Sources of Organizational Resilience:
Sustaining Production and Safety in a Transportation Firm

DISSERTATION

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Abstract

This study applies principles of the emerging field of Resilience Engineering to examine the relationship between how well organizations can adapt to disruption and how effective that organization is at proactive safety management. Prior research has shown that an organization can be highly adaptive to relatively frequent disrupting events in order to meet production pressure and economic goals, while at the same time that organization can have a weak safety record. However, transportation firms must meet the ultra-high safety expectations of government regulators, customers, and the public in general. At the same time, in order to operate successfully as businesses, these organizations must be highly adaptive to schedule disrupting factors such as customer desires, weather, seasonal trends, infrastructure concerns, and special events.

The study was conducted between August 2012 and November 2014 in partnership with a major transportation company. The firm served as an excellent natural laboratory for this research because, in addition to being inherently adaptive in normal operations, it has been a high achiever in proactive safety management.

The organization’s normal mechanisms for handling schedule changes were studied through ethnographic observations and interviews and provided a baseline for comparison. The main focus of the study was on how the organization responded to specific challenge events, which were observed directly and further explored through
follow-up interviews. Challenges included extreme weather events such as Hurricane Sandy and predictable periods of high transportation demand such as the Thanksgiving holiday. Other events, such as the Super Bowl, were challenging because operations were tightly focused in time and space. In all cases, poor handling of the consequences of a disruption could have a significant impact on the firm’s customers and its business base; a major safety incident could affect the long-term viability of the organization.

While normal operations had built in mechanisms to support smooth adaptation to the regularly occurring scale of disruptions, the company reconfigured these mechanisms to be prepared to keep up with the pace imposed by the challenge events. Relationships across levels, information flows, and decision authority all changed in order to make timely and effective decisions even though the challenges produced surprises that could not be predicted in detail. These reconfigurations included pushing initiative down to points of action and re-prioritizing responsiveness over cost. Such changes allowed for rapid decisions and actions to reduce the potential for events to cascade during large challenge situations or to mitigate or stop event cascades in progress.

The study also captured longer-term trends in the firm. Increased demand coupled with severe weather in the latter part of the study period tested the firm’s adaptability. It was able to increase organic resources to meet demand, but that process illustrated the interaction of financial challenges with performance pressures that required high adaptability.

The study adds to the body of empirical studies of resilience in action for the growing field of Resilience Engineering. The study highlighted patterns about organizations that
are able to demonstrate resilient performance in the face of potentially surprising challenges.
To Rita Marie
Acknowledgments

I’m honored to be the latest in a long and distinguished line of cognitive systems engineering students to have benefitted from the guidance of Dr. David D. Woods. Dave’s unwavering personal and professional support have broadened my horizons far beyond what I had hoped for when I started this program at The Ohio State University (OSU) four years ago. Dr. Philip J. Smith offered insights regarding the nature of computer supported collaborative work that proved invaluable as I examined how work was accomplished in my research setting. Dr. Blaine W. Lilly applies an uncommonly diverse set of perspectives to what are sometimes viewed as solely engineering problems, an approach I greatly benefitted from on this project. My friend, Katherine E. Walker, was the perfect colleague to have in exploring how to apply Resilience Engineering principles in a domain new to both of us.

I am deeply indebted to the highly professional -- and remarkably patient -- men and women of our research partner firm who shared their world with me; I hope this work will prove worthy of the time they invested in educating me. I’m especially grateful to our principal sponsors, Brian, Richard, and Bob. I’m also thankful for the generous financial support of the Eddowes fund and our transportation research colleagues at OSU. I could not have done this without the love and tireless support of my family and the inspiration of my father, Bill, the original Dr. Deary.
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Specialization in Cognitive Systems Engineering

Minor Field: Field Studies

Minor Field: New Product Development
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Chapter 1: Introduction

1.1 Relevance

Recent work in the field of Resilience Engineering (Hollnagel, Woods, & Leveson, 2006; Hollnagel, Pariès, Woods, & Wreathall, 2011; Nemeth & Hollnagel, 2014; Woods, in press) has examined the relationship between how well organizations can adapt to disruption and how effective that organization is at proactive safety management (Amalberti, 2006; Morel, Amalberti, & Chauvin, 2008; Amalberti, 2013). The results show that an organization can be highly adaptive to relatively frequent disrupting events in order to meet production pressure and economic goals, while at the same time that organization can have a weak safety record. In other words, being resilient (in terms of short run adaptability) can be mis-aligned with being safe especially in terms of the functions of proactive safety management such as anticipating, learning, and acting to reduce vulnerabilities before major accidents occur.

However, transportation firms must meet the ultra-high safety expectations of government regulators, customers, and the public in general. At the same time, in order to operate successfully as businesses, these organizations must be highly adaptive to schedule disrupting factors such as customer desires, weather, seasonal trends, infrastructure concerns, and special events.

Resilience Engineering holds promise for helping organizations improve their proactive safety management by learning lessons of success from themselves and others, as
opposed to simply critiquing failure. It is in this spirit that preliminary lessons of this study were presented at two academic conferences (Walker, Deary, & Woods, 2013; Deary, Walker, & Woods, 2013) and that this dissertation hopes to make its own modest contribution to an emerging and exciting field.

1.2 Resilience in brief

The notion of resilience has been explored in fields as diverse as ecology (Holling, 1973), energy (Lovins & Lovins, 1982), network-centric infrastructure (Alderson & Doyle, 2010), and human organizations (Weick & Sutcliffe, 2007), but terminology across and even within disciplines remains varied. The definition below from ASIS International (formerly the American Society for Industrial Security), a business continuity organization, captures in three sentences several popularly discussed aspects of resilience:

“Resilience: The adaptive capacity of an organization in a complex and changing environment. NOTE 1: Resilience is the ability of an organization to resist being affected by an event or the ability to return to an acceptable level of performance in an acceptable period of time after being affected by an event. NOTE 2: Resilience is the capability of a system to maintain its functions and structure in the face of external and internal change and to degrade gracefully when it must” (ASIS, 2009, p. 47).

Woods (2015) has identified four fundamental concepts of resilience that sound notes similar to those above, but with significant revision and extension. In their briefest form, these four labels for resilience are:
- Robustness: increased ability to absorb perturbations.

- Rebound: recovery from disrupting or traumatic events to return to previous or normal activities. Along with robustness, rebound is a term often used synonymously with resilience.

- Graceful extensibility: the capability of a system to stretch to handle surprise. Like the idea of graceful degradation, graceful extensibility is a sense of resilience that describes the ability to avert the sudden collapse associated with brittleness, but extensibility is an expression that recognizes that a stretched system is not necessarily failed one.

- Sustained adaptability: the architectural properties of layered networks that enable adaptation to future surprises as conditions change. Although it’s not clear what time scale ASIS had in mind in discussing adaptive capacity in a changing environment, Woods intended sustained adaptability to be understood as an evolutionary property of a system.

Closely related to the above concepts is another characteristic of resilience that Woods and colleagues found important, capacity for maneuver (CfM) (Stephens, Woods, & Patterson, 2015; Woods, in press). CfM represents the range of adaptive behavior available to a system to cope with events, variations, and challenges. Successful regulation of CfM enables a system to “sustain a potential for adaptive action in the future” (Stephens et al., 2015, p. 130).

Although this study will examine numerous properties of resilience, those above capture its most fundamental traits and set the stage for further discussion in subsequent chapters.
1.3 Study conducted

The Cognitive Systems Engineering Laboratory (CSEL) at The Ohio State University (OSU) conducted this study in partnership with a highly adaptive major transportation company. It builds on prior CSEL research efforts in Resilience Engineering, including work in cyber security (Branlat, 2011) and business continuity (Romine, 2012), among other domains.

The study’s data consisted of ethnographic observations and interviews conducted between August 2012 and November 2014. The author and another researcher performed observations and interviews for the first eight (and most intense) months of the project, while the author alone conducted the rest of the observations and interviews.

Observations began with “shadowing” workers in the firm’s operations center (OC) during periods of routine activity, followed by visits during periods of high demand, such as severe weather events and holidays.

All observations in this study were conducted by observing activities in progress, discussions with participants (of past or ongoing events) while they were on duty at their workstations, or in semi-structured interviews, all recorded using handheld notes. Use of information tools was noted, and some written metrics, communication, and policies were obtained.
1.4 Objectives

1.4.1 Objective 1: Identify critical elements in the balance between production and safety in this firm

This study was the result of partnership with a highly adaptive business that is also a high achiever in proactive safety management, providing a unique opportunity to identify the critical factors that allow such organizations to align resilience and safety. Although informed by theory, this study’s findings are grounded in observations of a resilient organization at work and offer specific examples of how the firm coped with challenge events.

1.4.2 Objective 2: Apply these findings in extending or modifying existing theories of Resilience Engineering

Understanding how groups such as our partner are able to align resilience and safety will provide a vital contribution to the field of Resilience Engineering and can provide guidance to transportation companies and other industries on how to carry out the key functions of proactive safety management. Resilience Engineering is a rapidly growing field, and this study offers a natural extension to its expanding body of work.
Chapter 2: Background and Literature Review

2.1 Overview
Resilience Engineering brings to bear the perspectives of organizational behavior and complex adaptive systems to address safety from a viewpoint that regards accidents “as breakdowns in the adaptations necessary to cope with the real world of complexity” (Woods, Dekker, Cook, Johannesen, & Sarter, 2010).
The chapter addresses some of the better-known models of safety that are considered (and modified) in Resilience Engineering. It briefly describes complex adaptive systems, which are foundational for this emerging engineering field. It then outlines patterns of resilience and failure that reflect the previously cited influences. These patterns of resilience and failure support much of the discussion in chapter 5.

2.2 Theories and models of safety
Resilience Engineering attempts to draw on a wide body of knowledge beyond the quantitative fields favored in traditional engineering practice. It relies on theories of safety based on research in human error, control theory, and organizational psychology.
Below are five of the more significant approaches.
2.2.1 Normal accident theory

In specifically analyzing the nuclear power accident at Three Mile Island (TMI), Perrow (1981) came to the conclusion that not only was an accident like that bound to happen at a nuclear power plant, it was bound to happen again. Similar accidents in other high-risk industries, such as those dealing with toxic chemicals, were also inevitable, and should be considered “normal.” Perrow evolved his 1981 paper into a book (1999, originally 1984) detailing a complete normal accident theory. At its heart were two sets of opposing characteristics for systems themselves (complex versus linear) and the coupling within systems (tight versus loose). However, Perrow did not claim that the properties of any one given system are, say, all linear or all complex; they are likely a mix of both.

2.2.1.1 Complex systems

According to Perrow (1999), in the complex system, interactions “are those of unfamiliar sequences, or unplanned or unexpected sequences, and not visible or immediately comprehensible” (p. 78). In the complex system, failures are difficult to isolate because: the equipment is tightly spaced; the connections among them are common-mode; subsystems are interconnected; substitutions are limited; feedback loops are many; controls are multiple and interacting; information is obtained indirectly; and understanding of the system on the part of its personnel is limited, in part due to the fact specialization is required.
2.2.1.2 Tightly coupled systems

In the tightly coupled system: time delays in processes are not possible; the ordering of process sequences is invariant; slack resources (e.g., supplies, equipment, personnel) are few; and buffers and substitutions must be designed into the system.

2.2.1.3 The normal accident

Perrow (1999) concluded that the combination of interactive complexity and tight coupling in a system might rarely produce an accident, but such an accident was inevitable, warranting the descriptor “normal” (or “system”) accident (p. 5). Systems he placed in this category included nuclear power, nuclear weapons, deoxyribonucleic acid technology, aircraft, chemical plants, space missions, and military early warning (p. 97).

2.2.2 Latent failure model

The latent failure, or “swiss cheese,” model of Reason (1990) has been enjoyed wide popularity in the safety community. The model assumed that accidents are not the result of a single major failure, but of the alignment of multiple, potentially small failures in both humans and machines, as depicted in figure 1 below.
While prior accident theories tended to regard only actions occurring in real time as events unfolded, Reason introduced the notion of the latent failure, a flaw that was already present in the system, but not revealed until triggered by another event. With machines, a latent failure might result from an intrinsic defect, such as the o-rings in the space shuttle Challenger, which coincided with the atypical condition of unusually cold weather at launch. With humans, a latent failure might be, for example, an unsafe act that resulted from a psychological precursor such as a cultural issue induced by management practices.
2.2.3 Control theory

The control theory of Rasmussen (1997) took a broad view of the dynamics affecting system safety, regarding it as an equilibrium to be maintained within boundaries of acceptable organizational behavior, as depicted in figure 2 below.

Figure 2. Boundaries of performance of acceptable behavior (Rasmussen, 1997, p. 190).

In Rasmussen’s model, the forces in play are: economic (management pressure toward efficiency); workload (pressure toward least effort); and safety (a counter gradient from “safety culture”). Behind the relatively simple graphic above is the assumption that there are complex interconnections and feedback loops among the actors in the system, as
one would expect in control theory of any sort; in applying engineering principles to an issue that is social as well as technical, it rejects simple linear theories of accident causation.

2.2.4 High reliability organizations

Building on foundational studies of safety in environments such as aircraft carriers (Rochlin, LaPorte, & Roberts, 1987), high reliability organization (HRO) theory has had a major impact on the safety community. Weick has served a leader of the HRO movement, and his more recent work with Sutcliffe (2007) distilled much of what they had come to believe about organizational safety into principles of anticipation and commitment.

2.2.4.1 Principles of anticipation

HROs are preoccupied with failure, and must avoid complacency by being on the lookout for early signs of failure. They are also reluctant to simplify, and assume that seemingly familiar unfolding events might have critical differences with past events that are masked. HROs are sensitive to operations and attentive to how work is actually being done at the sharp end of practice.

2.2.4.2 Principles of commitment

HROs are committed to resilience (of three types) in that they seek to develop capabilities: to absorb strain and continue to function during a challenge event; to bounce
back following a challenge event; and to learn from these events. HROs have a second commitment in the form of deference to expertise, which tends to decentralize control.

2.2.5 Amalberti’s three models of safety

Amalberti (2013) proposed that a complex system uses one of three distinct models of safety depending on the stance that stakeholders in the system take towards risk. He further argued that it would not be wise and may not even be possible to mix these models within a given system.

2.2.5.1 Resilience model

In the resilient setting, the economic model of the system assumes that practitioners seek exposure to risk and that the expertise of individual professionals enables them to innovate and cope with these risks. Commercial sea-fishing (Morel et al., 2008) is one such setting, as are Himalayan mountain climbing and combat aviation. Note that while most other theorists consider adaptation to be key characteristic of a resilient system, few equate resilience with intentional risk-seeking behavior.

2.2.5.2 HRO model

Amalberti (2013) described the HRO model (Weick & Sutcliffe, 2007) as being used in settings where risk is recognized as being inherent in the system, but is not sought out. Success in this model requires adaptation by groups, and not just individuals as in
the resilient case. Amalberti considered (non-combat) naval aviation (Rochlin et al., 1987), fire fighting, and the oil industry to be operating along HRO lines.

2.2.5.3 Ultra-safe model

In the ultra-safe model, risk is reduced as much as possible through the application of detailed procedures and effective supervision. His ultra-safe industries included commercial, passenger-carrying transportation (e.g., aviation, railroads, subways) and nuclear power.

2.3 Complex adaptive systems

Theories of complex adaptive systems (CAS) have been used to analyze such seemingly unrelated domains as the economy, the ecosphere, and immune systems. Although there is no universally agreed upon definition for them, Holland (1987) summarized some of their key attributes in early work presented at the Santa Fe Institute (as cited by Waldrop (1992)).

As is evident in section 2.4, which outlines Woods’ (2011) patterns of resilience, Resilience Engineering is heavily based on CAS thinking, hence the similarity of the language in 2.4 to that found in the subsections immediately below.

2.3.1 Decentralized networks of agents

First, Holland noted, CAS may be considered networks of agents, be they nerve cells in the brain or households in the economy. CAS have highly dispersed control, with no
master controller, and many levels of organization. Despite this lack of central control, CAS constantly rearrange their building blocks as they gain experience; a nation, for example, may choose to enter new alliances and trade agreements.

### 2.3.2 Anticipation and fitness

Holland further observed that CAS have the ability to anticipate and predict in support of their adaptation. Such anticipation may be observed in the conscious behavior of traders in the oil market; an unconscious form of anticipation appears in the form of genetic coding. CAS have many niches, and agents adapt to fill them, such as a worker choosing to become a computer programmer. Despite this, agents are never completely optimized for their environment; change to improve their fitness is a continual process.

### 2.4 Patterns of resilience

As noted earlier, Woods (2015) identified four labels for resilience: robustness; rebound; graceful extensibility; and sustained adaptability. In an earlier book he drew on findings from a diverse set of domains to identify widely observed patterns that produce different types of resilience (Woods, 2011). Below are patterns, along with sources cited by Woods, plus other relevant sources.

#### 2.4.1 Resilience pattern: Recognition of adaptive capacity

Resilient systems must be able to recognize their own adaptive capacity, especially when it is falling. In examining large, complex adaptive systems, Scheffer et al. (2009)
suggested that early-warning signals exist that enable the identification of tipping points where diminished adaptive capacity will collapse the existing system. The failure to identify (or provide) such warning signals can be catastrophic.

In many regards this pattern might be regarded as the most over-arching of the patterns, and a failure in this pattern is often the result of decompensation, as discussed in section 2.5.

### 2.4.2 Resilience pattern: Buffers and reserves

A more specific application of the pattern described above, this pattern acknowledges the importance of being able to assess the status of buffers and reserves, particularly in terms of physical (or at least quantifiable) resources. Cook & Rasmussen (2005) observed how resilient hospitals successfully deal with patient surges, known as “bed crunches,” through buffering of patients in select units and using other artful ways of managing patient transfers.

### 2.4.3 Resilience pattern category: Goal tradeoffs

This broad pattern identifies the need for resilient systems to shift priorities across goal tradeoffs, which are detailed below. Hoffman & Woods (2011) have also modified and expanded them in putting forth an argument that there are fundamental tradeoffs that bound the performance of human work systems.
2.4.3.1 Resilience pattern: Optimality-brittleness tradeoff

Alderson & Doyle (2010) demonstrated, in the context of CAS, a tradeoff familiar to many engineers, the notion that a system optimized for one quality (e.g., speed) will prove brittle in others (e.g., reliability). They also pointed out that such systems may prove hard to evolve (or adapt) to a changing environment over the long term.

