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DECISIONS IN THE DARK: A FRAMEWORK FOR DECISION-MAKING IN UNFAMILIAR SITUATIONS

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DECISIONS IN THE DARK: A FRAMEWORK FOR DECISION-MAKING IN UNFAMILIAR SITUATIONS

by

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September 2022

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This thesis seeks to understand an appropriate decision-making framework for the fire service to use in unfamiliar situations. Firefighters and emergency responders rely on pattern recognition when they are presented with familiar situations; however, relying on such intuition can result in costly time delays. A case study method was used to evaluate decision-making during disasters in the fire service and the mining industry. The fire service cases include the 1949 Mann Gulch Fire and the fire service response to the 9/11 attack on the World Trade Center. The mining case studies, both of which occurred in 2010, include the Deepwater Horizon oil spill and the Chilean mine collapse. The fire service cases were assessed to determine which decision-making tools were utilized and what additional factors influenced positive and negative outcomes throughout the events. The mining cases were evaluated to understand organizational structures and response systems. This thesis recommends that fire service leaders utilize expanded interdisciplinary teams to creatively seek alternative solutions when addressing unfamiliar problems. Using such teams will require leaders to expand response frameworks and alter familiar patterns of response to include outside agencies and nontraditional emergency responders. Finally, leaders should deliberately encourage open communication about successes and failures to encourage collaboration and innovation throughout the response.

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DECISIONS IN THE DARK: A FRAMEWORK FOR DECISION-MAKING IN UNFAMILIAR SITUATIONS

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requirements for the degree of

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ABSTRACT

This thesis seeks to understand an appropriate decision-making framework for the fire service to use in unfamiliar situations. Firefighters and emergency responders rely on pattern recognition when they are presented with familiar situations; however, relying on such intuition can result in costly time delays. A case study method was used to evaluate decision-making during disasters in the fire service and the mining industry. The fire service cases include the 1949 Mann Gulch Fire and the fire service response to the 9/11 attack on the World Trade Center. The mining case studies, both of which occurred in 2010, include the Deepwater Horizon oil spill and the Chilean mine collapse. The fire service cases were assessed to determine which decision-making tools were utilized and what additional factors influenced positive and negative outcomes throughout the events. The mining cases were evaluated to understand organizational structures and response systems. This thesis recommends that fire service leaders utilize expanded interdisciplinary teams to creatively seek alternative solutions when addressing unfamiliar problems. Using such teams will require leaders to expand response frameworks and alter familiar patterns of response to include outside agencies and nontraditional emergency responders. Finally, leaders should deliberately encourage open communication about successes and failures to encourage collaboration and innovation throughout the response.

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LIST OF ACRONYMS AND ABBREVIATIONS

EMS	emergency medical services
ERMA	Environmental Response Management Application
FDNY	Fire Department of the City of New York
GOPE	*Groupo de Operaciones Policiales Especiales* (Special Police Operations Group)
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NIC	National Incident Commander
NRS	national response system
OODA	observe, orient, decide, act (loop)
OSC	on-scene coordinator
RPD	recognition-primed decision-making
SONS	spill of national significance
UNH	University of New Hampshire
UPS	United Parcel Service

EXECUTIVE SUMMARY

Every day, firefighters and emergency responders solve problems that fit the typical patterns they have developed throughout their careers. Using past experiences as relatable patterns, they create mental shortcuts to develop successful strategies in a process called recognition-primed decision-making.[1] In some instances, however, new problems do not fit past experiences, and firefighters are forced to make decisions in unfamiliar settings such as pandemics, climate-related emergencies, and other nontraditional events. When firefighters rely on intuition in unfamiliar situations, they risk making mistakes and costing valuable time. This thesis seeks to understand an appropriate decision-making framework for the fire service to use in unfamiliar situations.

This thesis uses a case study methodology to understand decision-making during disasters in the fire service and mining industry. Two fire service case studies, the 1949 Mann Gulch fire and the 2001 response to the World Trade Center attacks, evaluate the different types of decisions made during the incidents and the effects of those decisions on the overall strategy and outcome. Two mining industry case studies, the 2010 Deepwater Horizon oil spill and the 2010 Copiapó mining accident, were evaluated to determine which interdisciplinary factors affected the outcome of the incidents.

The analysis reveals that the fire service traditionally relies on recognition-primed decision-making, which relies on past experiences for time-critical decisions. During the Mann Gulch fire and the response to 9/11, intuition both assisted and hindered responders. When novel solutions did not align with responders' previous experiences—such as using a burned-out area for responder safety—firefighters relied on their intuition, leading to negative outcomes. Additionally, as seen in the 9/11 response, information silos prevented decision-makers from fully embracing all incident factors and forced them to make decisions with an incomplete operational picture.

As shown in the mining industry case studies, interdisciplinary teams develop novel solutions to complex situations. Each example demonstrates how diverse teams form

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[1] Gary Klein, *Sources of Power: How People Make Decisions* (Cambridge, MA: MIT Press, 1999).

response frameworks, try innovative ideas, share results, and communicate with various members to develop solutions to unfamiliar problems. In short, cross-disciplinary expertise leads to increased creativity in selecting strategies and tactics during unfamiliar and complex situations because it provides greater depth and breadth of experience to craft solutions. Next, a key to innovation in response to a complex incident is sharing information and deliberately communicating strategies throughout the response framework. Thus, interdisciplinary situational awareness teams should co-locate and utilize shared communications to provide real-time information so that command staff members know the status of the incident as events unfold. Finally, emergency responders, traditionally the sole decision-makers in complex incidents, need to embrace innovation from experts from outside industries to foster discovery of potential solutions. Cross-disciplinary response frameworks can foster innovation if leadership and decision-makers support them. These key findings are summarized in Table ES-1.

Table ES-1. Key Findings

	Known or familiar situations	Unfamiliar situations
Decision-making process	Naturalistic decision-making through a reliance on previous experience	Expanded interdisciplinary team to rely on cross-disciplinary knowledge, creatively searching for alternative solutions
Sensemaking and information sharing	Situational awareness collected at the tactical level	Open discussion of ongoing incident status throughout entire response framework; leadership to encourage trial-and-error strategies and innovation
Response framework selection	Reliance on previously developed frameworks (Incident Command System)	Expanded response frameworks inclusive of outside agencies and nontraditional emergency responders
Intergroup communication	Reliance on traditional pathways of communication through command-and-control frameworks	Open pathways for communication and free sharing of success and failures; co-located teams to encourage group communication

The 21st century will continue to present new challenges for fire service leaders and first responders. This thesis provides potential paths for them to follow:

1. Decision-makers should allow cross-disciplinary teams to engage with fire and emergency response leaders when they are presented with unfamiliar situations.
2. Fire and emergency leaders should co-locate command and situational awareness teams to support real-time communication about the incident status.
3. Emergency response leaders should prepare to expand the response framework to incorporate entities outside the fire service.
4. Fire and emergency services leaders must embrace innovation when presented with unfamiliar situations and build command structures that support testing new ideas.

This thesis recommends that fire service leaders utilize expanded interdisciplinary teams to creatively seek alternative solutions when addressing unfamiliar problems. Using such teams will require leaders to expand response frameworks and alter familiar patterns of response to include outside agencies and nontraditional emergency responders. Finally, leaders should deliberately encourage open communication about successes and failures to encourage collaboration and innovation throughout the response.

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I. INTRODUCTION

Firefighters and emergency responders face difficult decisions under austere conditions throughout their careers by relying on past experiences and mental shortcuts; however, when they do not have relatable experiences to rely on pattern recognition, they use ad hoc decision-making to develop the best courses of action. Relying on ad hoc decision-making is especially common for novel situations because the decision-maker does not have a relatable experience. Developing experience throughout a firefighter's career means opportunities to build a library of relatable situations, but a single decision-maker cannot develop pattern recognition for all conceivable cases. Eventually, at some point in one's career, an unfamiliar situation will force a firefighter to use methods beyond intuition to make decisions. Fire service leaders will need to adopt practices that encourage a team-based approach utilizing multi-disciplinary groups open to nontraditional ideas rather than attempting to rely on previous experiences when facing unfamiliar situations.

This thesis examines decision-making during unfamiliar situations to determine which decision-making model could be used by emergency responders and what factors may contribute to the overall success of the incidents. This chapter presents the structure of the thesis by framing the current situation faced by emergency responders and describes how I conducted the appropriate research to determine which model could be used in the presence of unfamiliar situations.

