage to long-term objectives, especially in the face of a major disruption. The transportation firm studied for this paper maintains a strong awareness of each role's responsibility to maintain chronic goals, as a loss of adaptive capacity in a disruptive situation will both place lives and property at risk and threaten business viability. The chronic goal of safety must be strongly emphasized in any such challenge event.

By describing the actions of a highly adaptive firm in the face of disruptions, this paper identifies key behaviors that assist in the successful management of situations that may disturb business operations. Learning to anticipate and mitigate circumstances with high potential for cascade provides several benefits:

• Doctrine and techniques can be updated to support trade-off management,
• Priming coordinative groupings can consider new forms of resource allocation,
• Authority delegation and retention can be adjusted to better balance senior-level involvement and working-level empowerment,
• Information tools can be designed to facilitate new information flows about interdependencies, side effects, disturbance interactions and propagation paths.

Addressing resources such as these assists businesses in further building adaptive capacity and thus becoming more resilient in the face of disruptive change, particularly those events with a high potential for cascade.

ACKNOWLEDGEMENTS

We thank our transportation research partner, in particular the operations center staff. We also gratefully acknowledge the support of the Eddowes Fund and our transportation research colleagues at The Ohio State University.

REFERENCES

Cook, R. & Rasmussen, J. (2005). "Going solid": A model of system dynamics and consequences for patient safety. *Quality and Safety in Health Care, 14*(2), 130-134. doi: 10.1136/qshc.2003.009530

Deary, D. S., Walker, K. E. & Woods, D. D. (2013). Resilience in the face of a superstorm: A transportation firm confronts hurricane Sandy. *The Human Factors and Ergonomics Society 57th Annual Meeting*, September, 2013. Paper accepted for publication.

Hoffman, R. R., & Woods, D. D. (2011). Beyond Simon's slice: Five fundamental trade-offs that bound the performance of macrocognitive work systems. *IEEE Intelligent Systems, 26*(6), 67-71. doi: 10.1109/MIS.2011.97

Woods, D. D. (1994). Cognitive demands and activities in dynamic fault management: Abduction and disturbance management. In N. Stanton (Ed.), *Human factors of alarm design* (pp. 63-92). London: Taylor & Francis.

Woods, D. D. & Branlat, M. (2011). Basic patterns in how adaptive systems fail. In E. Hollnagel, J. Pariès, D. D. Woods & J. Wreathall (Eds.), *Resilience engineering in practice: A guidebook* (pp. 127–144). Farnham, UK: Ashgate.

Woods, D. D. & Hollnagel, E. (2006). *Joint cognitive systems: Patterns in cognitive systems engineering*. Boca Raton, FL: Taylor & Francis/CRC Press.

Woods, D. D. & Patterson, E. S. (2000). How unexpected events produce an escalation of cognitive and coordinative demands. In P. A. Hancock & P. Desmond (Eds.), *Stress workload and fatigue* (290-302). Hillsdale, NJ: Lawrence Erlbaum Associates.

Woods, D. D. & Wreathall, J. (2008). Stress-strain plots as a basis for assessing system resilience. In E. Hollnagel, C. P. Nemeth & S. Dekker (Eds.), *Resilience perspectives, volume 1: Remaining sensitive to the possibility of failure* (143-158). Aldershot, UK: Ashgate.