As described in the Woods (2011) patterns of resilience framework, the “optimality-brittleness” tradeoff was meant to convey that brittleness is a consequence of the pursuit of optimality. While this is a readily understood concept, the terminology did not represent a tradeoff between two positive qualities, such as the two tradeoffs that follow. Hoffman & Woods (2011) updated the phraseology to “optimality-resilience of adaptive capacity” tradeoff. Note that it isn’t simply called “optimality-resilience” since resilience is multi-attribute property. With the indulgence of the reader, this paper will continue to use optimality-brittleness for the sake brevity.

2.4.3.2 Resilience pattern: Efficiency-thoroughness tradeoff

Hollnagel (2009a) explained that thoroughness may be shortchanged in work settings in favor of efficiency due to lack of time or information. When such tradeoffs are poorly handled, one might find institutionalized attitudes regarding some practices such as “it is not really important” (at this moment) or “it has been checked earlier by someone else” (p. 35).
2.4.3.3 Resilience pattern: Acute-chronic tradeoff

Woods (2006a) emphasized that acute production pressures can compel the sacrifice of long-term goals such as safety. Among the examples he cited was the failure of the Mars Climate Orbiter. The program was conducted in the era of “Faster, Better, Cheaper” management at the National Aeronautics and Space Administration (NASA), in which mission objectives were not reduced despite severe cuts to budgets and personnel levels.

2.4.4 Resilience pattern: Perspective shifts

Agents in a resilient system shift their own perspectives and seek the diverse perspectives of others. Applying a complex systems approach, Hong & Page (2004) demonstrated groups of diverse problem solvers can outperform high-ability problem solvers. Working in the domain of air traffic control, Smith, Spencer, and Billings (2009) illustrated how perspective shifts and contrasts are essential in a highly distributed air traffic flow management system.

2.4.5 Resilience pattern: Changing interdependencies

Understanding interdependencies is essential to understanding a system, and a resilient system successfully navigates changes in these interdependencies. A case in urban firefighting studied by Branlat, Fern, Voshell, and Trent (2009) documented the challenges of coordinating interdependencies across roles, activities, goals, and levels in a multi-unit fire response that included a highly dangerous backdraft.
2.4.6 Resilience pattern: learning

Learning -- and, more specifically, learning new ways to adapt -- is a critical long-term issue for the organization aspiring to resilience. Hollnagel (2009b) placed it among his four cornerstones of Resilience Engineering along with anticipating, monitoring, and responding.

2.5 Patterns of failure

Woods and Branlat (2011) offered a description of patterns of failure, which, like the patterns of resilience, take on the thinking and language of CAS. Although the list below is not an exhaustive description of failure subpatterns, it does outline the three broad categories of patterns that they identified.

2.5.1 Failure pattern: Decompensation

Decompensation occurs when a system cannot deploy enough timely responses to match the challenges it confronts. Figure 3 below illustrates the decompensation process. Before decompensation begins, the system successfully compensates for disturbances with measured control inputs. As new and growing disturbances cascade, however, control inputs increase to the point where decompensation begins. Although the system might initially mask how hard it is working to maintain control, it will eventually exhaust its capacity to compensate, resulting in a decompensation event.
Figure 3. The basic decompensation signature (Woods & Branlat, 2011, p. 131).

In describing an example of an aircraft on autopilot in an asymmetric icing situation, Woods and Branlat (2011) noted that pilots may recognize and intervene to prevent a loss of control only after the autopilot has nearly exhausted its control authority, resulting in a bumpy and potentially dangerous transfer of control.

 Appropriately reflecting the origin in medicine of the term decompensation, Cook, Woods, and McDonald (1991; also Woods & Cook, 2006) characterized how medical providers attempted to check decompensation in anesthesia critical incidents. In a medical setting, a patient may be considered to have adaptive capacity in terms of, for example, cardiovascular system function. Providers attempt to manage that adaptive capacity using control mechanisms such as medications. With other medical complications representing additional disturbances, a cascade of additional demands can
produce decompensation in the cardiovascular (or other) systems. The challenge for the medical team is to balance all of these considerations in patient treatment.

Falling behind on the pace of operations is one type of circumstance that can lead to decompensation. Cook (2006) explored this issue at a higher level in the health care system in studying the management of beds in an intensive care unit (ICU). The resident in charge of bed management was known as the bedmeister, and, in the face of escalating demand for beds, had to decide which patients were potentially “bumpable” to other units. A fall in adaptive capacity is in this setting was termed by ICU personnel as a bed crunch, and this sort of decompensation in the hospital could have adverse consequences for patient care.

### 2.5.2 Failure pattern: Working at cross-purposes

Working at cross-purposes is a failure to coordinate conflicting goals across different groups, which may not even realize they are in conflict. As seen in a wider economic setting, the struggle to govern the commons (Dietz, Ostrom, & Stern, 2003) is reflective of this pattern. Individual users of pooled natural resources, such as pastures, may behave in a manner that is locally adaptive in individually grazing on the pasture, but globally maladaptive in that they collectively exhaust the resource absent effective governance.

Just one of several manifestations of working at cross-purposes is fragmentation over roles, which Woods (2005) identified as an issue in the Columbia disaster. In assessing
the effect of the foam strike on the orbiter, no individual on the mission team had complete view of the (flawed) technical analysis.

2.5.3 Failure pattern: Getting stuck in outdated behaviors

Getting stuck in outdated behavior (or being “stuck in stale”) is a failure to learn, especially when the behavior in question was once successful and is now no longer adaptive. One prominent type of breakdown within this pattern is failure to revise a current assessment of a situation as new evidence comes in, as was certainly the case at TMI (Woods & Hollnagel, 2006).

In terms of longer-term organizational learning, Cook and Woods (2006) have described distancing through differencing as a major impediment. This phenomenon reflects an organization’s inability to apply lessons from an incident (of its own or of another group) to the organization’s present situation. Although all airlines have likely studied the lessons of the Asiana flight 214 accident in San Francisco very carefully, an American carrier discounting this incident as the unique product of Korean aviation management practices would be exhibiting distancing through differencing.
Chapter 3: Study Conducted

3.1 Partner firm

This study was conducted in partnership with a major transportation company. The firm was particularly well suited as a natural laboratory for resilience research due to its scale and complexity; it conducted 24/7 operations throughout the United States (US), performing hundreds of movements a day, many initiated on short notice or requiring last-minute changes, resulting in tremendous schedule variability.

The firm was also of great interest because it successfully confronted, on a daily basis, the sort of acute-chronic goal tradeoffs recognized to be at the heart of resilient performance (Woods, 2006a). One fundamental trade long at the center of safety research (Reason, 1990) was an acute economic need to maximize production versus a chronic need to maximize safety. The difficulty of this type of tradeoff for this specific firm was exacerbated by the fact that a single major accident would not only place at risk lives and property, but, potentially, the viability of the organization as a business concern.

3.2 Study overview

This ethnographic field study focused on personnel and systems in the company’s operations center (OC). Its observations were conducted in two parts: orientation and critical events. Orientation observations began in August 2012 with a two-member research team (the author and Katherine E. Walker) “shadowing” OC members during
periods of routine activity, which allowed them to learn the firm’s standard processes and communication flows and establish a baseline for its adaptive behaviors. Observations also included some mid-level management meetings held outside the OC. The team conducted a combined total of approximately 70 hours of observations in this part of the project.

Having established a baseline understanding of the firm’s adaptations, the team planned to return for critical events of potential disruption known well in advance (e.g., holidays) as well as those providing shorter notice (e.g., severe weather events); this plan worked out well (from a researcher’s perspective) as “superstorm” Sandy arrived in October 2012 just as the orientation period was concluding.

Over 230 hours of observations were conducted in the critical events portion of the project, which included, in addition to Sandy, observations of other demanding situations as they arose. In 2012 and 2013 these included: Thanksgiving, Christmas/Hanukah/New Year’s, Super Bowl XLVII, winter storm Nemo¹, President’s Day, winter storm Saturn, and a special event for the firm’s customers. In 2014 these included: winter storm Hercules, Super Bowl XLVIII, Memorial Day, summer storms, and Independence Day.

Periodic follow-up observations and interviews and data analysis were also conducted, including consultations with the company’s safety staff.

¹ Although the naming of winter storms by the Weather Channel is a practice not endorsed by the National Weather Service (Bachman, 2014), staff at the partner transportation firm did use these storm names on occasion. The names also proved useful to the author in data collection and analysis.
Table 1 below summarizes the principal observation periods for the orientation and critical events noted above, including the number of hours of observation conducted in conjunction with each event.

<table>
<thead>
<tr>
<th>Year</th>
<th>Month(s)</th>
<th>Event</th>
<th>Hours of Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>August - October</td>
<td>Orientation</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>October - November</td>
<td>Superstorm Sandy</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>November</td>
<td>Thanksgiving</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>December - January</td>
<td>Christmas/Hanukah/New Year’s</td>
<td>10</td>
</tr>
<tr>
<td>2013</td>
<td>January - February</td>
<td>Super Bowl</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>February</td>
<td>Winter storm Nemo</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>February</td>
<td>Presidents’ Day</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>March</td>
<td>Winter storm Saturn</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>Customer event</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>Follow up</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>November</td>
<td>Follow up</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>January</td>
<td>Winter storm Hercules</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>January - February</td>
<td>Super Bowl</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>April</td>
<td>Follow up</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>Memorial Day</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>Summer storms</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>Independence Day</td>
<td>11</td>
</tr>
<tr>
<td>2014</td>
<td>August</td>
<td>Follow up</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>Follow up</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>October</td>
<td>Follow up</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>November</td>
<td>Follow up</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 1. Summary of observations.

The next chapter provides more detail on the orientation period and the critical events yielding the most significant findings: hurricane Sandy, Thanksgiving 2012, Super Bowl 2013, and winter and summer storms in 2014.
3.3 Data collection and analysis

Data were recorded and were subsequently analyzed through a coding scheme, which was used to identify the observation patterns and stories of interest described in the results chapter. These results were compared with existing theories of resilience and safety in the development of the discussion chapter.

3.3.1 Data collection

Data were collected using handheld notes during events of interest and in retrospective interviews patterned on the critical decision method (Klein, Calderwood, & MacGregor, 1989). When observations were conducted with events in progress, observers conversed with participants during periods of low activity and avoided conversation when workload was high, saving questions for subsequent lulls in the action or for follow-up interviews. When time permitted, observers on occasion had participants step through procedures, although not in a formal “talk aloud” manner. These observational data were supplemented by some materials from the partner firm, including policy documents and meeting minutes.

3.3.2 Observing critical events

When observing critical events, the research team found it useful to consider each event as having three phases, as outlined in figure 4 below.
For an event known well in advance, preparation for a specific occasion might begin as long as a year ahead of time and include the specific application of documented lessons learned from prior years. For winter storms, on the other hand, preparation might take one or several days. Peak periods of disruption typically lasted one to five days, with restoration to routine operations also consuming a day or two; Hurricane Sandy was exceptional in that it took nearly a week for some transportation facilities to come back on line.

Because the research team had completed an extensive orientation prior to the critical events, they were able to identify how behaviors changed during these events in comparison to routine operations. It’s also worth noting that while both researchers conducted joint observations of the same participants during the orientation phase of the project, their observations were separated in space and/or time during critical events in order to expand the scope of their coverage.

### 3.3.3 Observer participation

For the most part, the research team adopted an “observer-as-participant” role (Robson, 2011, p. 323); the observers announced their status as OSU researchers to participants, but the observers did not formally contribute to the work of the group.

<table>
<thead>
<tr>
<th>Preparation</th>
<th>Peak</th>
<th>Restoration</th>
</tr>
</thead>
</table>

Figure 4. Phases of observation.
However, as the term “observer-as-participant” implies, the researchers were impacting group activities by their mere presence in the work environment.

The one occasion when a researcher adopted a “participant-as-observer” role (Robson, 2011, p. 322) was when the author accompanied the firm’s forward deployed group to the Super Bowl in New Orleans. At that event, merely observing activities would have proved awkward, and the author performed materiel handling tasks in much the same way as other group members. However, the author took care to explain his OSU affiliation and research mission when introducing himself to group members.

3.3.4 Observer “invisibility”

In surveying the literature on ethnography, Stoddart (1986) identified a common thread that he described as “the theme of the invisible researcher. The invisible researcher is the ideal researcher who sees without being observed and, consequently, captures the natural field without tainting it” (p. 108, emphasis in the original). While taking care not to claim whether or not such idealized invisibility was actually attainable, he further defined different types or levels of invisibility claimed by ethnographers (pp. 109-112), some of which this author believes were relevant in his own research:

“Disattending: erosion of visibility by time.” Although participants in this study certainly attended to the observers when engaged in conversation, over time their other behaviors did not appear to be significantly different when being observed over the shoulder or when being observed discreetly from a distance; behaviors indicative of a
lack of concern with being observed included joking with other participants and occasional swearing.

“Disattending: erosion of visibility by display of no symbolic detachment.” The observers in this project took care not to stand out from participants in dress or appearance, wearing business casual clothes when they did and likewise wearing jeans when appropriate.

“Disattending: erosion of visibility by display of symbolic attachment.” Participants displayed company photo badges at all times, and the observers did the same, making them indistinguishable from regular employees. While observing Super Bowl operations in New Orleans, the author wore the same company polo shirts worn by the employees.

“Disattending: erosion of visibility by personalizing the ethnographer-informant relationship.” The observers did try to be as personable with participants as they would be with colleagues in other settings, learning about their families, schooling, careers, sports preferences, and the like. The observers similarly shared their backgrounds, including their academic interests. The author’s military experience was often a subject of discussion with participants whether the participant previously served in the military or not.

“Misrepresentation: masking real research interests.” The observers in this project never intentionally misled participants about their real research interests, and went so far as to explain Resilience Engineering theory to curious participants.
“Misrepresentation: masking identity as ethnographer.” The observers never intentionally hid their identities as ethnographers, which did require some effort since, as noted above, they did appear to be regular employees.

In summary, the observers in this project did behave in ways that promoted disattending on the part of participants, but never intentionally mis-represented themselves to those participants.

3.3.5 Observation of decision making

Observations and interviews centered on individual and group decision making. In observing how participants made decisions, the researchers explored a variety of issues, including those listed below:

- What types and sources of information were required?
- What coordination was required?
- How was the pace of decision making accelerated or slowed?
- What strategies were applied?
- What alternatives, if any, were considered?
- What authority was required?
- What policies applied?
- How did actual practice differ from official practice?
- How did critical events differ from the routine?
- How were production and safety goals considered?


- What similar events in the past proved the most challenging?
- What challenging events lie ahead?

The last questions above were especially important, because any conversation with a participant could involve a discussion of work in progress at that moment, memorable events from the past, or upcoming challenges. Noteworthy exchanges would prompt further discussions with other participants regarding the incident or issue of interest.

3.3.6 Data analysis

Data were analyzed using thematic coding (Gibbs, 2007). Notes were analyzed in three passes that started with initial coding, followed by refinement of the coding categories and then the selection of the most significant stories to support results and discussion. A total of 58 coding categories were applied, and are listed in five broad groupings in table 2 below. Of these 58 categories, approximately 40 were established at the beginning of the coding process, while the remainder were added later; some of the more significant additions are highlighted in the results in chapter 4.
<table>
<thead>
<tr>
<th><strong>Company Functions</strong></th>
<th><strong>Behaviors</strong></th>
<th><strong>Behaviors (con’t)</strong></th>
<th><strong>Conditions/Constraints</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Current-day sched</td>
<td>Recognize/adjust</td>
<td>Goal conflict</td>
<td>Weather</td>
</tr>
<tr>
<td>Next-day sched</td>
<td>Manage buffers</td>
<td>Initiative/assertive</td>
<td>Resources</td>
</tr>
<tr>
<td>Customer service</td>
<td>Optimality-brittleness</td>
<td>Info flow reconfig</td>
<td>Vehicle availability</td>
</tr>
<tr>
<td>Vehicle operations</td>
<td>Efficient-thorough</td>
<td>Ad hoc teams</td>
<td>Vehicle facts</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Acute-chronic</td>
<td>Remote teams</td>
<td>Cost</td>
</tr>
<tr>
<td>Dispatch</td>
<td>Perspective shift</td>
<td>Comm/coordination</td>
<td>Demand</td>
</tr>
<tr>
<td>Safety</td>
<td>Changing dependency</td>
<td>Handoff</td>
<td># of trips scheduled</td>
</tr>
<tr>
<td>Operations analysis</td>
<td>Learning</td>
<td>Error catch</td>
<td>Workload</td>
</tr>
<tr>
<td>Supervision</td>
<td>Adaptation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>Anticipation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Security</td>
<td>Cross-purposes</td>
<td>Info technology</td>
<td>Double bind</td>
</tr>
<tr>
<td>Executive managers</td>
<td>Stuck in stale</td>
<td>Artifacts</td>
<td></td>
</tr>
<tr>
<td>Vendors</td>
<td>Decompensation</td>
<td>Policy</td>
<td>Critical Events</td>
</tr>
<tr>
<td></td>
<td>Covert work system</td>
<td>Process</td>
<td>Hurricane Sandy</td>
</tr>
<tr>
<td></td>
<td>Work-to-role</td>
<td>Metrics</td>
<td>Thanksgiving</td>
</tr>
<tr>
<td></td>
<td>Knowledge</td>
<td></td>
<td>Super Bowl</td>
</tr>
<tr>
<td></td>
<td>Attention</td>
<td></td>
<td>Other events</td>
</tr>
</tbody>
</table>

Table 2. Coding categories.

Like other ethnographies, this research aims to capture both “emic” and “etic” views of its setting, representing the participants’ outlooks on their world along with views framed by academic theories (Pike, 1954, p. 8; Hill, 1993, p. 59). With each story, care was taken to correlate the potentially differing perspectives of the other participants observed and/or interviewed, available company documents, and when dual coverage of the same event was attained, the observations of both researchers. These results were then analyzed in light of existing theories in the hope of furthering the resilience and safety of this firm, the transportation industry, and organizations in other domains seeking to learn from this research.
Chapter 4: Results

4.1 Observation periods of interest

In many ways the most significant results of this study are derived from the contrasts found in the adaptations applied by the firm in periods of routine operations and those used during critical events with a high potential for disruption. The research team benefited from a period of relative calm between August and October 2012, during which they oriented themselves to the company’s scheduling activities and were able to develop a baseline of the firm’s adaptive mechanisms. This was followed almost immediately by hurricane Sandy, a “superstorm” of immense strength and scale that posed a potential significant threat to personnel and equipment. Shortly thereafter, the Thanksgiving holiday offered the challenge of high traffic demand on a few days across a variety of destinations. Early in 2013, the Super Bowl proved to be a unique test not so much due to the volume of traffic, but rather the tight geographic and time constraints imposed on the operation.