A. PROBLEM STATEMENT

Firefighters around the world respond to large and small disasters each day. When a person calls 9-1-1 on the worst day of one's life, a crew of firefighters often arrive and help solve various problems. Firefighters respond to everything from smoke alarms to house fires, to traumatic injuries and cardiac arrests, and even to animals stuck in odd places. To solve routine problems, firefighters rely on their experiences to guide their work. When they solve a problem, they mentally catalog the situation and actions taken, gradually building an inventory to rely on if they encounter similar circumstances again. This process, known as recognition-primed decision-making, allows for quick decisions that lead to best-case outcomes.[1] However, when firefighters encounter unfamiliar situations, there is no relatable framework for them to reference. Firefighters have no standard operating guidelines or rehearsed scenarios for complex issues such as pandemics and climate-related emergencies. Indeed, with the arrival of COVID-19, firefighters had to transition from their traditional role toward supporting the community in ways unfamiliar to anyone in the industry.

In January 2020, the first U.S. case of the novel coronavirus arrived in Seattle, Washington.[2] The onset of the virus in the United States put fire and emergency medical services (EMS) personnel on the front lines of caring for the sick and injured while developing plans to keep responders safe. Fire chiefs and agency administrators made decisions without the benefit of pre-established protocols or prepared response configurations. The last widescale response to a pandemic virus of a similar scale to COVID-19 was in 1918, when fire departments were not yet involved in providing medical care. In modern times, the fire service's mission and role continue to grow and expand beyond providing fire suppression and on-scene medical treatment, with firefighters solving much more complex issues.

The fire service has also encountered other extreme situations that have required leaders to move into complex problem-solving. The effects of climate change, for example, have resulted in extreme hurricane seasons like the 2017 trifecta of Hurricanes Harvey, Irma, and Maria. These events constitute three of the five most costly hurricanes on record.[3] While the response to natural disasters is a familiar responsibility in the fire service, the timing and intensity of these storms put a tremendous strain on resources, supplies, and aid to the affected communities.[4] The increased frequency and compounding effects of simultaneous storms have created a new level of complexity not regularly encountered in the fire service.

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[1] Gary Klein, *Sources of Power: How People Make Decisions* (Cambridge, MA: MIT Press, 1999).

[2] Mike Baker, "When Did the Coronavirus Arrive in the U.S.? Here's a Review of the Evidence," *New York Times*, May 15, 2020, https://www.nytimes.com/2020/05/15/us/coronavirus-first-case-snohomish-antibodies.html.

[3] "Hurricane Costs," National Oceanic and Atmospheric Administration, Office for Coastal Management, accessed March 15, 2021, https://www.coast.noaa.gov/states/fast-facts/hurricane-costs.html.

[4] Richard Terry Sylves, *Disaster Policy and Politics: Emergency Management and Homeland Security* (Washington, DC: CQ Press, 2008).

Climate effects have also increased fire intensity during wildfires seasons: 10.13 million acres were destroyed in the 2015 fire season alone—the most on record since 1960.[5]

Fire departments are expanding their capacity and roles as prehospital EMS providers. The challenges of community healthcare, behavioral health, and an increasing role in the houseless crisis across America are forcing fire service leaders to address problems with no immediate fixes and no operating guidelines to address the underlying issues. In Los Angeles alone, the homeless community is 14 times more likely than the housed population to call 9-1-1 and 19 times more likely to be transported to the emergency room.[6] In addition to the novelty of these issues, ongoing operations in the fire service and budgetary constraints add to the complexity. Fire chiefs who have spent their careers learning to solve problems from an operational perspective cannot rely on their experience to solve these unfamiliar issues.

Even though the scope of the fire service's responsibilities in these events—pandemics, wildfires, and natural disasters—are considered routine, compounding factors such as increased frequency, increased intensity, and broader geographic impacts alter the decisions necessary from the traditional duties of the fire service. Everyday situations, such as fires, car crashes, and emergency medical calls, are still prevalent throughout the fire service. Such familiar emergencies generally result in firefighters' using established decision-making algorithms and operating guidelines to bring about positive outcomes.[7] The patterns of these situations are familiar, and firefighters can use previous experiences to select the best courses of action by forecasting similar results.[8]

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[5] Katie Hoover and Laura A. Hanson, *Wildfire Statistics*, IF10244 (Washington, DC: Congressional Research Service, July 2021), https://crsreports.congress.gov/product/pdf/IF/IF10244/51.

[6] Tiffany M. Abramson, Stephen Sanko, and Marc Eckstein, "Emergency Medical Services Utilization by Homeless Patients," *Prehospital Emergency Care* 25, no. 3 (2020): 333–40, https://doi.org/10.1080/10903127.2020.1777234.

[7] Justin Okoli et al., "The Role of Expertise in Dynamic Risk Assessment: A Reflection of the Problem-Solving Strategies Used by Experienced Fireground Commanders," *Risk Management* 18, no. 1 (2016): 4–25.

[8] David J. Snowden and Mary E. Boone, "A Leader's Framework for Decision Making," *Harvard Business Review* 85, no. 11 (November 2007): 68–76.

Fire and emergency services have long relied on tools such as mnemonics, heuristics, and other mental processes to simplify decisions under time-critical constraints. Gary Klein, a pioneer in naturalistic decision-making, has described the process that firefighters use to apply known solutions to familiar situations as recognition-primed decision-making (RPD).[9] The naturalistic decision-making field evaluates decision-making in the real world, outside of fixed laboratory settings, to understand the phenomenon. As identified by experts in this field, during the stage of perception at the incident, the decision-maker recognizes known situations to establish a relatable pattern.[10] As a premise of naturalistic decision-making, the decision-maker must have a known experience and recognize similar patterns in current situations to compare against when making decisions. Klein's work on emergency response establishes RPD as one of the basic operating capabilities for firefighters and incident commanders. Its use in incidents establishes a known pattern of response, and this tool deliberately strengthens firefighters' reliance as they build a comprehensive library of experiences.

Moving beyond routine calls and into the complex realm of events, such as the COVID-19 pandemic, puts leaders into unfamiliar situations that require less reliance on algorithmic operating guidelines and more reliance on expertise.[11] For example, with the arrival of the pandemic, public health began to implement social distancing, face coverings, and quarantine requirements. Fire service leaders, having no experience in these operations nor established policies, were asked to address their workforce and develop strategies to keep their departments operational. When the current decision model (e.g., naturalistic decision-making) does not reliably result in the best course of action in the face of a problem, leaders must search for a new decision framework that provides a broader range of options and opportunities for educated and disciplined trial-and-error. Thus, this thesis explores a new

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[9] Gary Klein, "Naturalistic Decision Making," *Human Factors* 50, no. 3 (2008): 456–60, https://doi.org/10.1518/001872008X288385.

[10] Klein.

[11] "Strategic Decisions: When Can You Trust Your Gut?," *McKinsey Quarterly*, March 1, 2010, https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/strategic-decisions-when-can-you-trust-your-gut#.

model for decision-making when the fire service encounters complex problems without readily identifiable or predictable outcomes.

B. RESEARCH QUESTION

What would be an appropriate decision-making framework for the fire service to use in unfamiliar situations?

C. RESEARCH DESIGN

This thesis utilizes a case study analysis to understand an appropriate decision-making framework for the fire service to use in unfamiliar situations. I selected four cases for investigation: two were drawn directly from historical fire service records, and two were chosen from problems in the mining industry. Each case was selected based on available records of both first-person recorded testimony and supporting documentation of the incident, which helped pinpoint when certain decisions were made. The fire service case studies were selected based on the presence of RPD while the mining case studies were chosen for their reliance on multi-disciplinary teams and various leadership structures.

Data collection for each incident relied on diverse sources, including published works, government documentation, and first-person accounts through memoirs. Each case study has had numerous associated works and scholarly articles published. Government documents included after-action reviews, reports, and inquiry testimony. Finally, several decision-makers published memoirs after the incidents detailing their experiences and decision-making processes.

I evaluated the fire service cases based on a framework developed by Gary Klein to study naturalistic decision-making. Each case was examined to understand when decisions aligned with one of four categories: pre-selected options, comparative analysis, novel solutions, or recognition-primed decisions. Both the Mann Gulch fire and the incident response to the 9/11 attacks were examined to identify the decisions that were made and their impacts on the overall incident outcome. All four case studies were evaluated using a qualitative analysis based on the industry from which they were drawn.

The evaluation of the two mining industry case studies followed a four-step analysis like the fire service cases. However, the criteria for assessment were based on prevalent themes throughout the literature. Each case was evaluated using sensemaking tools, the process of teaming, communication throughout the incident, and the leadership styles employed. Each case study was examined to identify each criterion and the impact of the decision on the overall incident. The Deepwater Horizon oil spill and the Copiapó mining accident were selected and analyzed for the mining industry case studies.

D. CHAPTER OVERVIEW

Chapter II presents a review of pertinent literature on decision-making in known and unknown situations. It also explores the role of expertise and developing expertise as professional firefighters. Finally, the role of sensemaking from a personal and organizational level is presented.

Chapter III examines two fire service incidents that utilized traditional tools of pattern recognition in decision-making: the 1949 Mann Gulch fire and the fire department response to the World Trade Center attack in 2001. Each case study analyzes the decision-making models used and the relationship between the decisions and overall outcome of the incident.

Chapter IV presents different models applied by the mining industry, during the Deepwater Horizon oil spill and the Copiapó mining incident. Both disasters occurred in 2010 and relied on a multi-disciplinary response to overcome challenges. This chapter examines how the structure of such a response could be applied to fire and emergency services.

Chapter V analyzes all four case studies to understand the role of intuition in familiar and unfamiliar situations. It presents key findings on the components of a decision-making framework for emergency responders when presented with unfamiliar situations and recommendations for leaders to consider when implementing such strategies.

II. LITERATURE REVIEW

This literature review evaluates the body of research in the field of decision-making. It presents three areas of study: naturalistic decision-making, developing expertise, and organizational sensemaking. This literature review establishes naturalistic decision-making as a basic capability of firefighters and emergency responders. It then discusses the role of intuition and the concept of recognition-primed decision-making (RPD) as the basis for much of the decision-making in the fire service. It identifies the strengths of intuition and the limitations of incidents unfamiliar to responders. The literature review examines the field of expertise, recognizing the development of individual expertise and the power of deliberate practice to develop recognizable frameworks for the decision-maker. Finally, the literature review explores the field of sensemaking at an organizational level, demonstrating how it can affect response structures. Overall, while robust in areas with repeatable actions and known frameworks, the body of literature is weak in determining the components of decision-making in unfamiliar settings such as complex incidents.

One of the primary tools used by firefighters and emergency responders is naturalistic decision-making. The organizational zero-order capability, as described by Winter, is a capability routinely used by an organization's decision-makers to produce outputs of a specific type.[12] Essentially, the zero-order capability describes how an organization functions on a day-to-day basis; in fire and emergency services, that includes decision-making in responses to routine emergencies, such as medical calls and structure fires, using RPD as the basic decision-making model. When an organization encounters a situation outside the normal response, one model it may adopt is ad hoc decision-making.[13] Ad hoc decision-making, as described by Winter, is an opportunistic, creative process for discovering alternative strategies in the face of interruptions to an organization's basic operations.[14] This thesis focuses on ad

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[12] Sidney G. Winter, "Understanding Dynamic Capabilities," *Strategic Management Journal* 24, no. 10 (October 2003): 991, https://doi.org/10.1002/smj.318.

[13] Winter.

[14] Winter, 992.

hoc decision-making when the fire service is presented with situations that are unfamiliar to responders.

A. NATURALISTIC DECISION-MAKING AND RECOGNITION-PRIMED DECISIONS

Decision-making as a body of science began with the work of Herbert Simon—an economist turned behaviorist who went on to earn a Nobel Prize for his pioneering work in the field of decision-making. The early 20th century study of management and organizational efficiency was heavily influenced by the work of Frederick Taylor, who encouraged optimizing and simplifying work-based tasks to increase productivity.[15] According to Simon, the focus of management decisions should be on the manager, not necessarily the organizational structure.[16] Simon's bounded rationality theory posits that decisions are not optimized through analysis; instead, they are satisfied by the decision-maker given all conditions present at the time.[17] Simon's work on decision-making and bounded rationality set the foundation for decision-making studies from the individual perspective and established that decisions made by firefighters and emergency responders are not thoroughly examined during emergencies. Instead, firefighters make good-enough decisions based on current situations.

Research into decision-making has extended these concepts to the decision-makers' processing inputs into actions and directions on emergency scenes. Daniel Kahneman has advanced the work of Simon in the field of psychology, identifying systems within the mind that are responsible for decision-making. Building on Simon's work, Tversky and Kahneman have explored the role of heuristics—or mental shortcuts—in applying solutions with limited

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[15] Frederick Winslow Taylor, *The Principles of Scientific Management* (New York: Harper & Brothers, 1911).

[16] Jean-Charles Pomerol and Frédéric Adam, "Understanding the Legacy of Herbert Simon to Decision Support Systems," in *Encyclopedia of Decision Making and Decision Support Technologies* (Hershey, PA: IGI Global, 2008), 930, http://www.igi.global.com/chapter/understanding-legacy-herbert-simon-decision/11338.

[17] Esther-Mirjam Sent, "Rationality and Bounded Rationality: You Can't Have One without the Other," *European Journal of the History of Economic Thought* 25, no. 6 (2018): 1370–86, https://doi.org/10.1080/09672567.2018.1523206.

environmental information.[18] Kahneman, a Nobel laureate, describes two different processes in decision-making: system-one thinking describes rapid decisions that rely on intuition and heuristics to determine courses of action while system-two thinking describes slow, meticulous decision-making that requires analyzing numerous factors to determine the best course of action.[19] The work of Tversky and Kahneman have contributed a great deal to understanding how the brain processes decisions quickly when there is limited time to weigh a multitude of options. Fire and emergency responders regularly make such time-critical decisions and use these mental shortcuts to decide the best course of action as rapidly as possible.

Traditional studies of decision-making have often been undertaken in laboratory settings where outside variables can be controlled, and external factors cannot influence the outcomes. Gary Klein has taken the study of decision-making out of the lab and into the field by examining how fire commanders make decisions when presented with fires and other emergencies. His concept of RPD acknowledges the role of intuition and reliance on experience to make decisions.[20] Subsequent studies by Okoli, Weller, and Watt confirm the practitioner's dependence on intuition in emergency settings, demonstrating how decision-makers scan various relevant cues to select crucial patterns and make decisions.[21] Experience need not be individually developed, however; it can result from group learning in small teams that share experiences among members who identify patterns based on the shared information.[22] Nevertheless, each of these theories relies on pattern recognition's leading to the selection of outcomes based on experiences in like settings; few studies have explored the

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[18] Amos Tversky and Daniel Kahneman, "Judgment under Uncertainty: Heuristics and Biases," *Science* 185, no. 4157 (1974): 1124–31.

[19] Daniel Kahneman, *Thinking, Fast and Slow* (New York: Farrar, Straus and Giroux, 2011).

[20] Klein, *Sources of Power*.

[21] Justin O. Okoli, Gordon Weller, and John Watt, "Information Processing and Intuitive Decision-Making on the Fireground: Towards a Model of Expert Intuition," *Cognition, Technology & Work* 18, no. 1 (February 2016): 89–103, https://doi.org/10.1007/s10111-015-0348-9; Okoli et al., "The Role of Expertise in Dynamic Risk Assessment."

[22] Andrew W. Ishak and Elizabeth A. Williams, "Slides in the Tray: How Fire Crews Enable Members to Borrow Experiences," *Small Group Research* 48, no. 3 (2017): 336–64, https://doi.org/10.1177/1046496417697148.

role of intuition in unfamiliar situations.[23] When fire service leaders encounter a situation or event, they recognize patterns and relevant cues and then quickly decide a course of action, anticipating a successful outcome based on their decisions.

Kahneman and Klein diverge from Simon regarding the role of intuition in decision-making. Simon defines intuition as the patterns of recognition stored in the mind of the decision-maker.[24] Kahneman and Klein, in contrast, argue that judgments are subjected to too much noise in the environment for intuition to be a valid source of decision-making, thus coining the term *illusion of validity* to describe the false sense of confidence that accompanies decisions made strictly through intuition.[25] They argue that decision-makers use intuition by drawing on patterns developed over years of experiences to decide on plausible options based on mental simulations.[26] Both Simon and Kahneman and Klein agree, however, that skilled intuition can be applied when the environment provides a sufficient number of cues, and the decider has sufficient opportunity to learn the relevant ones.[27] Research in the fields of intuition and bounded rationality complements situations of high validity, which include objective cues and enough subsequent actions or outcomes to affirm or deny the efficacy of the decisions, such as repeated situations for firefighters and other emergency responders.[28] These studies confirm that responders make rapid decisions in emergency situations by relying on pattern recognition, the indication of cues, and their experience or expertise.