Another set of significant results of this study are derived from the contrasts found between the adaptations applied by the firm in the first year of the study and those available in the latter 15 months. As will be detailed in this chapter, increased customer demand and poorer weather significantly degraded the company’s performance in winter and summer 2014 in comparison to 2012 and 2013.
4.2 Routine operations 2012: Inherently adaptive

The team’s orientation to routine operations took place from August 23 to October 16, 2012. It was facilitated by the firm’s safety office, and started with a set of introductory meetings with middle managers overseeing key functions in the operations center (OC), which are outlined below. Later orientation sessions were primarily conducted as “over the shoulder” observations, with working-level OC team members explaining their job duties during pauses in activity, with some “talk aloud” descriptions of key tasks as well as retrospective descriptions of prior events of that same day or the more distant past.

4.2.1 Company safety function

The firm’s safety office was the principal sponsor of this study and served as the research team’s point of entry into the rest of the company. While managerially independent of and physically separated from the OC functions, it’s worth noting that the team had extended discussions with the safety office, given its vital role in developing and implementing company-wide safety policies. The safety office also provided an initial overview of the company that kicked off the orientation period.

In supporting this study, the office was performing tasks that Woods (2006b) identified as being vital for a safety organization: it was actively seeking information regarding the firm’s operations in actual practice (and not just as they are imagined by management or in policy); and it was aiming to reframe its view of safety issues and direct (or at least recommend) interventions.
Among the three models of safety proposed by Amalberti (2013), the company clearly operated on the assumptions of the ultra-safe model in terms of its attitude towards risk: it sought to reduce it as much as possible. The firm developed and applied detailed vehicle operator procedures, and employed extensive supervision of operators. This paper will later suggest, however, that not all company functions conformed to the tenants of this model.

It would be difficult to overstate the importance of safe operations to the company’s business model. The firm used the idea of safety prominently in its advertising and used it to differentiate itself from its competitors. As one scheduling manager put it, “we sell ultimate safety.”

4.2.2 Core OC functions first examined by the research team

The OC group included representatives from a diverse set of company functions. Although dozens of personnel may have been on duty at any one time, the following were some of the critical positions; each was supported by one or more staff members of a like specialty and was supervised by a middle manager. Below are the functions first examined by the team based on its pre-orientation assessment of what constituted key functions.

- Current-day scheduling: the current-day schedule team leader held authority to make routine, real-time decisions regarding the assignment of vehicles to meet customer requests and reconciled the potentially divergent goals of the different OC roles.
- Vehicle maintenance: the vehicle maintenance team leader provided maintenance status on all vehicles in the fleet, ensured that the schedule accounted for maintenance events, withdrew vehicles from service as needed if they were not fit for use, provided estimates regarding repair times, and released them for use on the schedule once repairs were completed.

- Vehicle operations: the operator assistant team leaders (there was one for each of several vehicle types) served as liaisons to operators in the field, exchanging information with the operators regarding vehicle performance, maintenance, weather conditions, facility status, and schedule and logistics changes.

### 4.2.3 Additional OC functions later examined by the research team

As the observation period continued, the research team started noting these other critical roles in the OC; although these were not initially represented in the list of coding categories in table 2, they were added later:

- Customer service: the customer service team leader clarified and prioritized known and emerging customer requirements, and assessed the possible customer impact of company-induced schedule changes, such as those resulting from vehicle breakage. The team leader also conferred with other OC staff regarding the best options to offer customers should a schedule or vehicle change become necessary.

- Vehicle dispatch: another function integral to the OC was vehicle dispatch. Their team leader coordinated vehicle route planning, accounting for such factors as weather, traffic patterns, and the status of origin and destination transportation facilities.
- Next-day scheduling: this team developed the next day’s schedule, which was typically handed over to the current-day team to execute at 1:00 am. They used specialized IT schedule planning tools in addition to the master schedule program used by everyone in the OC.

- Weather: while not seated in immediate proximity to the functions noted above, the weather team leader coordinated the use of electronic weather products and issued company-specific weather forecasts and alerts. Readily accessible to the core OC group, the weather team leader typically led off the OC managers’ meeting held each morning at 8:30 am.

- Line operators: since the focus of this study was the OC and its personnel, line vehicle operators were only observed directly when visiting the OC and at the Super Bowl 2013 forward deployment site. However, interactions with line vehicle operators and consideration of their issues by the OC staff were observed on nearly every visit to the center.

### 4.2.4 OC information systems

The company used a proprietary software program to produce and update its master schedule. All OC group members could view the master schedule, although permissions to alter it varied by position. Other capabilities available to all group members included telephone, e-mail, and instant messaging (IM). As current-day schedule issues arose, they were monitored, updated, and closed using a web-based action item tracker.
accessible to all core OC roles. Dialogue regarding issues in the action item tracker often took place in an electronic chat system.

Some functions, such as maintenance and next-day scheduling, had specialized information tools accessible only to staff in that function. During severe weather events, event-specific information was posted on a company intranet portal active only during the event.

### 4.2.5 Next-day scheduling decision making

Although the next-day scheduling team’s final product was instantiated in the master schedule program used throughout the OC, the team performed its initial look at the schedule two days ahead of time using a specialized schedule building program, which accounted for, among other things, the following factors:

- Trips for customers: requested trips by paying customers.
- Trips to move vehicles: the movement of empty vehicles to needed locations for which the firm did not collect revenue.
- Forecast: a projection including trips not yet booked.
- Maintenance: scheduled maintenance activity for specific vehicles.
- Subcontract: trips to be supported by vendors because the firm was not projected to have enough organic capacity that day.
- Spares: the number and location of spare vehicles and operators.
- Operators: operators were matched to vehicles based on the schedules of both.
- Uncovered trips: trip requests that exceeded organic and subcontract capacity.
Over the course of the two days before the schedule was handed over to the current-day team for execution, the next-day team worked to resolve potential issues. Among the factors listed above, two are of particular interest because they often required the special attention and intervention of humans:

- Operators: as one next-day scheduler put it, the schedule building tool was not as “creative” in scheduling operators as human schedulers, who were able to account for a higher number of variables than the automated system as well as the characteristics and behaviors of individual operators. In fact, the operator assignments were typically not even included in the initial schedule runs two days prior due to the complexity of that element of the schedule.

- Uncovered trips: next-day schedulers continually worked to reduce the number of uncovered trips, ideally having none by they time they handed off the schedule to the current-day team. If the schedule building tool showed that booked and forecast trips significantly exceeded available resources, they elevated the issue to middle or executive managers, who might elect to secure adequate resources by, for example, deferring maintenance or adding subcontractor resources. Similar options were available for addressing current-day issues, and are discussed in more detail below.

4.2.6 Morning meeting of OC managers

OC managers, including representatives of current-day scheduling, next-day scheduling, customer service, dispatch, vehicle operations, maintenance, and weather met daily at 8:30 am to review performance metrics and issues of the prior day and preview
activities of the current day, which served as a form of double-checking with the goal being the identification of potential problems in the schedule. This included a line-by-line assessment of the schedule by the entire group, with participants speaking up when they saw possible issues, including matters of timing and safety; participants then took action items to correct the schedule as required after the meeting.

These morning meetings were but one element of the firm’s routine that illustrated its sensitivity to operations, which Weick and Sutcliffe (2007) identified as a key characteristic of high reliability organizations (HROs). They also demonstrated several patterns of anticipation that Woods (2011) described as being important for resilient systems, including the ability to recognize the status of buffers and reserves and the ability to artfully employ perspective shifts in performing situation assessment.

4.2.7 Current-day OC decision making

From the moment the OC group began a new “day” (at 1:00 am), the schedule it received from the next-day scheduling function (as implemented in the master schedule program) was subject to continual change. The fundamental scheduling unit was a “line,” which identified a specific vehicle and its operator, customer, departure and arrival locations and times, maintenance status, and a host of amplifying data.

Circumstances prompting a change might have included a new or altered customer requirement, a vehicle break, or lack of operator availability (usually due to calling in sick). As potential changes arose, the current-day schedule team leader coordinated
inputs from the other functions to find scheduling solutions that satisfied both company and customer needs.

All of the team leaders in the OC also implemented standing policies and specific directions from their middle managers; team leaders elevated certain decisions to managers based on established rule sets or when they judged potential consequences to be particularly high or of great impact across several different OC functions.

4.2.8 Current-day OC shift change routines

Although there was some variation in shift change procedures among the different working-level OC positions, most functions followed handoff strategies similar to those found in other safety-critical domains (Patterson, Roth, Woods, Chow, & Gomes, 2004). There was always a verbal exchange regarding important issues between departing and arriving personnel (when they overlapped) and most functions had electronic pass down notes. Several participants reported checking the weather at home before every shift, and, similarly, several phone calls were observed in which off-duty personnel checked in ahead of their shifts to make inquiries of their counterparts when they saw media reports or company e-mails regarding potentially significant events.

Once an OC staff member completed discussions with her predecessor, she would typically scan the entire shift’s vehicle schedule to look for trips that might have potential problems, e.g., maintenance pending completion. As one current-day schedule team leader put it: “I absorb the schedule when I come in in the morning.”
In one particular instance, a vehicle operator assistant team leader saw a trip terminating at an unfamiliar destination; upon further examination, he discovered the destination facility wasn’t suitable for the scheduled vehicle. He ensured that the current-day schedulers changed the trip to a nearby destination, and then alerted the information technology (IT) staff so they would update the appropriate trip planning system to prevent a similar error in the future. This was an excellent example of how OC staff used their initial scans of the schedule at the start of a shift to identify and correct potential errors, and was typical of the sort of double-checking done continually throughout the OC. These observations supported previous findings that error correction in complex systems is distributed across a variety of human and machine agents (Hutchins, 1995; Smith et al., 2009; Woods et al., 2010).

4.2.9 Current-day OC scheduling options

When a same-day scheduling request arose or a change impacted an existing request, the solution to that trip’s scheduling issue was termed a “recovery.” Not surprisingly, deciding among potential options for a recovery involved a complex set of tradeoffs. Typical recovery options included:

- Using a vehicle from the same location that was scheduled for a later trip: this would cause a ripple effect since that later trip also had to be covered with another vehicle. The ability of the OC team to assess and address such ripple effects in a collaborative manner with their human teammates and automated tools was a fundamental skill of the OC staff.
- Using a vehicle from a different location: this was similar to the above in terms of ripple effect, with the additional impact of the cost to move the new vehicle to the necessary location, and the possible necessity of moving another vehicle to backfill the one that was just moved, etc.

- Late departure or less capable vehicle: a vehicle of the type requested by the customer might be available, but later than the requested time. A less capable vehicle might be available at or near the requested time. If the customer chose to depart as close as possible to the scheduled time, this required the customer to accept a less capable vehicle (along with a partial refund). Choosing the originally requested (more capable) vehicle meant a later departure. Both options would typically be presented to the customer for her to choose between.

- Vehicle upgrade: a vehicle of a type requested by the customer might have been available, but later than the requested time, while a more capable vehicle might have been available sooner. This was a potentially winning scenario for the customer if the firm provided the more capable vehicle because the customer would not be charged for the vehicle upgrade. However, the OC staff could elect to live with a late departure for the customer while holding on to the more capable vehicle in anticipation of subsequent recovery needs.

- Deferring maintenance: a vehicle scheduled for maintenance activity that wasn’t urgent (e.g., the vehicle was scheduled to start an inspection that wasn’t due for two days) might have had that maintenance deferred to meet an immediate scheduling
need. But this delayed the date it would return to service following the required maintenance, perhaps fouling future scheduling plans.

- Using a spare vehicle: if used, the spare would not be available for a subsequent scheduling need. A certain number of spare vehicles (and operators) were built into the schedule every day, and their type and location were considered carefully in the next-day scheduling process.

- Subcontracting trip to a vendor: our partner firm had relationships with vendors that provide similar transportation services. On routine days at the beginning of this study, it would be unusual for the firm to need to subcontract, which was undesirable for a variety of reasons, including cost, the uncertainty of vendor availability on short notice, and the company’s self-limiting policy of using only carefully pre-screened vendors. However, it might have been the last available option if organic capabilities were exhausted. Subcontracting a trip on a routine day, as observed at the beginning of this study, was a commitment significant enough that it required the working-level staff to coordinate with middle managers. As demand increased later in the study, subcontracting became much more prevalent.

- Adjust operator’s schedule: if the schedule issue hinged on operator availability, additional availability could be secured by starting an operator’s work week early or ending it later than originally planned (actions which were requests, not demands, of the potentially impacted operator).

Although the OC staff did not use the term, every decision concerning a recovery involved consideration of its impact on capacity for maneuver (CfM) (Stephens et al.,
2015; Woods, in press). In particular, the current day schedulers regarded themselves as the guardians of the firm’s transportation capacity. This will be explored further in the next chapter.

### 4.2.10 End-of-day and next-day considerations

In addition to the considerations detailed above, another important factor in schedule change decisions included ensuring that operators had adequate duty time remaining to complete the trip that day and would be able to obtain enough rest to start operations as scheduled for the next day, in compliance with company and regulatory requirements.

A related scheduling need was the positioning of vehicles at the end of the day so as to be available for needed trips the next day. If this consideration proved to be potentially problematic, the current-day schedulers would coordinate carefully with the next-day schedulers and other relevant parties (e.g., maintenance). In doing so, they would avoid the sort of unwarranted (or at least unexpected) shifts in planning that have been shown to be problematic in handoffs in healthcare settings (Patterson, Cook, Woods, & Render, 2004).

The partner firm was truly a 24/7 operation, with arrivals and departures around the clock, including overnight trips. The traffic volume was significantly lower at night than during the day, but fewer resources were available, posing different but no less challenging scheduling problems for the night shift.
4.2.11 Scheduling policy considerations

When processing new trips, a critical scheduling constraint was the response time stipulated in the customer’s contract; the firm always tried to meet a customer’s requested departure time, but was especially obligated to meet the request when the customer had provided adequate notice per the contract.

When an event like a vehicle break compelled a change in schedule (prompting a recovery), the company had standing time goals for: informing the customer of her best recovery alternatives; and the actual delay in travel. The company tracked these times as metrics, and also tracked incidents of longs delays, reporting significant delays in e-mails and in daily operational summaries and further documenting their circumstances in a case management system.

4.2.12 Weather, facility, or safety considerations

Trip alterations due to weather, facility, or safety conditions were addressed, in part, in regulatory and company policy that provided operational guidance. All OC staff were well versed in these rules to a degree appropriate to their function, including the customer service team. Trips in conditions that might push the limits in weather, facility, or safety policy required approval from a vehicle operator assistant team leader or manager.

4.2.13 Field operators in the decision making process

Unlike some of the other types of tradeoffs discussed in the sections above, schedule deliberations regarding weather, facility, or safety issues might also have drawn in the
field operators, who bore responsibility for the safety of their trips. Ironically, the fact that field operators were typically unaware of the other sorts of (non-safety) tradeoff decision making outlined in the previous sections had been noted as a source of frustration among operators, since they didn’t understand the drivers behind the many schedule changes to which they were subjected.

More problematically, some operators believed that schedule changes impacting them were the product of ill intent on the part of the OC staff, reasoning which in some cases prompted operators to push back or call in sick when issued a trip request. This seemingly became more prevalent after the firm equipped operators with smart phones and sent trip requests by e-mail. In the past, OC staff called operators with trip requests, which allowed staff and operators to build personal relationships along with mutual knowledge and shared assumptions. The negative effects apparently exacerbated by the introduction of the smart phone e-mail communication channel are, unfortunately, to be expected in light of findings regarding attribution in distributed work groups (Cramton, 2002).

4.2.14 High priority trip considerations

Any one of a number of customer considerations might make a trip a high priority for the company (e.g., a trip in conjunction with a special event). Changes impacting such a trip might require working-level staff in current-day scheduling and customer service to coordinate with their respective middle managers, either to obtain permission
to make the change or to provide notice after the fact that such a change had been made, depending on the circumstances.

### 4.2.15 Electronic coordination of recovery actions

As noted earlier, current-day recovery actions (schedule changes) in work were tracked in a web-based tool. Each recovery was represented as a row in a matrix. Each function responsible for coordinating on the recovery (e.g., maintenance, dispatch, customer service) was displayed as a column, with matrix entries being filled with one of three colored dots: red (recovery need not yet acknowledged by that function); yellow (recovery need acknowledged, but not yet concurred on); or green (recovery concurred on). The current-day schedule team leader was the final approval authority for any recovery. This system served as a formal means for ensuring multi-functional review for change actions, reviews that provided an opportunity to catch errors in recovery processing.

The recovery tracking tool was akin to a workflow system, but differed from such systems in that the coordination of action items did not need to be accomplished in a serial manner. The tool also did not meet with hostility from its users, as is often the case with workflow systems (Olson & Olson, 2010), in part because it was not perceived to be the product of an efficiency initiative.

Much of the dialogue regarding recoveries was captured in electronic chat traffic. Note only did this chat traffic serve as a means for real-time coordination, it also served as a record which the firm’s middle managers could use after the fact (sometimes days
later) to sort out the chain of events leading to specific change actions, enabling them to update coordination processes as required. The chat function, then, provided a medium that supported reviewability, which has been shown to be an important element of grounding in communication (Clark & Brennan, 1991; Patterson et al., 2004).

During most of the observations explored in this paper, the chat function stood apart from the recovery tracker. If one wanted to follow chat entries about a specific vehicle, one might have to scroll through the entire chat stream to find the entries of interest. In a later version of the chat function, separate chat streams were created for each recovery, making it easier to follow the dialogue for an individual change. However, when there were many (perhaps dozens) of recoveries in the queue, finding the latest chat entry (regardless of the change in question) required scrolling up and down the entire change list. Some OC staff found this new design clumsy to use in a busy environment.

4.2.16 Typical coordination requirements

The electronic schedule change tracker described above allowed the OC staff to see which functions had coordinated on a recovery. Ideally, all functions would coordinate before the current-day schedule team leader approved a recovery action. However, the current-day leader was empowered to act in the absence of coordination from one or more OC functions. Table 2 below depicts the most significant elements of coordination required for different types of recoveries.
<table>
<thead>
<tr>
<th>Recovery Type</th>
<th>CD</th>
<th>DX</th>
<th>MX</th>
<th>CS</th>
<th>OPS</th>
<th>SC</th>
<th>ND</th>
<th>MGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move a vehicle</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use spare</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late departure (same vehicle type)</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On time departure (lesser vehicle)</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On time departure (better vehicle)</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjust operator’s schedule</td>
<td>A</td>
<td>S</td>
<td></td>
<td>S</td>
<td>S</td>
<td></td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Defer maintenance</td>
<td>A</td>
<td>A</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use subcontract</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact high priority trip</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Table 3. Recovery coordination matrix.

- The current-day schedule team leader had to approve all recoveries.
- The dispatch team leader coordinated on recoveries that altered existing plans or created new plans for organic vehicles.
- The maintenance team leader had to coordinate on recoveries that resulted in deferring vehicle maintenance, a requirement that the current-day scheduling was not permitted to override. Such deferring of system maintenance activities to support primary organizational goals has been identified as a fundamental dynamic of resilient complex systems (Wears, 2010).
- The customer service team leader coordinated on changes that impacted (or were simply visible to) the customer. On the other hand, some recovery situations, such as deferring maintenance, were not necessarily visible to the customer.
- The vehicle operations team leaders were most concerned with recovery types that had potential adverse impacts on operators’ schedules or involved maintenance issues, weather, or unusual destinations.

- The subcontract function dealt only with subcontract needs.

- The next-day and current-day schedulers had to coordinate carefully, especially on the night shift. For example, next-day might be able to “steal” a night shift spare vehicle to address an issue in the next-day schedule, but would never do so without first conferring with the current-day staff.

- Manager intervention was rarely needed for the vast majority of scheduling actions, reflecting the sort of deference to expertise characteristic of HROs (Weick & Sutcliffe, 2007). Most decisions regarding vehicle operators and maintenance that had to be escalated to their functional managers or executives were done so as a matter of standing policy and were often driven by potential safety implications. The current-day and customer service managers most often had to weigh in on recoveries impacting high priority trips or the addition of subcontract assets.

4.2.17 Voice coordination of schedule changes

Discussions regarding schedule changes took place in person and over the phone. Interactions among key personnel were facilitated by their seating arrangements, which placed the current-day schedulers, the customer service team leader, the vehicle dispatch team leader, and the vehicle maintenance team leader all in close proximity to each other. Not only could they address each other directly, they could overhear each other’s
conversations and phone calls; one current-day schedule lead commented that he found it very important to listen to what was going on around him to stay abreast of emerging situations. This observation is in keeping with findings that the ability to overhear conversations among colleagues supports mutual awareness and anticipatory action in control centers (Patterson, Watts-Perotti, & Woods, 1999; Dugdale, Pavard, & Soubie, 2000). More broadly, these sorts of communication, no less than formal electronic coordination, support “the choreography of joint activity” that Klein and colleagues found essential to the maintenance of common ground (Klein, Feltovich, Bradshaw, & Woods, 2005).

Discussing the pros and cons of different change options and identifying novel options consumed much of the time of the OC staff, but listening to and inviting the opinions of others was recognized as a valuable part of their process. As one current-day schedule team leader put it, referring to her interactions with the two staff schedulers on her team: “Three sets of eyes are better than one.” And in describing the value of having worked with her partners for years, she noted: “We know how each other think.”

Although the vehicle operator assistant team leaders were not seated in close proximity to the participants described above, each operator assistant team leader was seated near a maintenance counterpart specializing in the same vehicle type. Their discussions frequently centered on maintenance issues that could impact a scheduled or potential trip. Sounding a chord similar to that voiced above by the scheduler, one operator assistant team leader likened his coordination with maintenance to a system of “checks and balances” to ensure that a vehicle had the necessary capabilities to safely and
successfully complete its trip. This philosophy was similar to what Rochlin et al. (1987) identified as the redundancy in management and decision making found in aircraft carrier operations and what Patterson, Woods, Cook, and Render (2007) described as collaborative cross-checks in healthcare.

4.3 Hurricane Sandy 2012: Prepared to respond

In analyzing the results of its observations of critical events, the research team found it useful to examine activities in terms of three phases: the preparation for the event, the peak of activities of the event, and the restoration to routine operations following the event. In the case of hurricane Sandy, the team’s period of observation began with four hours on the peak day of October 28, 2012, as depicted in figure 5 below.

<table>
<thead>
<tr>
<th>Preparation</th>
<th>Peak</th>
<th>Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>All preparation observations retrospectively obtained during peak &amp; restoration periods</td>
<td>4 hrs</td>
<td>26 hrs</td>
</tr>
</tbody>
</table>

25 26 27 28 29 30 31 1 2 3

October November

Figure 5. Hurricane Sandy period of observation.

The team subsequently spent nearly a week accumulating 26 hours of observations of restoration activities. Retrospective accounts of the planning phase were obtained during the peak and restoration phases.
4.3.1 Hurricane Sandy: A superstorm

Sandy emerged from a topical depression in the Caribbean Sea, was designated a Category 1 hurricane on October 24, 2012, and came ashore in New Jersey as a post-tropical nor’easter on October 29. It was widely considered a “superstorm” because its power increased as the result of an unusual confluence of weather effects, including a high-pressure cold front, which moved in from the north. Figure 6 depicts the scale of the Sandy weather pattern. The storm dissipated as it moved through Pennsylvania, and the National Weather Service (NWS) issued its last Sandy-related weather advisory on October 31 (Drye, 2012).

Sandy devastated the coastal areas of New York and New Jersey, killing more than 100 people, and leaving tens of thousands of people homeless and more than eight million homes without power (“Hurricane Sandy,” 2012). Having caused nearly $50 billion in damage, it was the second-costliest cyclone to hit the US since 1900 (not adjusting for inflation) (Blake, Kimberlain, Berg, Cangialosi, & Beven, 2013).
4.3.2 Unique challenges of responding to Sandy

For the NWS, Sandy posed a forecasting and public communications dilemma since tropical cyclones (hurricanes) are the responsibility of the National Hurricane Center (NHC), while non-tropical cyclones normally fall to local Weather Forecast Offices (WFOs). In delivering Sandy-related forecasts, NWS executed its standing policy so that the NHC issued hurricane watches and warnings for all areas south of Duck, North Carolina, while the for WFOs issued (non-tropical) cyclone watches and warnings as required for all areas north of Duck. While this transition caused no weather assessment problems for our partner firm, NWS identified issues with this approach in working with state and local officials and in terms of consistency on its own websites (NWS, 2013).

For the states and communities in the path of hurricane Sandy, responding to it was an enormous challenge given its destructive power and large spatial scale. Because the
storm moved slowly, it created a need for disaster response while impeding the ability of responders to conduct their life- and property-saving work, a complication not found with fast-moving severe weather patterns.

For our research partner, Sandy was a major threat because it struck a large, densely populated region in which the firm conducts a significant portion of its business. Although the company had a long history of successfully dealing with hurricanes, Sandy’s size and impact area tested it more intensely than prior storms.

4.3.3 Severe weather actions in policy

Severe weather is a known risk in the transportation industry; unsurprisingly, the firm had standing policies to deal with both local and widespread weather events. When weather was forecast to exceed certain parameters over a large geographic region, the effected area might be designated a weather impact zone (WIZ). Each WIZ carried a “level” categorization indicating the anticipated severity of the event and prescribing corresponding operational restrictions; at the highest level, operations ceased entirely within the confines of the zone. WIZ policy, then, served as the foundation of a key aspect of resilient response to large-scale events, the establishment of a range of conditions in which one can still manage “reasonable” operations (Caldwell, 2014).

Although forecasts from company meteorologists formed the basis for establishing a WIZ, authority to implement and terminate such zones rested with a senior operations manager. While no operator in the field could override a headquarters decision to cease operations, an individual operator could decline transportation requests otherwise
authorized by headquarters based on his own judgment regarding conditions in the local area. Such rule-based (or policy-based) operator autonomy was an example of a flexible routine recognized to be important to a resilient system (Grote, 2008).

4.3.4 Management changes the tradeoff space

A resilient organization not only makes acute-chronic goal tradeoffs in a sound manner, it recognizes when to shift priorities across goal tradeoffs (Woods, 2011). Such a shift began in the days leading up to Sandy’s landfall as the company started preparing for the arrival of the storm, and this shift elevated an array of safety considerations in response to an imminent major threat.

While meteorologists and middle managers recognized prior to October 25 that the hurricane would impact operations, on that day they began to regard it as an event that would require extra measures to protect personnel and equipment. Although a WIZ was not yet in force, managers began to plan for actions to include: removal of some vehicles from the zone and the need to shelter those that would remain; the deferral of some vehicle maintenance; the scheduling of travel for transient personnel so as to not “trap” them in the zone; and the excusal from duty of personnel residing in the zone. This sort of “batten down the hatches” approach to storm preparation has been categorized as one of the most straightforward techniques for successful proactive safety management (Hollnagel, 2013) and was followed by other transportation companies similar to our partner firm (Flynn, 2015).
The firm’s anticipatory actions were either documented in existing policy or were long-standing contingency operations practices. A response management group composed of executive leaders of the firm oversaw these and other hurricane planning activities, meeting twice daily (in person and/or by phone) in the days prior to landfall. The team provided direction and followed up on execution, ensuring actions were taken in accordance with their guidance.

Planning intensified as it became clear that Sandy would come ashore on October 29. Several WIZs were put in effect across the Northeast and Midwest, including some that ceased operations in designated areas on the afternoon of October 28, the day that proved to be the most challenging for the OC group.

4.3.5 Surface indicators of OC workload

As one seasoned OC veteran explained the workload associated with a severe weather event: “The actual storm is not a crisis--getting ready for the storm is a crisis.” For this transportation firm, preparations for hurricane Sandy peaked on October 28. To one acquainted with the routines of the OC, the patterns of communication that day clearly indicated that operations were under stress.

An unusually high volume of communication was immediately evident upon entering the center based on the level of background noise. Normally a quiet area easily conducive to concentration on computer-based work, the OC this day was a much louder place filled with numerous urgent discussions occurring throughout the room. Foot
traffic also increased as personnel in the center (and some from other rooms) moved around to conduct face-to-face conversations.

Even a brief examination of IT systems in use in the center showed the surge in workload that day. The number of pending actions in the OC recovery tracker was four to five times greater than the number seen on a routine Sunday. The growing list was visible evidence of increasing risk of the general form of system breakdown known as decompensation, or an exhaustion of the system’s capacity to adapt as challenges mounted (Woods & Cook, 2006; Woods & Branlat, 2011).

Another IT system, the severe weather event intranet portal, which was active only during such events, was in use at many desks. The portal’s most important function was to list the status of transportation facilities impacted by the storm, a list that expanded to dozens of locations as the day wore on.

The total number of people on duty in the OC was not particularly indicative of its increased workload as it was staffed with its normal Sunday crew; the few additional personnel, however, were middle managers normally not present on weekends.

4.3.6 Sources of OC workload

One source of the increased OC workload was the set of tasks that served to protect personnel and equipment, e.g., ensuring shelter for vehicles in the WIZ and consideration of work excusals for those in the zone. As the day progressed, vehicle-related tasks posed greater challenges as more personnel left work, leaving fewer field personnel, including subcontractors, to repair and shelter vehicles. Thus the hurricane created added
work for the field while at the same time decreasing the number of personnel available to carry out that work, further burdening the staff who remained on the scene.

Although middle managers and the OC staff anticipated additional transportation requests from customers hoping to complete movements both in to and out of hurricane Sandy’s path prior to its arrival, the large volume of last minute requests surprised nearly all participants. All new customer transportation requests were entered into the OC recovery tracker, and it was mostly the unresolved new requests that caused the number of items in the list to explode on October 28.

As discussed previously, hurricane Sandy engaged executives at the highest levels of the firm. This involvement increased communication both up and down the management chain. Data requests from high-level executives, while providing important local information for decision making, also served to increase OC staff workload. Such requests, along with the observed increase in OC communication generally, were indicative of the increase in coordinative burdens that accompanies the escalation of demands during a series of cascading problems; Woods & Patterson (2000) identified this phenomenon in examining system faults and anomaly response, but it’s directly applicable in this case, where the disturbance, a hurricane, produced a cascade of scheduling issues.

4.3.7 Adaptation successes in the OC

In a joint cognitive system of human and automated agents, it’s important for agents to be able to observe and direct the actions of others (Woods & Hollnagel, 2006). OC
staff members within line of sight of each other could visually assess the workload of
their colleagues; they and other staff outside the room could assess the workload of others
by monitoring shared IT tools and gauging their own workloads.

Recognizing the saturation of computer communications, many OC group members
conducted their most important business by phone or face-to-face. This reflected a
judgment that the communication partner was interruptible and needed to address a high
priority issue that might otherwise not receive timely enough attention. In some cases,
this technique was used to ensure that staff located outside the OC (and more insulated
from storm-related activities) adjusted their priorities to support actions dealing with
Sandy.

While nearly all OC staff members appeared to act more quickly in the face of
increasing demands, none better articulated the need for faster decision making than the
current-day schedule lead: “The key is giving a quick response to a new request,
otherwise it snowballs.” This statement acknowledged the potential for cascading
failures on October 28 and his approach to handling it.

In making faster decisions, he (and others) consciously elected to forego processes
designed to identify the lowest cost schedule options in favor of meeting as many
customer requests as possible within the bounds of their personnel and asset protection
protocols. In confronting the risk of saturation and decompensation, they favored
efficiency over thoroughness in decision making, which is a fundamental tradeoff made
in resilient systems (Hollnagel, 2009a; Woods, 2011; Hoffman & Woods, 2011; Woods,
in press). This behavior also represented self-awareness of cognitive limitations on the
part of an expert decision maker, much like similar examples of metacognition highlighted by Klein (1998). In addition, it’s important to note that the staff’s efficiently made decisions yielded an effective (in terms of timeliness), but not efficient, use of transportation resources.

When middle managers were not immediately available, some working-level OC members took the specific initiatives to act without the usual pre-coordination with those managers. For example, the vehicle maintenance team leader made decisions regarding the sheltering of vehicles outside the WIZ. Armed with the latest evolving weather information--and knowing the intent of the response management group and other leaders regarding vehicle protection--he took the actions he deemed best and advised his superior later. This was the sort of circumscribed initiative long held to be imperative in military operations (Finkel, 2011).

4.3.8 Adaptation failures in the OC

The presence of senior and middle managers in the OC on a Sunday was an adaption that most frequently served the working-level staff well, freeing them from some up channel reporting requirements. However, at least one middle manager insisted that his team leader participate in response management group telecons, which distracted him from other tasks. In addition, senior managers occasionally asserted authority over operational details they normally don’t exercise, such the specifics of vehicle movements and sheltering; this approach compelled working-level staff to produce time-consuming detailed reports that slowed their decision making on other pressing matters.
Despite a high degree of mutual understanding across the OC staff, there were some actions that could be characterized as “heedless” (though not intentionally so) of the impact on colleagues already working under great pressure. The continued processing of last-minute transportation requests by customer service representatives (who were under great pressure themselves) bogged down the entire schedule change decision-making process. Consideration of numerous unfulfillable requests consumed time better spent on more complex schedule adjustments. As a result, the customer service role should have been prepared to turn down requests up front rather than use up capacity on unfulfillable requests. They continued to act according to their normal role for their function, but this was now globally maladaptive for the OC as a whole (Weick & Roberts, 1993; Woods & Branlat, 2011).

It’s worth noting that some of the behaviors described above (e.g., senior managers asserting authority over operational details) and in the prior subsection (e.g., communication reconfiguration including increased voice traffic) were not anticipated by the research team before the project began; these behaviors were among those added later to the coding categories in table 2.

4.3.9 Landfall and beyond

Although scheduling problems were cascading in the hours prior to the WIZs taking effect on the evening of October 28, the WIZs succeeding in halting the cascade; this was a welcome, but unintended effect of the WIZ policy, which was not specifically designed to meter schedule demand. The hurricane’s landfall proved anti-climactic (for the firm,
not the communities in the storm’s wake), in no small part due to the company’s exhaustive preparations. It sustained no personnel injuries or significant equipment damage. It met many, though not all, last-minute transportation requests before Sandy arrived.

After the storm passed, customer transportation requests started to increase in response to improving conditions on the ground. However, restoration of service to the hardest hit locations took several days.

Maintaining a shared understanding across all OC functions regarding the status of transportation destinations was a point of emphasis in meetings of middle managers. As one scheduling manager put it on October 30: “Today everything is all about communication. We need to stay within our protocols. The portal is the way to go.” In other words, communication regarding suitable destinations needed to be coordinated across the company and with customers based on the latest facility status listed in the severe weather event intranet portal. Adding emphasis to this thought, a customer service manager declared: “We need to stick to our guns on the safety buffers we put in,” a comment regarding other safety-based restrictions on vehicle operations.

An interesting and important mechanism the firm used to restore service was its use of vehicle operator reports to assess facilities that may have been flooded or sustained other damage. Before scheduling numerous trips to such facilities, the OC staff would send in a single vehicle to scout the facility and report on its condition. OC managers then decided how many vehicles, if any, to schedule for that facility that day. This approach enabled the company to shift its operational boundaries in response to changing
conditions in a manner consistent with resilient systems (Woods & Wreathall, 2008; Woods, in press).

4.3.10 Learning from Sandy

In terms of formal learning, the company addressed some Sandy-related issues in standing cross-functional meetings among middle managers. In keeping with the firm’s reliance on highly experienced personnel in key positions, it would be fair to say the company considered the Sandy experience to simply be one of many incidents its staff would draw on in addressing future disruptions.

4.4 Thanksgiving 2012: Planning for demand

In the case of the Thanksgiving holiday period, the team accumulated 27 total hours of observations of the firm’s activities between November 6 and 27, 2012, as depicted in figure 7 below. Although observations began on November 6, the company’s preparations for this high demand period began many months earlier, as described, in part, in the sections that follow.
4.4.1 Unique challenges of responding during Thanksgiving

For our partner transportation firm, like many similar companies, Thanksgiving was an extraordinarily busy time, with the Sunday following the holiday being the single highest demand day of the entire year and the prior Tuesday and Wednesday being exceptionally demanding, too. In some years, weather posed significant complications for this already difficult week. And because many customers’ requirements were related to family events, their emotions could run higher in the face of schedule changes than might otherwise be the case for routine business events or less family-oriented occasions.