B. DEVELOPING EXPERTISE AND INDIVIDUAL PERFORMANCE

A key piece of information in both heuristics and naturalistic decision-making is the experience and expertise needed to provide skilled intuition when making decisions under time constraints. Again, Simon's definition of intuition describes a process whereby the

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[23] Daniel Kahneman and Gary Klein, "Conditions for Intuitive Expertise: A Failure to Disagree," *American Psychologist* 64, no. 6 (September 2009): 515–26, https://doi.org/10.1037/a0016755.

[24] Herbert A. Simon, "Making Management Decisions: The Role of Intuition and Emotion," *Academy of Management Executive* 1, no. 1 (1987): 57–64.

[25] Kahneman and Klein, "Conditions for Intuitive Expertise," 517.

[26] Kahneman and Klein, 516.

[27] Kahneman and Klein, 520.

[28] Kahneman and Klein, 524.

decision-maker recognizes the pattern quickly. Pattern recognition and the development of expertise are central to several researchers who explain how experts perform at high levels and how their expertise develops.

The study of expertise and exceptional performance—dating back centuries—has examined how people learn and excel at given skill sets or bodies of knowledge. One of the first researchers to explore individual accomplishment was Francis Galton, who believed genetics and environmental factors resulted in genius.[29] In studying eminent people throughout England in the 19th century, Galton sought to identify their key traits to forecast the ability of individuals to succeed.[30] According to Galton, individuals' abilities are finite, and capacity cannot be increased through practice and training.[31] Galton's work has been disproven by many over the years. Among them are Horn and Masunaga, who argue that intellectual abilities are fully developed in mature adulthood.[32] They further posit that various other factors affect intellectual growth beyond genetics, including environmental influences and even the various stages of a person's growth.[33] Thus, when firefighters enter their careers, they presumably are not fixed in their ability to develop problem-solving and decision-making skills. They will develop their experiences over time as they mature throughout their careers and develop their expertise based on such experiences.

Pattern recognition is a critical component of expertise, particularly in games and sports. In studying the game of chess and those who excelled at it, Adriaan de Groot, a forerunner in the field, has argued that chess players rely on memory and personal experience to determine the best course of play.[34] His seminal study involves chess players of all levels

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[29] K. Anders Ericsson, Robert R. Hoffman, and Aaron Zozbelt, *Cambridge Handbook of Expertise and Expert Performance*, 2nd ed. (Cambridge: Cambridge University Press, 2018), 10, CREDO Reference.

[30] Francis Galton, "Hereditary Genius," *Macmillan's Magazine* 19, no. 113 (March 1869): 424–31.

[31] Ericsson, Hoffman, and Zozbelt, *Cambridge Handbook of Expertise and Expert Performance*, 11.

[32] John Horn and Hiromi Masunaga, "A Merging Theory of Expertise and Intelligence," in *The Cambridge Handbook of Expertise and Expert Performance* (New York: Cambridge University Press, 2006), 598.

[33] Horn and Masunaga, 604.

[34] Ericsson, Hoffman, and Zozbelt, *Cambridge Handbook of Expertise and Expert Performance*, 232.

playing a game and reporting their movement considerations to a researcher.[35] The study reveals that novices often act without a deliberate approach to the game while masters often use bold moves early, relying on their knowledge of potential moves and limitations of game-piece movements. He notes that master-level players rely on their ability to memorize pieces and relatable patterns on the board.[36] Simon and Chase advanced this theory by evaluating master chess players' ability to recreate known game boards and familiar chess patterns and testing how quickly they could fill in the missing pieces, thereby demonstrating their mastery of the game.[37] Nevertheless, the experts in these studies could not perform when pieces appeared in ad hoc positions, demonstrating that the experts relied on pattern memorization rather than some form of processing.[38] The research into memory and expertise through games demonstrates that mastery is possible through years of practice in which decision-makers build an inventory of recognizable patterns. However, expertise cannot be developed when there is no relatable framework or pattern.

Another body of research has examined individual performance and applied training methods to grow expertise and improve outcomes.[39] Ericsson argues that deliberate practice enhances expertise, often under a coach's guidance, by breaking down tasks and improving small factors in each practice session.[40] Further, he acknowledges that novices, beginning on the path to individual performance, quickly plateau when they reach an acceptable level; it takes more practice and dedication to advance beyond this stage.[41] However, expert

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[35] Adriaan D. de Groot, *Thought and Choice in Chess* (Berlin: De Gruyter, 1978).

[36] William G. Chase and Herbert A. Simon, "The Mind's Eye in Chess," in *Visual Information Processing: Proceedings of the Eighth Annual Carnegie Symposium on Cognition*, ed. William G. Chase (Cambridge, MA: Academic Press, 1973), 215–81, https://doi.org/10.1016/B978-0-12-170150-5.50011-1.

[37] Chase and Simon.

[38] Fernand Gobet and Herbert A. Simon, "Templates in Chess Memory: A Mechanism for Recalling Several Boards," *Cognitive Psychology* 31, no. 1 (August 1996): 1–40, https://doi.org/10.1006/cogp.1996.0011.

[39] K. A. Ericsson and A. C. Lehmann, "Expert and Exceptional Performance: Evidence of Maximal Adaptation to Task Constraints," *Annual Review of Psychology* 47 (1996): 273, https://doi.org/10.1146/annurev.psych.47.1.273.

[40] K. Anders Ericsson, "Deliberate Practice and Acquisition of Expert Performance: A General Overview," *Academic Emergency Medicine* 15, no. 11 (2008): 988–94, https://doi.org/10.1111/j.1553-2712.2008.00227.x.

[41] Ericsson and Lehmann, "Expert and Exceptional Performance."

performance is limited in application to problem-solving within one's domain of expertise. For example, London taxicab drivers are world-renowned in their ability to memorize streets and locations throughout their city without the aid of a navigation system; however, this specialized knowledge applies only to London and is not transferable to New York City, where the patterns are different.[42] This research demonstrates the value of deliberate practice in developing expertise within a focused domain. However, it does not address developing expertise through exposure to cross-domain ideas and concepts.

To overcome the limits of specialization, fire service leaders need to vary their experience in domains outside the fire service. Experts tend to be partitioned in their knowledge, parceling out concepts and making decisions based on context.[43] They are susceptible to cognitive entrenchment, especially when decisions occur in areas of familiar context for decision-makers. As Dane describes it, cognitive entrenchment is a "high level of stability in one's domain schemas."[44] He suggests two factors that may limit the impact of cognitive entrenchment in expertise. First, experts in firefighting and other dynamic fields are less entrenched due to their work's varied nature. Second, experts who focus on tasks outside their domains may also limit their entrenchment.[45] This concept appears to comport with Simonton, who claims creativity can increase through exposure to other disciplines, such as a scientist engaging in the arts, resulting in greater domain-specific impacts.[46] Additionally, Uzzi argues there is a positive relationship between team-based approaches to scientific discovery, and the cross-disciplinary nature of teamwork results in greater knowledge

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[42] Katherine Woollett, Hugo J. Spiers, and Eleanor A. Maguire, "Talent in the Taxi: A Model System for Exploring Expertise," *Philosophical Transactions: Biological Sciences* 364, no. 1522 (2009): 1407–16.

[43] Stephan Lewandowsky and Kim Kirsner, "Knowledge Partitioning: Context-Dependent Use of Expertise," *Memory & Cognition* 28, no. 2 (March 2000): 295–305, https://doi.org/10.3758/BF03213807.

[44] Erik Dane, "Reconsidering the Trade-Off between Expertise and Flexibility: A Cognitive Entrenchment Perspective," *Academy of Management Review* 35, no. 4 (October 2010): 579, https://doi.org/10.5465/amr.35.4.zok579.

[45] Dane.

[46] Dean Keith Simonton, "Varieties of (Scientific) Creativity: A Hierarchical Model of Domain-Specific Disposition, Development, and Achievement," *Perspectives on Psychological Science* 4, no. 5 (2009): 441–52.

discovery.[47] Finally, Tetlock and Gardner have found that cross-disciplinary knowledge positively influences those considered super forecasters. The forecasters identified in the Good Judgment Project as “foxes” tend to seek new ways to look at problems across ideological and disciplinary boundaries.[48] This research presents critical concepts for problem-solving when decision-makers face unknown situations, including openness to incorporating new information and to exploring multiple hypotheses or solutions.

C. SENSEMAKING

Sensemaking is a field of organizational research with roots in social psychology, investigating how organizations make sense of congruent and incongruent information. Karl Weick, considered a founding researcher in the field, provides that sensemaking is different from the interpretation of facts or observations; it is more about the ways in which people develop their interpretations than about the products of interpretation.[49] Maitlis, Vogus, and Lawrence add to Weick’s definition with three interconnected processes: recognizing cues, interpreting cues, and engaging in action.[50] Hernes and Maitlis further contend that organizations are actually entities constructed by processes of sensemaking, that each component of an organization exists to understand a certain component of the industry or market, and that the whole organization is the sum of these processes.[51] This perspective on sensemaking focuses on the organization rather than the individual making sense of a situation. Fire and emergency services organizations are generally preformed as response agencies with mechanisms in place to gather information; however, this research suggests that complex situations will require coordination with other agencies to develop ad hoc organizations and make sense of more significant situations.

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[47] Stefan Wuchty, Benjamin F. Jones, and Brian Uzzi, “The Increasing Dominance of Teams in Production of Knowledge,” *Science* 316, no. 5827 (2007): 1036–39.

[48] Phillip Tetlock and Dan Gardner, *Superforecasting: The Art and Science of Prediction* (New York: Crown, 2015).

[49] Karl Weick, *Sensemaking in Organizations* (Thousand Oaks, CA: SAGE Publications, 1995), 13.

[50] Sally Maitlis, Timothy Vogus, and Thomas Lawrence, “Sensemaking and Emotion in Organizations,” *Organizational Psychology Review* 3, no. 3 (2013): 222–47.

[51] Tor Hernes and Sally Maitlis, *Process, Sensemaking, and Organizing* (Oxford: Oxford University Press, 2011), ProQuest.

The individual's use of sensemaking tools depends greatly on one's level of experience, yet attempting to apply solutions from dissimilar situations can result in time lost in response to the situation. Denrell and James label this phenomenon a "competency trap," which describes a decision-maker's tendency to rely on decisions made in previous situations without considering the long-run implications of the situation.[52] They go on to explain that decision-makers rely on familiar patterns even when trying new options could have improved the outcomes—that the perceived competency of the decision-makers has trapped them into choosing less-than-optimal solutions.[53] This phenomenon is manifest in the fire service when responders apply solutions to problems based on previous calls or situations, thereby limiting the potential for optimized solutions and allowing responders to jeopardize time and resources during time-critical situations.

D. CONCLUSION

This literature review focused on decision-making and expertise to understand how firefighters and emergency responders make decisions and build expertise in their fields. Research regarding decision-making in the fire service has generally focused on naturalistic decision-making and the role of experience in operational settings. While there may be disagreement throughout the research regarding the extent to which intuition plays, researchers generally agree that intuition is not appropriate when applied to unfamiliar situations. The body of research regarding expertise and knowledge suggests that firefighters and emergency service providers are not fixed in their abilities and have the capacity to build new frameworks of understanding. This concept is especially important given that pattern recognition is the basis for intuition. Finally, building a response structure that can take in information about the situation and develop strategic goals and objectives requires a new way of looking at situations.

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[52] Jerker Denrell and Gaël Le Mens, "Revisiting the Competency Trap," *Industrial & Corporate Change* 29, no. 1 (February 2020): 2, https://doi.org/10.1093/icc/dtz072.

[53] Denrell and Mens, 1.

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III. A LEGACY OF INTUITION

Decision-making in the fire service has long relied on experience-based intuition and standard operating guidelines, along with industry best practices, to solve complex problems. All of these are patterned responses. This chapter explores the application of intuition in two case studies. The first case study investigates the Mann Gulch fire of 1949, which took the lives of 13 smokejumpers due to a fast-moving fire and a situation that did not quite fit a recognizable pattern. The second case study examines the response to the World Trade Center on Tuesday, September 11, 2001. In this case study, the responding firefighters applied a typical response to an unfamiliar situation and, as a result, were forced to develop strategies that did not fit standard operational guidelines defined by the Fire Department of the City of New York (FDNY), resulting in the largest evacuation in the history of the fire service.

Each case study is presented in detail to trace the decisions points and various factors affecting the outcome. The analysis then follows the model utilized by Gary Klein to evaluate the presence of intuition in decision-making at emergency scenes.[54] Each case study is assessed to determine the type of decision-making process used given the environmental conditions present, and the decision-makers are assessed to determine whether the decision involved pre-selected options, a comparative analysis technique, a novel option, or an intuition option (see Table 1).[55]

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[54] Klein, *Sources of Power*, 23.

[55] Klein, 23–24.

Table 1. Decision Point Analysis

Decision Points	Definition
Pre-selected option	Option made through pre-selected courses of action, through orders issued by someone else (standard operating procedures and industry standards)
Comparative evaluation	Two or more options considered by the decision-maker, comparing potential outcomes
Novel option	New and creative courses of action selected by the responder; improvised from previous situations, dissimilar to the present cues
Recognition-primed decision (intuition/experience)	Familiar pattern recognized and known strategy applied with a high probability of success

This chapter seeks to understand how naturalistic decision-making, specifically RPD, affects the leader when presented with situations that do not fit a recognizable pattern. Each case study illustrates examples of operations fitting a pre-selected course of action based on the day's industry standards and operating procedures. Then, as the intensity of the situations increased, leaders made critical decisions between various options without the benefit of time to analyze options comprehensively. Finally, in the presence of unfamiliar situations, the leaders were forced to select novel options that did not fit a traditional or expected course of action. The 9/11 case study presents a situation in which firefighters were forced to abandon the known firefighting strategy, pivoting toward evacuation and a historic effort to save thousands of lives. The Mann Gulch case demonstrates how the use of an escape fire saved the life of a crew foreman while confusing crew members who ultimately did not survive the fire.

A. MANN GULCH, MONTANA

The Mann Gulch fire represents an occupational lesson that forced the fire service to evaluate risk and decision-making under extreme conditions. Mann Gulch is situated along the upper Missouri River in the Helena National Forrest, approximately 20 miles north of Helena. The canyon comprises a mixed fuel load of dried grass, shrubs, and light trees lining valleys and steep slopes. The fire started on August 5, 1949, after a lightning strike ignited a small fire. The weather conditions on the day of the fire were categorized as extreme for the region—with temperatures reaching 97°F and fire danger projected to be 74 out of 100, the most dangerous fire projection—according to fire behavior modeling used at the time.[56] The firefighters who initially responded believed this fire to be routine given the fuel types present, the weather conditions forecasted, and the area's topography. The smokejumpers dispatched to the fire judged that the blaze could be controlled overnight and that they would be hiking out by ten o'clock the following day, meeting the goal of the Forest Service's "10 a.m. rule."[57]

The fire service deployed a crew of smokejumpers to the fire after the fire spotter identified it. The goal of the smokejumping program is to drop firefighters from the air into remote locations where early fires are burning.[58] The crew jumped with all their equipment to be self-sufficient for at least 48 hours, including equipment necessary to keep the fire small and contained to the immediate area.[59] The local fire district ranger, a former smokejumper, deployed to the fire and worked for nearly four hours alone before the arrival of the airborne firefighters.[60] The smokejumper program was still relatively new to the Forest Service in 1949, having started in 1940.[61] The 14 smokejumpers selected for this fire were young men between 17 and 28, some with military experience but all with a passion for the outdoors and an adventurous spirit.[62] The crew's foreman, Wagner (Wag)

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[56] Norman Maclean, *Young Men and Fire* (Chicago: University of Chicago Press, 1992), 42.

[57] Carrie Berger, Stephen Fitzgerald, and Daniel Leavell, "Fire FAQs—Managing Wildfire for Resource Benefit: What Is It and Is It Beneficial?," Oregon State University Extension Service, April 2018, https://catalog.extension.oregonstate.edu/em9193/html.

[58] Emily Meriam and Ross Donihue, "Smokejumpers: 80 Years of Wildland Firefighting," Esri, accessed February 19, 2021, https://storymaps.arcgis.com/stories/381fcd4a36584aa28f9d836247d9a939.

[59] "Smokejumpers," U.S. Forest Service, accessed August 15, 2022, http://www.fs.usda.gov/science-technology/fire/people/smokejumpers.

[60] Richard C. Rothermel, *Mann Gulch Fire: A Race That Couldn't Be Won* (Ogden, UT: U.S. Department of Agriculture, 1993), https://doi.org/10.2737/INT-GTR-299.

[61] Meriam and Donihue, "Smokejumpers."

[62] Maclean, *Young Men and Fire*.