4.4.2 Demand forecasting

Although it was an extremely busy period, Thanksgiving provided the firm the opportunity for much advance planning. It fell on a known date, and the company had extensive data on prior Thanksgivings for use in estimating future demand. And, unlike, Christmas, it fell on the same day of the week every year, making Thanksgiving demand forecasting less challenging than that required for the yuletide holiday. As has been
found in studies of supply chains, accurate forecasting was an element of anticipation that was essential for resilient operations (Pettit, Fiksel, & Croxley, 2010).

### 4.4.3 Maintenance planning

Given the high demand for vehicles during Thanksgiving week, the maintenance team planned on as little scheduled maintenance (e.g., vehicle inspections, periodic maintenance) as possible during this timeframe, boosting vehicle availability. Successful execution of this concept required great attention to detail and risked potential resource issues before and after the holiday, when an increase in planned maintenance would result in lower vehicle availability.

Regardless of the best plans for scheduled maintenance, unscheduled vehicle maintenance arose every day of the year, holiday or no. The firm carefully coordinated with its maintenance vendors in the field to assess their availability over Thanksgiving so as to know what vendor resources they’d have on hand to address acute maintenance problems. They also took on additional maintenance personnel at their larger facilities to provide added capability at these select locations.

### 4.4.4 Customer scheduling

During the Thanksgiving timeframe (and other busy holiday periods), the firm relaxed its normal schedule constraints (from the company’s, not the customer’s, perspective), providing itself greater predictability and more flexibility in responding to customer requests. It required customers to make their transportation requests farther in
advance than would normally be the case during non-holiday periods. The company also reserved the right to slide (backward or forward) the requested customer departure time so as to be able to spread out trips across its schedule, reducing crunches at particularly popular departure times. These holiday scheduling rules served to relax production pressure in a manner consistent with resilient performance and proactive safety management (Madni & Jackson, 2009).

4.4.5 Use of subcontracted vehicles

Closely related to the demand forecast was the projected need for subcontracted vehicles. As noted earlier, the use of vendor vehicles posed a particularly tricky tradeoff since they incurred extra cost, yet might be needed if organic assets were not sufficient. They also might not be available when required if not booked far enough in advance. Once booked, they were actually preferred over organic vehicles in certain situations since their procurement was a sunk cost.

The question during the Thanksgiving timeframe was not if subcontracted vehicles would be needed, but how many. The issue consumed attention not only in routine scheduling meetings, but in sessions specifically dedicated to addressing subcontracting needs. The approach adopted by the firm’s managers added capacity in a manner often seen in organizations seeking to create resilient supply chains (Christopher & Peck, 2004).
4.4.6. Operator scheduling

As noted earlier, decisions regarding when to end an operator’s duty day could impact the next day’s schedule as operators required a minimum interval for rest in between duty periods. Anticipating potential traffic delays on Sunday, the scheduling team took care to not start operator duty days any earlier than necessary (especially for spare crews) to ensure enough operator availability late in the day on Sunday.

4.4.7 Changing destinations

On Sunday, certain destination facilities were very likely to experience traffic delays. In some cases, the OC team changed the destination for a vehicle to a nearby facility in response to (or in anticipation of) a delay at the original destination. A variety of factors came into play regarding such decisions, including the size of the delay and, most especially, the customer’s preference. Such decisions also needed to account for the fact that other companies would be making similar moves at the same time, which might cause a traffic surge at the new destinations.

4.4.8 Few peak problems

In the event, the firm had few issues in executing its Thanksgiving schedule, and those that arose were within the realm of the expected for this travel period. Delays occurred in high traffic locations, but those almost inevitably occur in this timeframe and were outside the control of the company.
The firm did make extensive use of the relaxed scheduling constraints it afforded itself in sliding customer requested departure times, and this flexibility was essential to successful schedule fulfillment.

The most frequently cited reason for smooth execution noted by multiple participants (who presumably also placed great stock in their firm’s planning) was: good weather. Several people predicted things would go well given favorable weather, and after the fact others highlighted it as a success factor for this particular event.

One interesting intangible mentioned by several participants regarding their excellent performance (in terms of timeliness) was the idea that the firm’s employees knew that the Thanksgiving holiday was “game day” for them. As a result, the OC staff and operators would really stretch to meet the schedule; an operator, for example, might be less inclined to call in sick at this time than during a non-holiday period. Several participants said that employees understood that Thanksgiving was a time when customers were really counting on their service and were likely to remember if the company went the extra mile for them, or left them disappointed.

4.5 Super Bowl 2013: Forward deployment

In the case of the Super Bowl, which was held in New Orleans, the research team accumulated 68 total hours of observations of the firm’s activities between January 2 and February 6, 2013, as depicted in figure 8 below. Although observations began on January 2, the company’s preparations for this high demand period began much earlier, almost immediately following the 2012 Super Bowl in Indianapolis. Of the 58 hours of
observations during the peak period, 12 hours were performed by one research team member in the OC on February 3 and 4 and the remainder were accomplished by the other team member working at the firm’s forward deployment site in New Orleans.

![Table: Time Distribution of Super Bowl Preparation, Peak, and Restoration](image)

Figure 8. Super Bowl period of observation.

### 4.5.1 Unique challenges of responding during the Super Bowl

Although the Super Bowl did produce a spike in transportation requests in comparison to a routine weekend, which in and of itself would prove taxing, the major challenge for the firm regarding this event was the large number of trips scheduled in a tight timeframe out of a limited number of facilities, most out of a single facility. Although trips into New Orleans were spread out between Thursday January 31 and Sunday February 3 (game day), nearly all of the trips outbound were scheduled either immediately following the game or later in the morning on Monday February 4.

### 4.5.2 Forward deployed group

In response to the unique challenges of the Super Bowl, the company sent a group of nearly two-dozen personnel to serve as a forward deployed group to ensure a smooth
flow of vehicles, operators, and customers in and out of their New Orleans facility.

Staffed primarily from the firm’s headquarters, the group was a handpicked team of vehicle operator assistant team leaders, vehicle dispatchers, customer service representatives, and other staff members providing operator, maintenance, IT, security, and safety support. The group leader was a senior executive in charge of vehicle operations. The current-day scheduling function did not send a representative since its leadership believed its staff did not gain added insight from being present at the New Orleans facility and were better utilized in their usual roles at the headquarters.

Although they did not express their arrangements in quite these terms, the decisions of functional managers regarding participation in the forward deployed group reflected both sides of the tradeoff regarding distant supervision and local action (Woods & Shattuck, 2000). Among other considerations, the managers of participating functions, in particular the senior executive in charge of vehicle operations, valued the access to what was happening “on the ground” in New Orleans. On the other hand, the current day schedulers were more concerned with the broader view of the firm’s distributed operations, which they believed would be better obtained back at headquarters.

**4.5.3 Primary facility selection**

During routine operations, the firm would, insofar as was possible, accommodate the specific transportation facility requested by customer. In preparation for the Super Bowl, however, the leaders of the forward deployed group surveyed potential operational sites in person beforehand and selected one to be its primary facility for the event for all
customers, with key criteria being vehicle parking capacity, available vendor support, and proximity to the Super Bowl venue, the Mercedes-Benz Superdome. Having made a facility selection, the group went to great effort to reserve ample space for its vehicles and establish a strong relationship with its vendor, which provided vital services, including fuel. These parking and fuel capabilities served as critical elements of the company’s adaptive capacity for the event, for without them, operations at the facility would be impaired or impossible, regardless of the number of people in the forward deployed group.

### 4.5.4 Alternate facility identification

Although it scheduled its customers through the primary facility, the firm also assessed the capabilities of alternate facilities in the region to be used in the event of weather, traffic, or other contingencies, going so far as to reserve vehicle space at some of these locations.

### 4.5.5 The war room

In addition to parking space for the vehicles, the firm needed office space for its group, with one key area being known as the “war room.” Insofar as the forward deployed group served a command and control (vice a logistical) function, the war room served as the hub for that activity. Some of the critical functions provided in the war room included:
- Radio communication: although not limited to the war room, radios were in use by all personnel there (and by the rest of the team) to synchronize the movements of vehicles, operators, customers, and team members.

- IT: computer applications available to war room group members in New Orleans were nearly the same as those found in the company’s headquarters and included, most importantly, the master schedule program. Very few group members outside the war room, however, had access to computers, an exception being the vehicle operator assistant team leaders who had the same tablets normally issued to operators in the field.

- Arrival and departure tracking: one person in the war room had, among his other duties, the responsibility to announce vehicle arrivals over the radio, which was very important information for nearly all team members to know. The announcements and subsequent radio traffic involved transmissions by relatively few participants; not unlike voice loops used for coordination in other settings, the radio net was used by most participants as a way to “listen in” on activities and keep pace with events (Patterson et al., 1999).

- Vehicle parking map: not only did the team have a lot of vehicles to keep track of in the parking area, the firm’s vehicles were mixed among those of other companies, making the task even more difficult. However, knowing correct vehicle locations was vital for fueling and supplying the vehicles, as well as simply getting operators and customers to the right place. One person in the war room was dedicated to keeping the parking map up to date, and this (electronic) map was projected on a wall in the room and periodically printed out in hardcopy.
- Operator support: operator support personnel were there to provide operators the information they would normally receive prior to a trip, such as weather.

- Vehicle dispatching: a vehicle dispatcher was assigned to the war room to provide exactly the same sort of dispatching service provided by her counterparts at the company’s headquarters, with the added benefit of being able to discuss potential issues in person.

- Vendor liaison to the group: the firm arranged for the facility vendor to staff the war room with one of its own personnel to ensure it was aware of the status of the firm’s vehicles and the firm’s priorities for servicing them, in particular fueling them.

- Team liaison to the vendor: although technically not part of the war room, there was a member of the firm’s team assigned as liaison to the vendor’s own command and control room, his primary function being the clarification of the status of the firm’s vehicles, which was particularly important for departures. The role of such organizational liaisons or “interpreters” has been found to be valuable in other settings, such as interagency power and water control rooms (van Eeten, Boin, & de Bruijne, 2010).

4.5.6 People movements

In addition to planning for capabilities such as parking capacity and war room functionality, the forward deployed group devoted a great deal of effort to planning the processes for moving people. These movements included:
- Customers: on arrival, customer service representatives used golf carts to escort local area transportation vendors to meet customers as they arrived in an area close to the buildings being used by the firm’s forward deployed group. On departure, customer service representatives also used golf carts to escort customers riding in local transportation to their departing vehicle if their vehicle was about to depart shortly. However, customers whose vehicles were not ready for immediate departure (due to departure delays or early customer arrival) were welcomed in a waiting area and subsequently driven to their departing vehicle in a company van.

- Operators: vehicle operator assistant team leaders used golf carts to transport line operators from their vehicles upon arrival and to them upon departure. Company personnel also transported operators to and from hotels in vans.

- Staging area: integral to the ballet of company golf carts, vans, and local transportation was a large patch of concrete that could accommodate all of loading, unloading, and caravanning described above. This was the first Super Bowl that the firm had the luxury of a large space for these activities, and group was very pleased to have been able to secure it.

The vast majority of forward deployed group members were devoted to executing the people movements described above, whether as coordinators or drivers, with a key goal of the personnel movement plan being the minimization of wait times for customers and vehicle operators.
4.5.7 Departure scheduling

The scheduling of departures was subject to many more constraints than would be present during routine operations. One overriding consideration was a government imposed restriction on departures (or arrivals) at select transportation facilities from 90 minutes before kickoff until one hour after the end of the game. Although history had shown that the restriction might be lifted early, the firm could not be assured of that. The company also had to reserve departure schedule slots for its vehicles, competing with other firms (and individuals) to secure them.

4.5.8 Timing of operator pickups from hotels

As noted in section 1 of this chapter, operators had a set limit on the number of hours per day they could work and a minimum rest period between duty periods. Because of the potential delays associated with departures, particularly those on Sunday after the game, as well as uncertainties regarding traffic between the operators’ hotels and the facility, setting the time to pick up operators from the hotels was a difficult decision.

Picking up operators too late would delay customers on departure, but picking up too early would “start the clock” on the operators’ duty day prematurely, limiting their ability to operate should they be delayed on departure, encounter issues enroute, or have particularly long distances to travel. The forward deployed group leaders discussed this subject with the schedulers back at the company’s headquarters via telecon on Thursday of Super Bowl week. They arranged several waves of pickups, with many occurring around 8:00 pm local time, two and a half hours after kickoff.
4.5.9 Delivering the safety message

With nearly two dozen company personnel working at a facility unfamiliar to most of them, the group’s leaders, including operations and safety executives, recognized the importance of emphasizing safety issues. They did so during planning meetings and during an “all-hands” safety and security meeting during the team’s first day on site, where potential facility hazards (including “blind corners” on driving routes), security procedures, and driving rules were reviewed. These reminders were representative of the sort of preoccupation with failure found in HROs (Weick & Sutcliffe, 2007) and sense of precariousness characteristic of resilient systems (Woods, in press).

One interesting point raised by the team’s leader was the importance for each member to stay within his or her own area of expertise when dealing with customers, vendors, other transportation companies, and each other, an important consideration given the mix of people on site in an unfamiliar environment.

Unsurprisingly, all personnel working outdoors in the vehicle operations area were supposed to wear reflective vests, a standard procedure but also a visible reminder of the need for caution when dealing with large numbers of moving vehicles.

4.5.10 Initial operations: warming up with arrivals

Thursday of Super Bowl week was the first day of operations for the forward deployed group, and vehicle arrivals were evenly spread across that day, Friday, Saturday, and Sunday morning; the number of departures on Sunday after the game and
on Monday roughly equaled the number arrivals on the first four days. Not only was the pacing of the arrivals easier to cope with than the departures, the possibility of schedule disruptions was higher for departures given the greater potential for departure delays. So, the four-day arrival period made for a good opportunity to work out facility, communication, and process issues amongst the team members and with the vendor before facing the more chaotic (roughly 18-hour) departure period.

4.5.11 Arrivals get busy

The busiest day for arrivals at the facility was on Sunday, with vehicles from many companies arriving throughout the day prior to game time. Without prior warning, the vendor running the facility suddenly decided that arriving vehicles could no longer drop customers near the vendor’s buildings, but would, rather, drop them in remote parking areas. This prompted some debate among the team as to the best way to pick up the customers: by escorting their local transportation to the remote parking areas (not normally done on arrival, as it was some distance and involved navigating a blind corner, among other things); or by picking up customers in company vans and then transferring them to local transportation near the buildings, which might inconvenience the customers but would avoid having the local transportation driving in unfamiliar areas.

Representatives from customer service, the vehicle operations, and safety collectively decided that escorting the local transportation to the arriving vehicles would be the most effective and an acceptably safe way to handle the situation. And it turned out this process was used for less than an hour and was followed without incident.
However, the safety representative found it surprising that the facility vendor changed the drop off point procedure with such little warning (i.e., essentially no notice).

4.5.12 Communicating in person

The above incident represented an issue that was so important to functioning of the forward deployed group that the firm’s parking manager came out of the war room to speak with the customer service representatives and vehicle operator assistant team leaders himself, vice simply announcing the change over the radio; this was not unlike some of the critical in-person communications observed in the OC during hurricane Sandy. The forward deployed group’s executive leader was also observed to periodically gather the vehicle operator leaders in person to relay changes or emphasize procedures.

4.5.13 Shifting to night operations

In order to handle departures that began immediately following the game and continued into the early hours of Monday, the team was split into shifts for Sunday and Monday, with the “night” shift nominally working 9:00 am-1:00 pm, 8:00 pm-3:00 am, and 7:00 am-1:00 pm, and the “day” shift nominally on duty 9:00 am-8:00 pm and 5:00 am-3:00 pm. In reality, many personnel, perhaps motivated by the camaraderie of the group, exceeded their nominal shifts, and some leaders worked straight through the night occasionally taking short naps. Many group members had participated in the Super Bowl before and even those who had not did have a clear idea of what to expect in terms of the
shift demands of the event, and took a certain pride in having pulled their weight during a challenging period.

### 4.5.14 Considerations when the power went out

Although there were no departures in progress during the first half, operator support personnel were picking up operators from their hotels in vans and had a large number of pickups scheduled at approximately 8:00 pm. Then, to the surprise of the firm and football fans around the world, the lights went out in the Superdome early in the third quarter at around 7:42 pm. In both the OC and the war room, several concerns emerged regarding what, at that moment, was an indeterminate delay in the game:

- The later the game ended, the more likely it would be that large numbers of customers would reach the vendor facility at once. This would make the logistics of receiving the people more difficult.

- Departure times might not merely slide along to the right along with the game’s end time (recalling there was still nominally a one-hour restriction on all departures following the game). If a departure missed its scheduled time because the customer was late (or other reason), it might have to go to the end of the departure queue.

- Delayed departure times might leave operators unable to complete their trips within their allowable duty days, assuming they started their duty days as originally scheduled.
4.5.15 Actions when the power went out

Being aware of the above considerations, schedulers in the OC scanned the scheduled departures for those most likely to have issues making their departure times or running out of duty day for the operators. The OC current-day schedule lead considered requesting new, later times for the earliest scheduled trips in order to beat their competitors to the punch to secure these later slots in the case of a large number of missed early departures. However, the lights came back on in the Superdome (resulting in an approximately 30 minute delay in the game) before they executed that contingency plan, which turned out to be unnecessary.

The delay caused no issues with operator duty day. Perhaps most interestingly, one of the van drivers picking up operators from their hotels reported that the lights out delay actually made the operator pickup plan easier to execute; had there been no delay in the game, some operators would not have been in place when their customers arrived.

4.5.16 Departure coordination

As spelled out in earlier sections, each departing vehicle had a scheduled slot time. Because of the short time between departures, departing vehicles had to have both operators and customers ready to go at their scheduled time, and any vehicle requesting to depart that subsequently was not ready for any reason (e.g., not all customers had arrived) would confuse (and annoy) the facility vendor and government personnel coordinating the departures; such a vehicle might also be sent to the end of the queue.
To preclude such missteps, the forward deployed group took extra measures to organize departures. Customers were not taken to their vehicles until all customers in that party had arrived. Once the operators and customers were in the place, the operators coordinated with the war room to get approval to depart, and the war room coordinated with the facility vendor. Such extra steps are not needed during routine operations, but were but essential in keeping the tight Super Bowl departure schedule orderly. They were also part of the firm’s strategy of instilling confidence in the vendor and the government that their forward deployed group and vehicle operators would provide accurate status updates, enabling the company to use all of their allotted slots and perhaps take advantage of other departure opportunities in what was bound to be a fluid situation.

4.5.17 Communication reconfiguration

In addition to some of the in-person (vice radio) communication noted earlier, another interesting communication reconfiguration was the occasional use of mobile device communication (voice and text) between the OC staff and the forward deployed group. Although primarily reliant on information from the war room regarding vehicle status, in some cases the OC staff made queries of the vehicle operator assistant team leaders directly since they were actually driving around the parking area and saw the vehicles and their operators in person. Such informal communication strategies have been found to be effective in the work of distributed teams in transportation settings (Roth, Mutler, & Raslear, 2006).
4.5.18 Ground collision

Although the entire Super Bowl event was executed almost entirely without incident for our partner firm, one event that occurred in the early hours February 4 did cause some confusion. A company vehicle that was in its proper parking spot was the third vehicle in a chain collision; the vehicle that initiated the collision hit a second vehicle that hit the company’s vehicle. This resulted in damage that was minor, but which rendered it unfit for customer use; it was replaced on the schedule by a spare vehicle.

While this was a simple incident, it prompted an hour’s worth of communication among the OC, forward deployed group, and facility vendor (including transmission of photographs) to explain the chain of events that had transpired. This communication included the “backchannel” mobile device exchanges between the OC staff and forward deployed group members outside the war room of the sort discussed earlier. It also prompted the OC current-day scheduling team leader to walk around the OC to speak to with people in person to help clear up misunderstandings. Once the basic facts were clarified, the maintenance personnel on site and at the OC coordinated options for moving the damaged vehicle to a repair facility.

4.5.19 Smooth departures

From the perspective of the firm, departures, on the whole, went smoothly. Insofar as there were delays, they were attributable to the traffic system as a whole rather than problems with the company’s planning and execution of the departure process. The only reportable safety incident was the damage to one vehicle cited above, but, regardless of
how one wishes to attribute the cause of that incident, it would not fall to the company as their vehicle was appropriately parked.

4.5.20 Learning from New Orleans

Although the firm did not formally note lessons learned from all high demand events (e.g., winter storms), it did do so for the Super Bowl, institutionalizing the sort of learning shown to be critical for resilient systems (Hollnagel, 2009b). The compilers and keepers of those lessons were operations support personnel who would be considered “core” members of the group who made the trip every year. Some of their key lessons included:

- Fueling: the biggest problem cited by the New Orleans forward deployed group was delays in vehicle fueling, which they noted would have to be addressed with whichever facility vendor they choose to work with in the future.

- Staging area: on the plus side, the staging area for the company’s golf carts and vans and the local transportation was “a big win,” making it easier to unload, load, caravan, and park.

- Operator pickup times: the lessons learned suggested operator show times should have been 30 minutes earlier than scheduled, which was in agreement with the van driver’s observation that, in the event, the power outage (coincidentally) helped to compensate for this timing issue.
- Safety vests: one safety-specific note was the need to ensure all personnel were issued and wore reflective vests for outdoor operations at all times, as was their original plan.

- Whistles: another safety-specific lesson was to issue all personnel whistles to be blown to stop an unsafe act in progress, although the lessons learned do not note a specific act from the New Orleans event that might have inspired this recommendation.

While the firm placed great stock in documenting the specifics related to Super Bowl, it’s likely that the real reason that many in the company felt that New Orleans (and previous games) were a success was the experience of its personnel. This view was reflected succinctly by the group’s leader, who, when asked on Monday morning why things ran so smoothly, simply pointed to three of his vehicle operator assistant team leaders and said, summarizing the number of years each had with the company: “This works because of 16 years, 12 years, and 12 years.”

4.6 2013 and 2014: Years of change

The previous sections of this chapter provided a snapshot of our partner transportation firm’s performance from August 2012 through the Super Bowl in February 2013. While analyzing the data from these observations, the author returned to the OC periodically over the next 21 months to collect more data to provide a comparison with the initial observations. Figure 9 below provides an overview of these observation periods.
As will be shown in the sections that follow, poorer weather coupled with increased demand and fewer resources proved to be a combination that decreased operational performance in 2014, the second winter and summer seasons observed in this project.

4.7 Winter 2013: Intermittent challenges

One especially astute interview participant, an operations analyst, expressed his concern in December 2012 that bad weather in the coming winter coupled with greater demand and diminished resources might combine to degrade the company’s operations to an extent not yet experienced by some senior executives. His concern was well founded, but did not materialize for another year. On the whole, winter 2013 did not have particularly severe weather. According to the National Climatic Data Center (NCDC, 2013), the period December 2012 to February 2013 yielded above-average temperatures for most
states east of the Rocky mountains. It did, however, include some noteworthy winter storm events.

4.7.1 Winter storm Nemo

In early February, cold low pressure from Canada merged with a coastal storm to form winter storm Nemo, which, produced blizzard conditions in the Northeast on Friday the 8th and Saturday the 9th (NCDC, 2013). Not unlike hurricane Sandy, Nemo prompted the firm to establish WIZs that called for operations to cease in much of the Northeast, in this case on Friday evening.

Although the company did not stand up a response management team of the size used in hurricane Sandy, it did convene a smaller group for Nemo in a meeting Friday afternoon to review pending trips and storm preparation. The scheduling executive chairing the session explained that much of their business could have been handled by e-mail, but he decided to meet in person because he wanted to ensure participants were on the same page. This behavior was not surprising as it was in keeping with findings that face-to-face conversation is the most powerful means of coordinating group work (Kiesler & Cummings, 2002). Based on their discussions, the executive directed that customers and vehicle operators scheduled for Saturday morning trips in the affected areas be notified that they would not be departing until noon at the earliest. The group also discussed the need for added protection for vehicles in four locations that did not have adequate indoor shelter space.
In the OC, the noise level on Friday was high has voice communication, both face-to-face and by phone, increased. However, workload and stress were lower than for the Sandy event, as was evident from discussions with participants and the shorter electronic queue of scheduling action items.

Observations from Nemo also provided excellent examples of the sort of anticipation and coordination that occurred continually in the OC. On Friday, current-day schedulers moved vehicles from other areas to Maryland in anticipation of potentials needs the following day in New York and New Jersey. This strategy was similar to the hurricane response practices of Waffle House Restaurants, which called for the shipment of additional supplies to restaurants just outside of the path of a hurricane so that they would be readily available once the storm passed (Ergun, Heier Stamm, Keskinocak, & Swann, 2010).

Nemo also highlighted an issue that could arise more frequently with storms on a lesser scale the Sandy: questions from customers regarding the suspension of service for weather-induced safety reasons. When the firm ceased operations in areas still being served by competitors, customers sometimes questioned the company’s judgment. The firm did not appear to change its decisions in response to these inquiries, but did have to emphasize the benefits of its conservative safety approach to its customer base.

4.7.2 Presidents’ Day

In 2013, Presidents’ Day fell on Monday February 18. As with other holidays, the company planned carefully for this event, with special attention on the need for
subcontracted transportation. Even current-day schedulers anticipated the event well in advance; in the midst of winter storm Nemo on Saturday the 9th, which was not as bad as some in the firm predicted, current-day schedulers coordinated with maintenance to move vehicles into planned maintenance in time to complete it before the following weekend.

The firm took advantage of the special scheduling rules in place for select holidays, turning away some transportation requests that did not meet the earlier-than-usual deadline; it did this more frequently in 2013 than in prior years when demand was lower and resources more plentiful, a trend which will be discussed in more detail in the sections that follow. These trip request denials occurred despite the presence of spare vehicles and crews because the participants recognized the need to keep spares in the schedule to fulfill existing commitments. Schedulers also moved some requested departure times (earlier and later) in order to accommodate more trips, another flexibility afforded during holidays.

4.7.3 Cold in the Southeast

Among the weather issues confronting the firm in March was intense cold in the Southeast. In Miami, March 4 turned out to be the coldest day in all of 2013 (NWS, 2015), and this low temperature was partially responsible for the very long delay of a trip departing from the Florida city. One OC staffer noted that that this delay would have been avoided had the vehicle been properly sheltered the night before as was the company’s practice for such weather conditions in that region of the country.
The staffer further observed that this oversight might have been averted if the company still had its quality control function, which was eliminated as a result of the business losses the firm suffered in the recession that officially began in December 2007 (National Bureau of Economic Research, 2008). The elimination of roles such as quality control in order to attain greater efficiency is a typical reaction of organizations attempting to cope with pressure to be “faster, better, cheaper” (Woods, 2006; Woods & Wreathall, 2008).

4.8 Winter 2014: Weather, resources, and demand

For our partner firm, winter 2014 saw the convergence brutal weather and increased demand with no increase in resources. The weather was characterized by below-average temperatures and numerous winter storms east of the Rockies, with seven Midwestern states recording a “top ten cold” winter season (one of the ten coldest ever); Detroit logged its most ever snowfall for the season and New York, Philadelphia, Chicago, and Boston all had top ten seasonal snowfalls (NCDC, 2014c). Storms throughout the month of December 2013 resulted in at least four massive highway crashes (involving 30 to 65 vehicles) and major airport delays in the Northeast. The weekend before Christmas (December 21-22) welcomed winter storm Gemini, with warmer temperatures that, rather than providing winter relief, produced high winds and ice (NCDC, 2014a). January opened with a major event (winter storm Hercules) that afflicted the Northeast, followed later in the month by three winter storms that hit the Southeast (NCDC, 2014b). February started with winter storm Nika, which caused a power outage in southeastern
Pennsylvania second in scale only to hurricane Sandy, and included three additional storms along the east coast that caused significant travel disruptions (NCDC, 2014c).

4.8.1 Resource and demand trends

Previous sections in this chapter described events that resulted in spikes in demand for the firm’s transportation services, spikes that were expected when they occurred in conjunction with holidays and the Super Bowl. In looking at the longer term, the trend worth noting was an approximately 6% increase in total annual demand in 2013 (over 2012) and an approximately 8% increase in 2014. Company managers expected the improving economy to boost demand, but were surprised by an especially large increase in the popularity of its more affordable transportation offerings.

Although pleased by the higher sales figures, the firm faced a stiff challenge in delivering on its sales promises. As noted earlier, the recession that began in December 2007 significantly decreased customer demand, prompting the company to lay off employees and begin a process of decreasing the size of its vehicle fleet. In the fall of 2014, it began a process of recapitalization that would slowly add new vehicles. The plan would eventually increase the number of vehicle operators as well, but would not restore the size of the support staff to its pre-recession level. Subcontracting for vehicles, which for several years occurred only at holidays, became a more frequently used option, but also remained expensive and required planning months in advance to be used most efficiently. This expansion of subcontracting capacity effectively extended the range of demand conditions in which the firm could successfully operate, a shift which served as
an example of graceful extensibility and a marker of its resilience (Woods & Wreathall, 2008; Woods, in press).

4.8.2 Winter storm Hercules

Winter storm Hercules was one of several taxing events to strike the firm in winter 2014. Between 2 and 3 January it covered the Northeast in two feet of snow (NCDC, 2014b). Its impact on the firm’s performance on 3 January was substantial: on-time performance was about 15% below normal (for a good weather day) and the number of lengthy delays was about five times greater than usual, despite a very large number of subcontracted vehicles.

4.8.3 A cycle of decline over the course of a day

The days of winter storm Hercules were typical of those associated with particularly bad weather. In terms of the weather itself, it was the direct cause of delays and cancellations for vehicles that were otherwise functional and staffed with operators. With regard to demand, bad weather prompted higher than forecast demand as customers turned to the firm as an alternative transportation option when their primary means became unable to support them, with some customers making transportation requests just ahead of storm fronts. This increased demand resulted in higher than expected utilization of both vehicles and operators, leaving fewer timely scheduling options available, further increasing delays and cancellations. Higher than expected utilization also produced more vehicle breaks and operators calling in sick, driving still higher utilization and more
delays and cancellations. In short, bad weather prompted a large increase in the three recovery triggers noted in section 3.2.6: new requests; vehicle breaks; and unexpected losses of vehicle operators. The cycle of decline always abated, but it did so in ways that were not positive: trips became increasingly delayed, perhaps until the following day, or were cancelled. This cycle is depicted in figure 10 below.

![Figure 10. Cycle of performance decline on a bad weather day.](image)

When caught in the cycle described above, workload for the OC staff increased dramatically. As the recovery triggers increased in number and frequency throughout the day, the resources available to address them shrunk, making the work needed to identify a viable recovery option more difficult while the queue of recovery actions in progress
grew longer. And as the day progressed, recoveries were less successful in one or more of the following aspects: they required more complex adjustments elsewhere in the schedule; they used expensive subcontract assets; they were late in comparison to the time requested by the customer; they actually triggered more recoveries because the initial recovery vehicle broke or operator reported in sick; or they subsequently fell apart because evolving weather issues hampered vehicle and/or operator movements. As one participant noted, the winter storms “crushed” the firm’s ability to move vehicles and operators to cover trips.

4.8.4 A cycle of decline over days

As the effects of Hercules lingered into a third day, the impact of high workload on the OC staff was aptly summarized by a night shift scheduler on 4 January: “for the last three nights, I’ve had someone telling me when I’m coming in to ‘just go home.”’ In terms of performance, it was reported by several participants as being typical of several days in a row of bad weather and high demand: increased vehicle and operator utilization produced more vehicle breaks and operator sick calls. Over the course of this study several periods with several days of bad weather were observed to follow these general trends, although not all metrics followed strictly negative trends in all cases. However, even if all measures of performance did not significantly degrade during every day of a storm, OC participants reported being increasingly tired or stressed by the high workload induced by strings of bad weather days.
4.8.5 A very bad month and season

The cumulative effect of Hercules and other winter storms in the month of January 2014 produced the worst service delivery performance observed in this study. The firm tracked the time delay incurred each time a recovery was needed and set a standard for this time; in January, recovery time exceeded the standard by 50%. Not surprisingly, January was also the month with the worst observed maintenance performance, with the percentage of vehicles available for use being 10% below the target availability.

In terms of recovery time, the next worse month observed was February 2014 (33% above the target time), followed by December 2013 (25%). As noted earlier, December included winter storm Gemini, which one current-day scheduler described as being worse for the OC than hurricane Sandy.

The bad service performance proved problematic for the firm in dealing with its customers. As one participant noted, customers were understanding of the impact of an event on the scale of hurricane Sandy, but less forgiving of issues induced by smaller scale storms in one region that rippled into delays in other parts of the country.

4.9 Summer 2014: Surprisingly challenging

Although staff and managers at the firm were well aware that bad winter weather would negatively impact operations, they generally regarded summer as a less challenging season. The summers of 2012 (just winding down as this study began) and 2013 were not especially taxing, but 2014 proved more daunting.
4.9.1 Typical summer periods of high demand

The company was very conscious of when high demand typically occurred during the summer, and applied the same holiday scheduling rules it used at Thanksgiving to Memorial Day, Independence Day, and Labor Day: it required customers to make their transportation requests farther in advance and reserved the right to slide (backward or forward) the requested customer departure time. Holiday scheduling rules were never applied in June, which historically was not a difficult month.

4.9.2 Unanticipated June challenge

June 2014 presented challenges similar to those evident in the preceding winter. Demand was up about 8% over the 2013, but resources (vehicles and operators) had not grown appreciably. The weather was highlighted by numerous damaging thunderstorm wind events in the Northeast and Southeast (NCDC, 2014d).

One three-day stretch, Wednesday June 11 to Friday June 13, was particularly trying, as it included thunderstorms along much of the eastern seaboard each day. As one OC staff member explained when trying to restore order to the schedule on June 14: “If I can maintain a zero batting average that would be okay, as long as I don’t go negative.” The company’s performance numbers over this spell of bad weather reflected the staff member’s fatigue: operator sick calls were about double the usual average; the vehicle breakage rate exceeded the usual average by 10% on the 13th (and 30% on the 14th); and the average time each day to execute recovery trips exceeded the firm’s target time by 10% to 67%.
Reflecting on the previous week and looking ahead to the week beginning on Monday June 16, one OC manager wondered: “When do we pull out of this funk?” Unfortunately, the funk continued throughout June and the average time for the entire month to get recovery vehicles in place exceeded the target time by 25%, which was as bad as December 2013.

4.9.3 Workload takes its toll

In discussing the long-term effects of the stress and high workload that were most severe in winter 2014 and that continued into the summer, a group of managers explained that they were have trouble getting OC staff in some functions to take on overtime, which had not been a problem in the recent years. They also lamented increased personnel attrition, including individuals in key positions and some who left without having jobs lined up before departing.

4.9.4 Chronic decompensation

As noted in section 3.3.5, Woods and Cook (2006) characterized decompensation as an exhaustion of the system’s capacity to adapt as challenges mount. Miller and Xiao (2007) have further defined the sort of decompensation described by Woods and Cook as an acute condition exemplified by a short-term exhaustion of adaptive mechanisms. Miller and Xiao expanded on this concept with what they termed “chronic decompensation,” or a long-term erosion of adaptive capacity. The operational performance of this study’s partner firm in 2014, its seeming lack of resource buffers, and
other indicators such as staff attrition were consistent with their depiction of chronic
decompensation.
Chapter 5: Discussion

5.1 Overview

The results of this study provide abundant material for exploring the nature of resilience and its relationship to safety. This chapter uses the study’s empirical findings to expand on different approaches to resilience, including: cross-scale interactions (Woods, 2006a); the stress-strain adaptive landscape (Woods & Wreathall, 2008); and four general concepts of resilience (Woods, 2015). It then considers findings in light of major theories of safety, including: latent failure (Reason, 1990); control theory (Rasmussen, 1997); and Amalberti’s (2013) three models. It also compares lessons learned from the research partner firm with those learned in the case of European airspace closures precipitated by the eruption of an Icelandic volcano in 2010. The chapter closes with thoughts on the study’s limitations, ideas for future work, and some concluding remarks.