Dodge, was the most experienced firefighter at 33 years old. The crew was not a formed team; instead, it was a collection of individuals selected for the assignment based on a jump rotation; while most men knew one another, Dodge did not know the crew members nor they him.[63]

The crew flew to the fire in a Douglas C-47 Skytrain from Missoula. The ride to the fire was so turbulent that one man felt too ill to continue and opted not to jump due to airsickness. Before the jump, Dodge and the aircraft spotter, Cooley, surveyed the fire area to understand the fire, the unburned fuel, the geography, and the fire conditions. The plane circled the jump site several times to identify the prevailing winds and select an appropriate landing site. Dodge and the spotter decided to jump from a higher altitude than the standard 1,200 feet, recognizing the risks of high winds on a low-altitude drop. The 14 firefighters jumped from the plane and landed near the drop site; the only casualty of the jump was the crew radio, which was destroyed on impact. The fire was estimated to have spanned 50–60 acres at the time of the jump.[64]

The crew successfully landed in the drop area and assembled. Dodge directed the assistant crew boss, Hellman, to take the crew and locate all supplies, preparing to fight the fire. Dodge then met up with forest ranger James O. Harrison, a former smokejumper who had been working on the fire by himself after it was discovered on August 5. Dodge and Harrison scouted the fire, developing a prediction about where the fire would spread and determining the best tactics to limit the spread and control the flames.[65] The two men had a quick lunch and set out to meet with the crew. Dodge directed the men to begin down the valley toward the Missouri River to establish an anchor point and begin their attack on the fire. An anchor point is a location to start firefighting operations, where the fire line starts around the fire.[66] As the crew made its way toward the river, Dodge noticed that the fire

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[63] Maclean.

[64] Maclean.

[65] Rothermel, *Mann Gulch Fire*.

[66] “Anchor Point,” National Wildfire Coordinating Group, accessed September 27, 2021, https://www.nwcg.gov/term/glossary/anchor-point.

had jumped beyond where he assumed it to be and that it was burning immediately below them at the bottom of Mann Gulch.

The three primary variables affecting wildland fires are the weather conditions at the location of the fire, the topography of the land where the fire is burning, and the fuel types burning.[67] Fires burning in dense materials, such as heavy timber and large logs, require much more energy to burn than a smaller fuel type, such as grasses and brush, which tends to burn very fast and hot.[68] The Mann Gulch fire started on the south side of the gulch in mature ponderosa pines estimated to be 60–100 years old. The fuels on the north side of the gulch were younger Douglas fir trees, but between the two were lighter fuels of grass and brush.[69]

By the time Dodge and Harrison had joined the crew, the fire had moved out from the timber understory and into light grasses along the north slope of the gulch, a location below the firefighters. Fires in timber understory require much more fuel to burn hot and move quickly, but fires in light grasses burn more rapidly and present a risk to those firefighters unaware that the fuels have combusted. Dodge recognized the hazard of the fire burning below them, driven by a strong wind and light fuel ignition. He immediately ordered the crew to sprint for the top of the ridge to flee the flames. The terrain was steep, and the climb would have been challenging even under normal conditions; however, the run was even more difficult with the fire burning behind them and gaining fast. During the run, Dodge did the unthinkable; he pulled out a book of matches and intentionally lit a fire in front of him, seemingly putting fire between the men and their escape. As Dodge's escape fire burned ahead of him, he stepped into the charred remains and begged the crew to join him in what is now known as a safety zone—an area where fuel has been removed

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[67] "Wildland Fire Behavior," National Park Service, accessed October 9, 2021, https://www.nps.gov/articles/wildland-fire-behavior.htm.

[68] National Wildfire Coordinating Group, *Fire Behavior Field Reference Guide*, PMS 437 (Potomac, MD: National Wildfire Coordinating Group, 2021), https://www.nwcg.gov/publications/pms437/fuels/surface-fuel-model-descriptions.

[69] Rothermel, *Mann Gulch Fire*.

and firefighters are safe from the advancing flames.[70] Unfortunately, the crew did not heed the advice of Dodge and continued to run uphill. Only two would survive the sprint.

Thirteen smokejumpers perished that day—eleven consumed by the fire and two succumbing to their wounds shortly thereafter.[71] Dodge survived the flames in his makeshift safety zone, and firefighters Bob Sallee and Walter Rumsey escaped through a small crack between two boulders on the upper ridge of Mann Gulch. The assistant crew boss, William J. Hellman, and firefighter Joseph Sylvia completed the sprint to the ridge top, only to suffer fatal burns during their escape. They both died within days.

After the events of August 1949, the Forest Service sought to understand what had happened in the mountains of Montana and what could be changed to improve the safety of wildland firefighters, including those in the smokejumper program. On September 26, 1949, a review board was convened to investigate the events of the Mann Gulch fire. In addition to receiving testimony from survivors, the review board was flown to the scene of the incident to review the site and corroborate witness accounts.[72] Of particular interest to the panel was the use of the intentionally lit fire set by Dodge. After consulting with experts, the board ultimately ruled that such a tactic was in the best interest of the crew's safety and did not result in the death of the smokejumpers. The use of the "escape-fire method" was specifically listed as the third of four recommendations from the panel.[73] The remaining recommendations also became foundational to the training of firefighters—training on situational awareness, crew cohesion, and an increased emphasis on fire behavior and predictions of catastrophic fire events.

In the years since Mann Gulch, firefighter training has improved tremendously by incorporating the lessons learned from this event. The Forest Service has developed a fire laboratory to understand wildland fire behavior, fire crews all carry silver pup-tent-style

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[70] "6 Minutes for Safety: Safety Zones 1 (LCES)," National Wildfire Coordinating Group, November 2021, https://www.nwcg.gov/committee/6mfs/safety-zones1-lces.

[71] Hutch Brown, "Mann Gulch Revisited," *Fire Management Today* 78, no. 1 (2020): 59.

[72] U.S. Forest Service, *Report of Board of Review: Mann Gulch Fire* (Washington, DC: U.S. Forest Service, 1949), https://www.nwcg.gov/sites/default/files/wfldp/docs/sr-mg-report-of-board-of-review.pdf.

[73] U.S. Forest Service, 14.

emergency fire shelters, and every firefighter learns the fundamentals of having lookouts, good communication, escape routes, and safety zones.[74] The principles of each training topic have been derived from incidents such as the Mann Gulch fire.

B. ANALYSIS OF DECISION-MAKING AT THE MANN GULCH FIRE

Smokejumpers working in Mann Gulch demonstrated numerous decisions utilizing pre-selected options in the early stages of the fire. The jump from the airplane into the burning area was considered routine and, aside from a radio mishap, went according to plan and training.[75] Firefighters on the ground, upon landing, followed standard procedures and set about organizing tools, feeding themselves, and preparing for the oncoming work ahead of them.[76] By all accounts, the early stage of this incident fit within the typical framework of firefighting for the men assigned to the Mann Gulch fire, even with some one-off situations, such as the radio malfunction. The pre-selected options laid out in firefighter and smokejumper training appear to have established the crew in the optimal spot to start the firefight, according to the established practices of the day. The early stages of the response to Mann Gulch used the pre-selected actions and orders from the crew foreman to best establish team members and begin working the incident; once the firefight began, however, things changed dramatically.

The decision when to start firefighting and where to begin initial actions presents one of the most poignant examples of the comparative analysis for the foreman, Wag Dodge. Initially, after landing, Dodge set his crew to task by having them arrange their tools while he scouted the fire and chased down a voice on the hillside, which happened to be James Harrison. The crew followed Dodge's orders as was customary of the smokejumping program at that time.[77] Dodge's initial survey of the fire led him to believe

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[74] Mark Matthews, "The Development of Safety Training after Mann Gulch," Wildland Fire Lessons Learned Center, 2009, 3, https://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=e4bb81e0-1910-4721-abe7-7ef6bc942631.

[75] Rothermel, *Mann Gulch Fire*, 2.

[76] Dave Turner, "The Thirteenth Fire," *Forest History Today*, Spring 1999, 27, https://foresthistory.org/wp-content/uploads/2017/02/The-Thirteenth-Fire.pdf.

[77] U.S. Forest Service, *Mann Gulch Fire*, 87.

that it “wasn’t bad. It was burning along the top of the ridge. I thought it would continue up the ridge.”[78] Dodge had two options to attack the fire—to start near the drop zone along the ridge or to move the men down toward the Missouri River.[79] When Dodge recognized that the conditions of the fire at the upper edge of the front were too hot to attack, he then decided to attack the fire from the riverside.[80] As crew foreman, the lead decision-maker on the crew, Dodge would decide the best place to attack the fire, so if the fire conditions indicated it was unsafe to attack the blaze head on, he would decide to move the crew to a more advantageous position. The comparative analysis conducted by Dodge indicated that the safer path was to move the crew below and start operations near the river; however, he did not account for additional variables present in the situation, including weather factors and fuel model changes, which affected fire spread. A comparative analysis assisted the crew members in this case, as the foreman decided for the crew; even with limited information, Dodge made what he believed was a sound tactical decision.

In lighting the safety zone fire, Dodge demonstrated a novel solution in smokejumping and firefighting. Before Wag Dodge touched matches to the grass at Mann Gulch, safety zone fires were not a standard practice for the Forest Service. Training for smokejumpers in 1959 included no information about burning out safety zones, and the curriculum comprised only eight hours of fire behavior, fire suppression, and escape fundamentals.[81] Dodge testified at the board of inquiry that he had never used an escape fire before, even though he had “been run off of big fires.”[82] Nor had he ever been instructed to light an escape fire before in his fire service training.[83] There is anecdotal

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[78] Rothermel, *Mann Gulch Fire*, 2.

[79] Brown, “Mann Gulch Revisited,” 57.

[80] U.S. Forest Service, *Mann Gulch Fire*, 121.

[81] Martin E. Alexander, Mark Y. Ackerman, and Gregory J. Baxter, “An Analysis of Dodge’s Escape Fire on the 1949 Mann Gulch Fire in Terms of a Survival Zone for Wildland Firefighters,” Wildfire Today, 2009, 3, https://wildfiretoday.com/documents/AnalysisDodgeEscapeFireon1949MannGulchFireSurvivalZone.pdf.

[82] Mann Gulch Fire Board of Review, *Proceedings of the Mann Culch Fire Board of Review* (Missoula: Mann Gulch Fire Board of Review, 1949), 123, https://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=a6e0fcf3-4fa9-4fd0-9e8e-4a381add486c&forceDialog=0.

[83] U.S. Forest Service, *Mann Gulch Fire*, 123.

evidence to suggest that Dodge had learned the technique from studying Native American fire strategies in the northern plains and had even discussed the potential use of this technique before 1949.[84] The use of burnout operations to create a safety zone was not part of the smokejumper or firefighter curricula for the U.S. Fire Service before 1949, and while Dodge might have considered the tactic, the use of the safety zone burnout serves as a novel solution in this case study. Wag Dodge applied a new tactic to the situation presented to the crew, and it ultimately resulted in saving his life; the tactic was not part of the expertise of a smokejumper and was unique in its application in this setting. The foreman did not have formal training in burnout operations for safety zones and applied a tactic he believed would save lives, even though it was unfamiliar to his crew.

Crew members relied on their own experiences when presented with the option of utilizing the burned-out safety area and did not join Dodge in the safety zone. None of the men were trained in the use of safe zones as it was not part of firefighting training; thus, Dodge's novel solution to a life-safety issue was foreign to the men.[85] Survivors testified that they saw Dodge light the fire, saw him enter the burned-out area, and heard him calling for his crew to join him in the safety zone.[86] None of the men joined Dodge in the safety zone, opting instead to attempt to outrun the blaze, with most of the men failing to do so and losing their lives to the heat and flames.[87] Dodge's fire was a novel solution and one that did not fit an established pattern in the minds of the men responding to the Mann Gulch fire. With no established frame of reference, the men defaulted to their original plan and continued beyond the relative safety of the burned-out patch. Neither Wag Dodge nor the rest of the smokejumpers had any knowledge of this tactic nor the chance of success in using fire to create a haven from more fire. Dodge asked the men to follow him, to trust the tactic, yet they opted to rely on their intuition rather than trust the foreman and this novel tactic.

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[84] Maclean, *Young Men and Fire*, 105; Alexander, Ackerman, and Baxter, "Dodge's Escape Fire," 2.

[85] U.S. Forest Service, *Mann Gulch Fire*, 87.

[86] U.S. Forest Service, 118.

[87] Maclean, *Young Men and Fire*, 95.

C. 9/11, NEW YORK

The World Trade Center served as a recognizable icon along the New York skyline after its completion in 1973. Construction began on August 5, 1966, near the financial district and the Hudson River, and seven years later, the World Trade Center's twin towers officially opened.[88] Tower one, the north tower, stood as the tallest building in the world at 1,368 feet, with a footprint of approximately an acre. Tower Two was slightly shorter than its twin at 1,362 feet and equally occupied a one-acre footprint. Each building was 110 stories tall.[89]

The construction design for the twin towers was unique in that the exterior of the buildings bore the weight of the superstructures, allowing for more interior space and an open floor plan. The Port Authority required that the facilities have a massive 10,000,000 square feet of office space combined in the towers, so lead architect Minoru Yamasaki designed 110 stories for each to accommodate this request. Yamasaki coordinated with Emery Roth and Sons to build the structure over 80 stories, achieving the necessary height and square footage.[90] Yamasaki, driven by the demand for open floorplans and wide spaces on each floor, opted to use a framed-tube design whereby the exterior frame supported the weight of the buildings. The plan resulted in open office spaces with limited interior columns.[91] The tubular structure of the building limited the window size available on each floor, and according to Goldberger, the "result was that windows took up only 30 percent of the façade … as compared to 50, 60, or 70 percent on many other modern skyscrapers."[92]

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[88] Therese P. McAllister et al., "Introduction," in *World Trade Center Building Performance Study*, FEMA 403 (Washington, DC: Federal Emergency Management Agency, 2002), I-2, https://www.fema.gov/pdf/library/fema403_ch1.pdf; Angus Gillespie, *Twin Towers: The Life of New York City's World Trade Center* (New Brunswick, NJ: Rutgers University Press, 1999).

[89] Gillespie.

[90] Gillespie.

[91] Paul Goldberger, *Up from Zero: Politics, Architecture, and the Rebuilding of New York* (New York: Random House, 2004), 27.

[92] Goldberger, 27.

One major obstacle in the design of the World Trade Center towers—and certainly a consideration on 9/11—was the ability to move people throughout the buildings. Given the massive size of the towers, it was inconceivable to move people around them with a single elevator. Planners created a system of elevators like a subway system.[93] High-speed elevators carried people to sky lobbies serviced by banks of local elevators; the sky lobbies were established on the 44th floor and the 78th floor of the towers. Using this system to move people throughout the building increased usable space in the structure from the typical 62 percent per floor to 75 percent.[94]

The attacks on 9/11 were not the first attacks on the buildings. On February 26, 1993, six people died when a truck bomb exploded on the B-2 level of the parking garage. The explosion and damage destroyed power to the building, sent smoke up to the 95th floor of the towers, and left 1,042 people injured. Only 15 people received traumatic injuries from the blast; the other 1,027 injuries resulted from smoke inhalation or traumatic injuries from the evacuation of 50,000 people from the Trade Center towers.[95] The FDNY's response to the incident resulted in over 750 vehicles and thousands of firefighters on scene.[96] The explosion destroyed fire protection systems, knocked out power to the building, and caused extensive structural damage to several basement levels.[97]

Out of the 1993 bombing came two significant findings that would affect strategic and tactical operations at the 9/11 attacks on the twin towers. The first finding was the need to understand evacuation from the twin towers. Moving 25,000 people from each tower through smoke conditions proved an enormous task for fire crews operating on the scene. The building evacuation was the largest the FDNY or any other fire department had ever

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[93] Gillespie, *Twin Towers*, 76.

[94] Gillespie, 78.

[95] William Manning, ed. *The World Trade Center Bombing: Report and Analysis* (Emmitsburg, MD: U.S. Fire Administration, 1993), 1, https://www.usfa.fema.gov/downloads/pdf/publications/tr-076.pdf.

[96] Simon Reeve, *The New Jackals: Ramzi Yousef, Osama Bin Laden and the Future of Terrorism* (Boston: Northeastern University Press, 1999), 14.