5.2 An organizational framework for resilience: Cross-scale interactions

Before discussing the application of models of resilience to this case, it’s important to note that Resilience Engineering, especially as applied to safety, seeks to accentuate what an organization does right rather than exclusively focusing on what goes wrong (Hollnagel, 2013). Any group seeking to evaluate and strengthen its own resilience should adopt this stance as it reflects on its performance.
5.2.1 Cross-scale interactions framework in Sandy

One useful approach for assessing organizational resilience is to examine cross-scale interactions, both upward and downward. Woods (2006a) characterized the downward elements as strategic in nature, such as the resolution of organizational goal conflicts, and the upward elements as tactical, including the use of workarounds to implement strategic guidance (see also Tjørhom & Aase, 2011).

Observations conducted during Sandy revealed these upward and downward activities to be at work in how the company prepared for and responded to the crisis, as shown in figure 11 below. Note that the diagram calls attention to the anticipatory and directive nature of the top down actions, with the bottom up reflecting adaptations in pace to events. The figure also accounts for actions that both promote and hinder flow across the levels. The subsections that follow examine how the observations above are appropriate for this framework, and also spell out how they relate to different patterns of resilience detailed by Woods (2011), patterns of failure described by Woods and Branlat (2011), and requirements for the coordination of joint activity (Klein et al., 2005).
5.2.2 Response management group

The response management group of executive leaders, which met twice daily in the days leading up to the hurricane’s landfall, provided direction regarding the firm’s actions in anticipation of the hurricane, followed up to ensure compliance, and made adjustments in the face of evolving circumstances. It embodied a collective recognition of adaptive capacity at the highest echelon of the firm, making and disseminating strategic decisions. For example, the group decided on a set of locations outside the hurricane zone to be used for the collection of vehicles evacuated from the zone; during routine operations, the details of such movements were generally left to working level personnel in the OC.
One reason that the response management group proved effective was because its members were well acquainted with each other based on their daily interactions on routine business as well as their convening for large-scale weather events. Their experience working together during these challenges would have likely served them well had they been faced with a completely unanticipated crisis.

5.2.3 Dynamic weather impact zones

A significant top down contributor to our transportation firm’s resilience in this incident was the establishment WIZs that ceased (or curtailed) operations in designated areas at specific times. The WIZs served to synchronize the actions of different OC roles in both time and space, and their use formalized an acute-chronic tradeoff that ensured that chronic safety needs overrode acute production concerns. Woods (2006a) termed this sort of decision a sacrifice judgment; in this case, the actions of senior leaders temporarily relaxed production pressure in order to avoid pressing too close to the boundaries of safe operations.

Without the zones, operators and OC staff would have had to make individual decisions to cancel or change dozens of trips. But thanks to the zones, they did not have to reach separate conclusions regarding some destinations that all would have agreed were clearly out of weather limits. This freed them to spend more time changing the timing and/or destination of trips originally planned to enter or leave the WIZs, and to make more difficult decisions regarding trips at the timing and geographical boundaries of the zones, or other areas with marginal weather. The zones also served as the sort of
shared script that Klein and colleagues (2005) found to be an aid in supporting inter-
predictability among team members, enabling them to coordinate their joint activities in
reference to common objectives and timing.

5.2.4 Strategic safety tradeoffs

In addition to the execution of the WIZ policy, the decisions (made or endorsed by
the response management group) to evacuate vehicles from the zones, remove transient
personnel, and excuse from work local personnel also represented a choice to place
chronic safety considerations ahead of acute production issues.

5.2.5 Circumscribed initiative

Turning to the bottom block in figure 11, one means by which working level OC
schedulers adapted in pace to events as the hurricane approached was taking initiative.
The vehicle maintenance team lead took such initiative in sheltering vehicles outside of
the nominal WIZ without first obtaining permission from his supervisor, as would be the
case in normal circumstances. He felt comfortable doing so because he knew this was in
keeping with the intent of the response management group.

As depicted in figure 11, this taking of initiative is described as “circumscribed.”
This modifier is important since the nature of the initiative taken at the working level was
not unlimited; it was, rather, initiative in accord with goals as mutually understood across
scales in the organization. The activities promoting this mutual understanding are
depicted in the cross-scale flows block of the diagram and discussed further below.
5.2.6 Faster decision making

In addition to taking initiative, working level OC staff simply made decisions (that were already within their normal purview) more quickly in hurricane Sandy than they would on a more routine day, a necessity for them to keep pace with events. In particular, the current-day schedulers considered far fewer recovery scheduling options during the peak of the Sandy activity than would be the case on a normal day.

5.2.7 Effective response over cost

Faster decision making often led to the selection of the most effective (most timely) solutions to scheduling requests as opposed to the least costly options. Several OC schedulers also noted the need, during the busiest periods, to address the immediate schedule issues as quickly as possible without regard to other downstream effects, such as impacts on the next day’s schedule.

5.2.8 Communication reconfiguration

One of the most interesting and surprising observations in this study was the reconfiguration of communication in the OC to increase the use of voice traffic. Although electronic communication was usually fast enough on a normal day, during Sandy these channels became clogged; some staff members then elected to interrupt colleagues by phone or in person to ensure their most vital messages were received and understood.
5.2.9 Senior management abreast of ops

Depicted in the left-hand box in figure 11 are several observed characteristics of the firm that promoted communication and coordination flows across scales during the hurricane Sandy event. The response management group’s close monitoring of operations and the active presence of middle OC managers on night and weekend shifts were examples of the means that the firm used in successfully responding to changing interdependencies and coordinating potentially conflicting goals across scales of the organization.

5.2.10 Middle management buffers the working level

In addition to staying abreast of operations themselves, the middle managers of the OC were, in some cases, able to shield staff at the working level from executive inquiries, freeing the working level to handle real-time tactical issues. This proved to be another effective technique for coping with changing interdependencies.

5.2.11 Working level knows top priorities

As noted earlier, OC staffers were well aware of management’s top priorities, so much so that they on occasion took initiative to bypass normal coordination processes to fulfill objectives in a timely manner. This understanding enabled the pursuit of high-level goals even in the face of changing interdependencies.
5.2.12 Senior management needs additional data

Working counter to the cross-scale flows discussed above was a set of cross-scale bottlenecks that are depicted in the right-hand box in figure 11. For example, while there were obvious benefits to senior management staying on the pulse of operations, their need for information, especially during the busiest periods in the OC, added to the cognitive and coordinative workload of the staff. In describing the requirements for coordinating joint activity, Klein and colleagues (2005) highlighted the need to control the costs of coordination; even well intended attempts to assist actually create extra demands and work can greatly outweigh any advantages from the interactions.

5.2.13 Senior management over controls

In addition to needing more information, senior management’s assertion of authority over vehicle operations at a level of detail normally beyond their concern was another example of increasing the costs of coordination. While aiming to be helpful, this overcontrolling also placed added load on the staff. This behavior, along with the information demands noted above, represents in some ways the potential downside to the otherwise beneficial habit of senior management staying abreast of operations.

5.2.14 Processing unfulfillable requests

In processing last-minute transportation requests that were in all likelihood unfulfillable, customer service representatives were able to assure customers that they made every effort to meet their needs. However, even examining these requests slowed
the work of schedulers attempting to solve more complex issues. Customer service in this instance exhibited two patterns of adaptive system breakdown identified by Woods and Branlat (2011): it was stuck in outmoded behaviors (or “stuck in stale”), failing to adapt its process to changing circumstances, which in turn left it “working at cross-purposes” with scheduling and maladaptive in relation to larger system goals.

5.2.15 System reconfiguration

Among the characterizations above is a description of communication reconfiguration. Looking at all of the elements of the cross-scale interactions framework in this subsection, taken together they may be considered a partial description of a larger system-wide reconfiguration undergone by the firm during Sandy. Elements of this reconfiguration included the formation of an ad hoc leadership group, changes in the organization’s acute-chronic and efficiency-thoroughness priorities, and additional factors that both aided and hindered information flows across scales. Understanding more about how such system reconfigurations during challenge events change the balance across goal tradeoffs is a promising area for further study and modeling.

5.3 A physical analogue for resilience: Stress-strain adaptive landscape

While the cross-scale interaction framework offers many useful lessons for organizations preparing to cope with challenge events, the firm’s performance as observed over the course of this project also affords an opportunity to apply a more generalized approach
for assessing system resilience: the stress-strain adaptive landscape. Figure 12 below shows the landscape as originally presented by Woods and Wreathall (2008).

Figure 12. The stress-strain adaptive landscape (Woods & Wreathall, 2008, p. 148).

5.3.1 Stress-strain in material science

As used in material science, a stress-strain plot depicts load on a material (or stress) on the y-axis and the degree to which the material stretches under that load (or strain) on the x-axis. Initially, strain increases uniformly as a function of stress, an area of the graph termed the elastic region. At higher levels of stress, strain increases non-uniformly, an area known as the plastic region. At the highest levels of stress, gaps appear in the material until it fractures or fails.
5.3.2 Stress-strain as a resilience analogy

In an organizational resilience sense, stress corresponds to demands and strain resembles the responses of the system to those demands. In what Woods and Wreathall (2008) called the uniform region, the organization’s responses stretch uniformly in a manner according to its plans and procedures; Woods (2006) also described this area of performance as the system’s competence envelope. Woods and Wreathall further characterized the responses employed in the uniform region as being elements of the system’s base, or first-order, adaptive capacity.

In the extra region, demands exceed the organization’s capability to respond in an on-plan manner with base adaptive capacity, opening gaps in its ability to function efficiently and safely. To operate at all in the region, the system calls on extra, or second-order, adaptive capacity in terms of additional resources, more work, and new strategies. Such capacity is costly; as represented by the decreasing slope of the curve in the extra region, each increment of demand in this area requires a greater increment of response than in the uniform region. As demands increase across the extra region, the system depletes its adaptive capacity and fails, or further adapts and re-organizes itself, as shown in the restructured region.

5.3.3 Additional resources in the extra region

Certain aspects of our partner firm’s performance across the entire period of observation correlate remarkably well with the stress-strain analogy, especially its use of resources. The most fundamental resources needed for the company’s operations were
vehicles and operators. On any given day, the organic assets available for use, including spares as well as those scheduled for specific trips, would be considered to be part of the firm’s base adaptive capacity. While operating with spares available, the system was functioning in the uniform region.

The most obvious extra adaptive capacity would come in the form of subcontract assets added to the schedule at the last minute; in reality as in the model, these were expensive resources. However, in addition to simply subcontracting more, the OC had various mechanisms for stretching its organic capabilities, including deferral of maintenance, upgrading vehicle requests to meet scheduled times, and scheduling operators closer to the end of their duty days or extending their work weeks. Once again, these choices were costly, sometimes in terms of reducing the available options to meet future demands.

5.3.3 More work in the extra region

While operating in the extra region, workload was higher for the OC staff as well as the operators. Every recovery resulted in additional tasks, and the amount of work required for each successful recovery increased as resources became scarcer. Cognitive and coordinative effort could skyrocket, as was certainly the case during hurricane Sandy and other severe weather events.
5.3.4 New strategies in the extra region

In addition to performing more work in the extra region, OC staff also applied new, or at least non-routine, work strategies. One approach was performing more efficient but less thorough searches for recovery options. Another was more voice (face-to-face and telephone) communication, as well as the use of back channels. In exercising authority, some strategies, such as the taking initiative at the working level, were successful, while some intrusions on operational details by senior executives contributed to workload bottlenecks.

5.3.5 Exhaustion and near failure

Our partner firm was never observed to experience system failure in the form of a major accident while the operation was performing in the extra region. However, it did on occasion exhaust its extra adaptive capacity and cease being able to respond to added demand. Such conditions developed during periods of severe weather when performance marked by large numbers of delays and long recovery times further degraded into slips to the next day and outright cancellations; days like these produced the very bad performance at the height of the winter storm season in January 2014 and other similar months.

One particularly interesting example of extra adaptive capacity exhaustion was hurricane Sandy. Because the WIZ that halted operations in much of the Northeast on the evening prior to landfall also extended into the next day, the company quickly shifted from the brink of exhaustion to functioning in the uniform region. Although it did
recuperate from episodes of exhaustion in other severe weather periods, it did not
typically have the benefit of the operational downtime afforded by the Sandy WIZ and
did not necessarily return as quickly to the uniform zone.

5.3.6 Mis-calibration and surprise regarding the uniform region

Woods and Wreathall (2008) have noted that organizations are often mis-calibrated
in terms of being able to assess their adaptive capacity relative to the potential demands
that they face. In a stress-strain framework, they overestimate the size of their uniform
region of performance. A group’s resilience is reflective of its ability to perform (and act
on) an accurate assessment. Weick and Sutcliffe (2007) likewise found that such
organizational self-awareness or calibration was a fundamental trait of HROs.

On the other hand, one consequence of mis-calibration is surprise. Wildavsky
(1988) identified two types of surprise: quantitative, which is a matter of frequency or
degree; and qualitative, which is something truly unexpected.

In the course of this study, the firm did not experience genuine qualitative surprise.
It did, however, show mis-calibration as exhibited by some critical quantitative surprises.
Increasing demand for its services coupled with very adverse weather and a static organic
resource base produced worse than expected performance in late 2013 and 2014.
Numerous participants anticipated these types of trends, but none foresaw their
magnitude and severe consequences.
5.3.7 Mis-calibration and brittleness

As described in the Woods (2011) patterns of resilience framework, the “optimality-brittleness” tradeoff was meant to convey that brittleness is a consequence of the pursuit of optimality. It’s evident that our partner firm pursued a resource strategy after the recession that sought to better optimize its economic efficiency, which left it more brittle in the face of increased customer demand and challenges such as severe weather. Brittleness, then, can be thought of as a consequence of the mis-calibration discussed in the section above.

5.3.8 Re-organization in the restructured region

The ability to improvise has been recognized as an essential quality of a resilient organization (Boin, Comfort, & Demchak, 2010; Bea, 2011), in particular the ability to reconfigure operations in the manner of, for example, a medical team in an overcrowded emergency department performing patient treatment in hallways (Wears, 2010). Such impromptu work re-organization under high demand is represented in the stress-strain space in the restructured region.

Our partner firm was especially adept at re-organizing its work under challenging conditions, as demonstrated by the forward deployed Super Bowl team in New Orleans when it shifted its flow for customer pick up during the peak period of arrivals. The initiative taken by the vehicle maintenance team leader to shelter vehicles outside the nominal WIZ during hurricane Sandy was another excellent example.
5.3.9 Temporary expansion of base adaptive capacity

As outlined at the beginning of this section, the OC could be considered to be operating in the uniform region if the resources and capabilities scheduled to be at its disposal were adequate to meet the demands of that shift. This means that the highest demand days did not necessarily produce the most organizational strain if enough adaptive capacity was available. This was accomplished through the temporary expansion of the uniform region with additional base adaptive capacity, as illustrated in figure 13 below.

Figure 13. Temporary expansion of the stress-strain uniform region.

The best examples of the temporary expansion of the uniform region were seasonal and special events, such as Thanksgiving and the Super Bowl. Through careful planning, the company brought on additional resources that had the potential to make these periods...
relatively low-strain. They also expanded adaptive capacity by applying special 
scheduling rules, and, most interestingly, through the added motivation of employees 
who felt obligated to “step up” on these occasions. Over the course of the study, the firm 
became more liberal in the acquisition of subcontract assets on a more frequent basis. As 
depicted in the figure above, measures taken to temporarily expand base adaptive 
capacity are more costly in comparison to those employed in the initial uniform region.

5.3.10 Non-temporary expansion of base adaptive capacity

Although the firm had planned for a slow growth of organic resources in 2014, the 
reality of higher than expected customer demand compelled it to expand its plans for 
adding vehicles and operators to its fleet. These were complex decisions driven not only 
by capital investment considerations, but by timelines for hiring and training as well. The 
company also brought on some more support staff; however, chastened by the recession, 
they didn’t intend to return to the higher staffing levels of the 2007 timeframe.

5.4 A general description of resilience: Four concepts

Woods (2015) attempted to clarify the disparate notions of resilience swirling in 
academic, policy, and practitioner domains by offering four concepts that captured varied 
meanings of resilience: robustness; rebound; graceful extensibility; and sustained 
adaptability. Our partner firm demonstrated all of these concepts, which are also useful 
to consider in relation to the previously discussed resilience frameworks.
5.4.1 Robustness

Robustness is a term popularly synonymous with resilience. Woods (2015) defined it as an “increased ability to absorb perturbations” (p. 6). He agreed with Doyle and Csete (2011) that “Robust control is risk-sensitive, optimizing worst case (rather than average or risk-neutral) performance to a variety of disturbances and perturbations” (p. 15624). Woods further pointed out that any system optimized to be robust with regard to a specific set of disturbances and perturbations would become brittle with regard to others, as expressed in the previously discussed optimality-brittleness tradeoff (Woods, 2011; Hoffman & Woods, 2011).

The performance of the firm during periods of bad weather in 2014 reflected decisions made by the company that had the effect of making it more robust in terms of its ability to absorb potential financial perturbations, but more brittle as it approached the boundaries of its vehicle and operator capacity in the face of high customer demand.

5.4.2 Rebound

Rebound is another concept widely associated with resilience. Woods (2015) characterized it as the capacity to recover from a disrupting or traumatic event to return to previous or normal activities. He added that a system’s ability to rebound is function of the degree to which the challenge event is a surprise and what the system has done beforehand to prepare for surprise.

In general, the company was able to rebound after a single day of bad performance because, for the most part, it would start the next day with few carryover effects from the
previous day, e.g., not many unfulfilled trip requests from one day spilled over into the next one. However, several days in a row of bad weather and high demand (particularly in 2014) often resulted diminished rebound and degraded performance as measured in recovery time, vehicle breaks, operator sick calls, etc. This was not due to the challenges being completely surprising, but, rather, due to the convergence of somewhat higher than expected demand, worse than average weather, a reluctance to take on added organic resources, and the time required to bring on those resources.

Rebound from the hurricane Sandy is an especially interesting case. On the day prior to landfall, the nature of the challenge was a surprising spike in last minute travel requests, resulting significant and highly visible scheduling decompensation. But the rebound was just as abrupt since the implementation of the WIZ terminated operations in much of the Northeast suddenly eliminated demand, or at least demand that the system was willing to accept.

5.4.3 Graceful extensibility

Woods (2015) described the notion of graceful extensibility as the ability of a system to stretch to handle surprises and events that challenge the system’s boundaries. He held this quality to be in opposition to brittleness, or sudden system collapse at a boundary. Woods further explained that while the more popular term “graceful degradation” referred only to system breakdowns, “graceful extensibility” accounted for the potential for system success in such circumstances.
Our partner research firm exhibited both senses of graceful extensibility, bending (and degrading) without breaking in some challenging situations, while succeeding in meeting its own standards (and those of its customers) in others.

5.4.3.1 Graceful extensibility as successful performance

The company best achieved performance success in challenge periods when the events were known well ahead time, as was the case with Thanksgiving and the Super Bowl. As noted earlier, the firm expanded adaptive capacity on these occasions by bringing on additional assets and applying special scheduling rules. The firm also met its performance standards during severe weather events when it had adequate subcontract vehicles on hand to meet customer demand.

Within the stress-strain resilience framework, graceful extensibility producing successful performance is represented in the temporary expansion of base adaptive capacity depicted in figure 13 above. The fact that extensibility can yield successful, and not merely degraded, performance supports the notion of a temporarily expanded uniform region in the stress-strain analogy; if this were not the case, extensibility in the face of high demand would map into the extra region in figure 12 above, which is, by definition, an area of degraded performance.

5.4.3.2 Graceful extensibility as graceful degradation

While the it is useful to think of graceful extensibility as a form of stretching that can produce success, it should also account for gracefully degraded performance as
Periods of high demand and bad weather did result in significant delays and cancellations that can only be considered to be a degraded level of performance, albeit not brittle in nature.

Although many of the forms of adaptive capacity employed by the firm were used in situations of both successful and degraded performance, some adaptations were indicative of decompensation and degraded performance. For example, a high level of noise in the OC, resulting from communication reconfiguration in the form of increased voice exchanges, was typically indicative of decompensation that was evidenced by longer delays and a greater number of cancellations.

5.4.4 Sustained adaptability

In examining the evolution of systems over time, Woods (2015) identified the quality of sustained adaptability as being critical for resilience. Once again citing Doyle and Csete (2011), he described the nature of the system’s architecture as being especially important in supporting its ability to adapt over time in the manner first discussed by some of the earliest works on resilience (Holling, 1973). While robustness to a particular challenge is the result of an optimality-brittleness tradeoff, sustained adaptability is the mechanism through which that tradeoff is made.

As discussed above, the firm was robust in schedule performance when challenged with bad weather and spikes in demand prior to 2008, but brittle in financial performance when challenged with the recession. It evolved (intentionally) to increase its financial robustness, but was surprised by the degree it became brittle in scheduling. This, in turn,
led to added resources to address this brittleness. In the sense of a stress-strain space accounting for demands on scheduling, these added resources were a non-temporary expansion of base adaptive capacity.

5.5 Knowing the limits: The pursuit of resilience and safety

Resilience and safety are related, but certainly not synonymous, concepts, and there are even contradictions among those theories of resilience that claim to have safety-specific applications. Observations conducted in this study and its resilience analysis highlight in very interesting ways different facets of the more prominent models of safety.

5.5.1 Safe performance, economics, and workload

Participants in our research partner firm were clearly subject to the forces (external and self-imposed) identified by Rasmussen (1997) and illustrated in figure 2: pressure to be efficient; obligation to be safe; and compulsion to reduce workload. The opposing natures of economic efficiency and safe performance have been discussed in earlier subsections, and the idea that there are distinct boundaries for economic failure and unacceptably safe performance is readily understandable. Behaviors indicative of pressures both to be efficient and be safe were found throughout the observations.

The distinction between unacceptable workload and unacceptably safe performance is more nuanced. This is due, in part, to the perhaps flawed idea that there is a constant gradient toward least effort that is in continuous opposition to the push for safety. When OC staff were not facing major challenges, they generally had (and used) time to look for
potential safety issues in scheduling options, which did not reflect a desire to exert the least possible effort. However, there were certainly boundaries of unacceptable workload for the OC staff individually and collectively, which were evident during periods of decompensation. These periods would seem to be more coincident than not with periods of potentially unsafe performance, which calls into the question the relationship between the performance and workload boundaries in the Rasmussen model.

5.5.2 Latent failures

Participants in the OC did not specifically articulate thoughts regarding the latent failure model (Reason, 1990). Nonetheless, many felt that they were one element of a group that needed to be alert to potential sources of failure in the scheduling process, and would have likely agreed that their operation provided defense in depth to prevent possible safety issues. As described earlier, it was notable that staff in functions not typically associated with safety, such as customer service, were vigilant with regard to safety problems in trip scheduling.

5.5.3 Ultra safety and high reliability

Within Amalberti’s (2013) framework, the company fit the ultra-safe model in that it sought to reduce risk as much as possible. Like other transportation firms of this class, it managed vehicle operators with detailed procedures and extensive supervision.

However, while the OC staff shared the safety goal of reducing risk as much as possible, its methods had much in common with HROs, as defined by Weick and
Sutcliffe (2007) and interpreted by Amalberti (2013). The OC staff relied on group adaptation and not on detailed written procedures. The core function of the OC, current-day scheduling, had commonly understood practices, but no written procedures at all.

The OC did not correlate with Amalberti’s interpretation of HROs in that it did not operate on the assumption that risk was inherent in its operations (certainly not to the extent that risk is regarded as inherent to non-combat naval aviation and fire fighting). But OC functions were clearly predicated on the principle that continuous schedule change was endemic to their business, which explains the HRO-like behaviors they exercised in response.

5.5.4 Awareness of limits

A theme common to various theories of resilience and safety is individual and organizational self-awareness of where current and future operational performance falls in relation to limits. Insofar as our research partner firm has been successful in meeting the production and safety expectations of its business plan and of its customers, it has done so due in no small part to its awareness of its own capabilities and limitations. OC staff members worked to meet both production goals and safety standards, doing so with a solid understanding of how their roles interacted with others in the system. Managers and executives shared this understanding.

However, this understanding was far from perfect, as most prominently exhibited by the relatively poor performance of the firm during bouts of severe weather in 2014. Even after understanding improved, some necessary measures to add resources to meet demand
could not be executed overnight, resulting in an extended period of highly taxed operations. This reality serves as a caution that even the most self-aware and safety conscious organization is not immune to the pressures of a competitive business environment.

5.6 Limits unknown: The 2010 European volcanic ash crisis

The transportation company studied in this paper is an example of an organization that coped quite successfully with a variety of challenges, many of them weather related; its performance during one large-scale weather event, hurricane Sandy, was particularly noteworthy. By contrast, the management of airspace in the European Union (EU) following the eruption of the Icelandic volcano Eyjafjallajökull in 2010 has been widely criticized on numerous fronts, so it’s worth pausing to compare these cases.

5.6.1 The volcanic ash incident in brief

Following the eruption of Eyjafjallajökull on April 14, 2010, its plume of volcanic ash spread across European skies, prompting the cancellation of flights starting on April 15 and the closure of much of the continent’s airspace from April 16 to 19. Changing ash conditions and new procedures resulted in the opening of much airspace on April 20 and 21, with nearly all airspace being available on April 22; more limited disruptions occurred through May 17. The International Air Transport Association (IATA) initially concluded that 100,000 flight were cancelled and that the airlines lost $1.7 billion (€1.3 billion) in revenue in the week of peak disruption in April; a later scholarly study found
that nine major European airlines suffered loses totaling €3.3 billion over the course of one month (Ragona, Hansstein, & Mazzocchi, 2011).

### 5.6.2 Failure to anticipate

There has been ample cause for decades to be concerned about the danger to aircraft posed by volcanic ash. Between 1953 and 1979, there were 129 reported incidents of aircraft encountering ash clouds (Guffanti, Casadevall, & Budding, 2010). The evolution of aircraft technology in the 1970s increased the vulnerability of airliners to volcanic ash; jets operated at higher speeds and altitudes with engines running at higher temperatures, and greater flight volume also created more opportunities for incidents. Higher operating temperatures increased the likelihood that ash particles would melt in engine’s hot sections; when these materials re-solidified in the cooler sections, they could prompt ignition flameout and engine shutdown (Przedpelski & Casadevall, 1994). Two Boeing 747s were nearly lost in ash mishaps in the 1980s, sounding the alarm regarding the growing ash threat; between 1980 and 1998, volcanic ash caused more than $250 million in damage to engines, airframes, and avionics (Miller & Casadevall, 2000, as cited in Sammonds, McGuire, & Edwards, 2010).

Despite this known challenge, research to determine the levels of ash density that cause damage has been woefully lacking; as recently as last year, the US delegation to International Airways Volcano Watch Operations Group of the International Civil Aviation Organization (ICAO) declared that “The airworthiness of aircraft operating in low concentration levels of volcanic ash is not well understood” (Albersheim, 2014, p. 1).
This lack of knowledge contributed to the very simple international standard for flight near volcanic ash clouds that was in effect in 2010: “AVOID AVOID AVOID” (ICAO, 2007, p. I-3-19, emphasis in the original); the procedure did not anticipate intentional operation in any known ash clouds at all.

There were also signs in the distant and immediate past that Icelandic volcanoes were a source of trouble. In 1947, the Hekla volcano produced a substantial eruption. More recently, seismic activity in the region was above normal levels since 2009, indicating an increase in the possibility for eruption, and the actual eruption of Eyjafjallajökull started on March 20, nearly four weeks before the ash cloud arrived over continental Europe. Despite these troubling signals in March and April, no significant action was undertaken in Europe to address ash cloud forecasting or monitoring issues, or to further engage engine and aircraft manufacturers, or to coordinate response mechanisms in anticipation of an Icelandic ash cloud event (Sammonds et al., 2010).

5.6.3 Failure to coordinate

One of the most remarkable aspects of the Eyjafjallajökull event was the lack of coordination among EU member nations; at that time, there were 27 different air traffic zones in the EU, and the authorities governing them could each impose its own flight ban. This completely fragmented approach added to the chaos that airlines and passengers experienced in coping with an inherently difficult situation (Alemanno, 2011). It also failed to address major transnational problems experienced in other modes of transportation stressed by the shutdown of air travel (Alexander, 2013).
The EU’s ministers of transport met on 19 April, five days after flight cancellations began, and they decided to have the European Commission and the European Organisation for the Safety of Air Navigation (Eurocontrol) divide the continent’s airspace into three types of zones and open it accordingly: areas with high ash densities would remain closed; areas with moderate ash densities would be open, but with restrictions; and those not affected by ash would be open without restrictions (EU, 2010). The scientific issues with these classifications have been touched on earlier and will be addressed further below, but the convening of a multinational group to deal with Eyjafjallajökull did belatedly bring some order to the response. In the wake of the event, the EU agreed to much-needed changes including: the establishment of a crisis coordination cell; the use of transnational airspace blocks; and improved air traffic network and safety management (Alemanno, 2011).

5.6.4 Failure to assess

As Brannigan (2010) exhaustively documented, the scientific consensus regarding an ash density limit for safe aircraft operations was, quite simply, that there was no known safe limit. An international workshop on volcanic ash conducted by the World Metrological Organization (WMO) in March 2010, a mere three weeks before the flight disruptions began, concluded that “There continues to remain no definition of a ‘safe concentration’ of ash for different aircraft, engine types or power settings. In order to give a reliable and justifiable ‘all clear’ once a plume has dispersed enough to be
undetectable, clear limits of ash content are required from both the manufacturers and aviation licensing authorities” (WMO, 2010, p. 1).

Despite the lack of a scientifically defensible limit for safe operations, the pressure to alleviate the economic impact of the flight ban was enormous. The airlines were among the most vocal groups calling for the resumption of flights, which was ironic in that: they were conspicuously absent from earlier international forums to address the ash problem (including the 2010 WMO workshop); and they claimed to have expert opinion supporting their position, but failed to publically name these experts. In the end, the limits used by the EU were set significantly below ash densities known to cause problems, but were not made with reference to levels (above zero) known to not cause problems, because such levels have yet to be determined (Brannigan, 2010). In any case, there is likely no single limit, as limits would vary by engine type, flight envelope, power setting, and time of exposure.

5.6.5 Eyjafjallajökull and Sandy

The relative ease with which the partner transportation firm in this study dealt with hurricane Sandy in comparison with the EU’s handling of the Eyjafjallajökull volcanic ash event is quite striking. Sandy caused tens of billions of dollars in physical damage and inflicted dozens of fatalities, while the impact of the volcano was limited, for the most part, to the grounding of air traffic. However, government and corporate officials in the US were rebuked much less severely in the press for their missteps in Sandy than were their European counterparts for problems during Eyjafjallajökull. Our partner
company was one of innumerable organizations in the US that mounted a commendable hurricane response.

One factor that benefitted the firm was the fact that the performance of its vehicles in high wind, storm, and hurricane conditions is well known. More specifically, safe operating limits have been established by the vehicle manufacturers. For the EU or any other aviation governing body to deal successfully with a future volcanic eruption, comparable limits must be established for safe aircraft operations in or near ash.

Not content to operate on an ad hoc basis in bad weather, the company established weather-related policies for its operations, including the one governing weather impact zones. As described above, the EU has taken some positive steps in this direction, although they have yet to be put to the test.

Perhaps most significantly, the firm was led during Sandy by an executive response management group, which also convened during other contingencies. The capability afforded by this group would be essential during future challenge events, especially those that have not been foreseen. The EU should have anticipated an Icelandic volcanic ash event, but, although they did not, they still would have still responded much better in 2010 had they been able to quickly assemble a crisis coordination cell; their plan to establish one is a critical step forward for them in developing a sound organizational foundation for effective crisis management.
5.7 Limitations of this study

Like other programs of naturalistic observation, a significant strength of this research is its documentation of work as actually performed in a safety-critical domain of interest. Observers had unfettered access to select functions of the OC, and were privileged to receive in-depth tutoring on OC roles, very candid comments, and the opportunity to see events unfold in real time.

However, there were realities of this research that were limitations even within the bounds of naturalistic studies. Data collection, for the most part, was limited to handheld observer notes as audio and video recording were not permitted. While having two observers present for some of the most critical events was remarkably valuable, additional observers would have been very helpful. The company’s written and electronic documentation of events were too sensitive to be turned over to the research team. Although most OC functions and staff vehicle operators were available for observation, line vehicle operators and customers were only observed at the Super Bowl site in New Orleans. These conditions, while limiting, proved to be worth the immense benefit of the access granted to the firm’s personnel and operations.

This study explored a particularly interesting firm, but it was only a single company that has been compared with studies of other firms and industries. Making such comparisons through first-hand observation of other organizations would have been highly constructive.

In comparison to other methods of research, naturalistic observation does not shape the conditions of observation to control for variability and verify specific phenomena of
A broader program of research that combined naturalistic observation with staged world exercises and controlled experiments would appeal to a wider audience than exists for naturalistic observation at present.

5.8 Future studies

Resilience Engineering is still maturing as a discipline, leaving open countless opportunities to contribute to its body of knowledge. Such opportunities should be cultivated with other firms in safety-critical domains. This is an extremely challenging proposition regardless of the type of research pursued, as the time of practitioners is valuable irrespective of the method of study. Not surprisingly, the author suggests that naturalistic study of other transportation firms as well as other industries such as energy, health care, first responders, and defense, would significantly bolster the body of knowledge.

Many argue that the true test of organizational resilience is the ability to cope with genuine surprise. This study has documented surprises experienced by participants, but these surprises were of a more quantitative nature and not completely shocking. By definition, no study can anticipate a truly shocking surprise, but a team embedded with an organization that experienced one would provide invaluable results.

This study briefly raised the possibility that a system undergoes reconfiguration when faced with challenge event. This notion merits further consideration, along with exploration of how such reconfigurations change the balance across goal tradeoffs.
Although this study was informed by the work of other disciplines, including control systems, medicine, ecology, and public policy, these fields were not represented on the research team. As was noted at a recent conference on Resilience Engineering hosted by the Lloyd’s Register Foundation, transdisciplinarity is an oft-stated governmental and institutional research goal that is matched by very little financial support in grant award and other funding processes. The author hopes that Resilience Engineering can overcome this inertia, for, as Gheradi and Turner (1987) observed, “Hegemony in inquiry eliminates choice, whilst the <<exploration of assumptions involves the exploration of choice>>” (p. 36, brackets in the original).

5.9 Concluding remarks

Another apt quote for the discussion of this study comes from Balzac (1847/1970), who exclaimed that “Happiness is without history” (p. 80). He argued that once the characters in a tale overcame their obstacles, there was no more story to tell. Sadly, the history of safety studies is often a grim recitation of accidents that are quite devoid of happy outcomes. In contrast to that perspective, this study set out to offer positive cases, and recommends that organizations seeking to improve their resilience and increasing their safety can learn much from lessons provided by the example of our partner firm.

5.9.1 Habitual anticipation

Organizations should have the means in place to develop clear strategies and safety guidance for coping with challenge events well in advance of a crisis, and implement this
guidance in policy. This is an important form of anticipation that provides structure to the organization’s thinking about possible contingencies, and shapes its responses in both simulated and actual events; properly realized, policy can institute mechanisms that support synchronization across time and space and promote inter-predictability among team members.

5.9.2 Successful interactions across scales

Organizations should have the means for senior leaders to coordinate and disseminate tailored direction for specific challenge events as they unfold, activities typically performed through a response management group or crisis coordination cell. In addition to handling real-world events, the group should practice for rare, high consequence contingencies they might not otherwise have the opportunity to experience. By continually pressing the boundaries of its capabilities in exercises, the response management group will be better prepared for an unanticipated operational event presenting a truly qualitative surprise.

Working level staff should have the ability to adapt in pace to changing conditions by being empowered to make faster decisions, including the authority to take circumscribed initiative and the means to reconfigure communication. Higher echelons must be in touch with the working level without making their inquiries burdensome.
5.9.3 Sensing organizational strain

Organizations should have an awareness of their own adaptive capacity and how it is changing, both in real time and over the long term. The stress-strain space offers a useful analogy for leaders to consider in assessing their own organization’s resilience. But attaining such awareness is one thing, while acting to correct the issues this awareness makes manifest requires a deeper commitment.

5.9.4 Learning

A key to organizational awareness is the pursuit of learning at all levels. This is necessary to simply cope with existing challenges, and becomes an urgent imperative when considering the very real need to rise to completely unforeseen demands. Our partner firm’s pursuit of organizational learning is demonstrated, in part, by its support of this project. Other organizations would do well to follow its example in seeking disparate perspectives as a part of a learning culture.
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