[97] Rita Fahy and Guylene Proulx, *Human Behavior in the World Trade Center Evacuation* (Gaithersburg, MD: National Institute of Standards and Technology, 1997), 714, https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=909239.

encountered.[98] The second finding was the need for enhanced communications systems in the World Trade Center complex. Radio communications were difficult to transmit out due to the vast radios operating on the repeaters and limitations of the radios themselves. Firefighters relied on human repeaters whereby one responder retransmitted another person's radio transmission to reach command.[99] In response to these findings, the Port Authority made several changes to the World Trade Center complex, including pressurizing stairwells and installing additional repeaters on each tower. Such stairwell pressurization uses fresh air to create a positive pressure environment in the stairways to push smoke out and theoretically create cleaner airspace for occupants to evacuate.[100] The Port Authority repeaters were installed atop World Trade Building 5, directed toward the twin towers, and were intended to provide interoperable communications across responding agencies to the World Trade Center complex.[101]

On Tuesday, September 11, 2001, the United States experienced one of the worst attacks in the nation's history. At 8:46 a.m., American Airlines Flight 11, bound for Los Angeles from Boston, flew directly into the upper floors of the north tower of the World Trade Center in New York City. The Boeing 767–223ER was carrying 10,000 gallons of Jet-A fuel and had 92 people on board—11 crew members and 81 passengers.[102] Fifteen minutes into the flight, the plane was hijacked and deliberately flown into the building at approximately 443 miles per hour.[103] The impact destroyed seven floors of the north building from the 92nd to the 99th floor, killing or trapping 1,300 people. The fuel from the plane poured down pipe chases and elevator shafts, spreading fire throughout the superstructure of the 110-story building. At 9:03 a.m., 17 minutes after the crash of Flight

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[98] Manning, *The World Trade Center Bombing*, 13.

[99] Manning, 14.

[100] W. Z. Black, "Stairwell Pressurization and the Movement of Smoke during a High-Rise Fire," *ASHRAE Transactions* 121 (2015): 216–31.

[101] S. Shyam Sunder et al., *Final Report on the Collapse of the World Trade Center Towers: Federal Building and Fire Safety Investigation of the World Trade Center Disaster* (Gaithersburg, MD: National Institute of Standards and Technology, 2005), 164, https://doi.org/10.6028/NIST.NCSTAR.1.

[102] 9/11 Commission, *Staff Report* (Washington, DC: 9/11 Commission, 2004), 7, http://www.archives.gov/research/9-11/staff-report-sept2005.pdf.

[103] Sunder et al., *Collapse of the World Trade Center Towers*, 182.

11, United Airlines Flight 175 slammed into the side of the south tower of the World Trade Center at approximately 542 miles per hour, striking and damaging the 77th through the 85th floor.[104] The Boeing 767–200 had approximately 9,100 gallons of Jet-A fuel and 65 people on board—56 passengers and 9 crew members.[105] The south tower collapsed first at 9:59 a.m., 56 minutes after it had been struck. The north tower fell at 10:28 a.m. after sustaining structural integrity for 1 hour and 42 minutes. With the towers' collapse came the unimaginable death toll—2,977 people lost their lives—including 343 FDNY firefighters, paramedics, and staff.

In 2001, the FDNY was staffed by 8,648 firefighters working across five boroughs.[106] On the morning of September 11, the initial response to the incident called for a high-rise response from the 1st Battalion, which encompasses parts of lower Manhattan and the financial district. Battalion Chief 1, Joseph Pfeifer, was the first responding commanding officer to respond to the fire and witnessed the impact of American Airlines Flight 11 into the north tower.[107] Having witnessed the plane fly directly into the World Trade Center, Chief Pfeifer knew that as the first chief, he would assume command, and he recognized the gravity of the situation.[108] He requested a working fire assignment and immediately upgraded it to three alarms, bringing hundreds of firefighters to the scene. In all, each tower would request a five-alarm assignment for the building, resulting in much of the on-duty personnel for the entire city being assigned to the incident.

Battalion 1 personnel were intimately familiar with the World Trade Center buildings, regularly responding to various calls. According to a documentary directed by James Hanlon and French brothers Jules and Gédéon Naudet, crews from tower Ladder 1 and Engine 7 typically responded to the World Trade Center five times a day for various

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[104] Sunder et al., 182.

[105] 9/11 Commission, *Staff Report*, 19.

[106] Stephanie Gaskell, "FDNY at Pre-9/11 Numbers," *New York Post*, December 12, 2003, https://nypost.com/2003/12/12/fdny-at-pre-911-numbers/.

[107] Joseph Pfeifer, *Ordinary Heroes: A Memoir of 9/11* (New York: Portfolio/Penguin, 2021).

[108] Pfeifer, 11.

calls, resulting in tremendous crew knowledge of the building's interior layout and operating systems.[109] When the crews responded to the high-rise fire in the north tower on 9/11, they worked as they usually did, parking in the same spots, donning personal protective equipment, and gathering their gear to respond to the fire burning 77 stories above them. The same documentary followed Chief Pfeifer during the early stages of the response, providing insights into the decisions, the actions, and the frustrations of responding to an incident of this complexity.

Information was slow to develop during the response as communications were difficult and overwhelming. Chief officers selected the initial strategies, and they determined that rescuing people would be the primary goal.[110] Chief Pfeifer and the other responding chief officers at the towers directed crews to ascend the towers and initiate firefighting operations. The responding crews, recognizing the elevators were out of service due to the damage, had to make the climb up the towers.[111] Unfortunately, firefighters would be ascending the same stairs that people were evacuating, thus slowing their climb. Firefighters could be expected to climb approximately one floor every two minutes with gear, which would be slowed dramatically with additional people in the stairwells.[112]

The south tower was struck 17 minutes after crews arrived at the north tower, and the command structure split between the two buildings—the north tower would collapse at 10:28 a.m. Chief Pfeifer made one of the most important decisions in his career and in the history of the FDNY immediately after the collapse of the south tower: he reported to all companies working in the remaining structure, "Command Post to Tower 1, all units evacuate the building."[113] This order effectively abandoned the building and instructed

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[109] *9/11*, directed by James Hanlon, Jules Naudet, and Gédéon Naudet (2002; New York: CBS, 2002); 9/11 Commission, *Staff Report*.

[110] Pfeifer, *Ordinary Heroes*, 22.

[111] Bruce Dearstyne, "The FDNY on 9/11: Information and Decision Making in Crisis," *Government Information Quarterly* 24, no. 1 (2007): 35, https://doi.org/10.1016/j.giq.2006.03.004.

[112] Sunder et al., *Collapse of the World Trade Center Towers*, 192.

[113] Pfeifer, *Ordinary Heroes*, 44.

firefighters to exit and evacuate anyone they could with them on their way out. The decision to evacuate the north tower likely resulted in thousands of lives saved on the morning of September 11. It is estimated that 85 percent of the occupants in the north tower escaped the building before its collapse, and 91 percent of the occupants in the south tower escaped before its collapse.[114] Furthermore, climbing to the 90th floor in the north tower would have taken hours before the requisite compliment of firefighters were at the correct height to attack and control the blaze.[115]

When the planes struck the World Trade Center, many different variables came together to create optimal conditions for building collapse. The design of the buildings meant that when the planes struck, they impacted the exterior supporting structure of the framed-tube design. Communications in the buildings hampered transmissions between firefighters responding to the scene and those operating in the buildings. Thousands of gallons of jet fuel burned several floors of the towers and took elevators off-line, resulting in long climbs for emergency responders. Finally, there had never been an incident like this for firefighters to reference in their careers. A commercial jet airliner had never before crashed into a skyscraper in the history of the United States. The decisions made by incident commanders such as Chief Pfeifer were made using the best available information on scene and likely resulted in thousands of lives saved that morning in New York City.

D. ANALYSIS OF DECISION-MAKING AT THE 9/11 COMMAND POST

Responders to the World Trade Center relied heavily on pre-selected modes of operation in the initial response to a fire on the upper floors of the World Trade Center's north tower, especially in the first hour of operations. Apparatus locations were pre-designated, and responders were familiar with the building layout and systems operations; incident commanders requested additional alarms and followed protocols for a significant incident.[116] These protocols involved emergency responder crews' initiating fire attack

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[114] Sunder et al., *Collapse of the World Trade Center Towers*, 158, 160.

[115] Sunder et al., 159.

[116] Pete Hayden, "Incident Command 9–11: Lessons Learned at the World Trade Center" (presentation, FEMA Emergency Education Network, 2012), 3, 12, https://www.hsdl.org/?view&did=722189.

operations by gathering equipment and making their way up to the fire floors, seemingly to extinguish the flames and rescue occupants, all with the understanding that they would be fighting the most significant fire in FDNY history.[117] The siloed communications and coordination of police and fire units, which was the custom of the day, meant that the two disciplines operated autonomously from one another.[118] Information was slow to develop on the actual scope of the incident on 9/11, and responders relied on known patterns of response to establish the foundation of the command-and-control systems for firefighting and rescue operations. In the absence of outlier information about this emergency response, the responders used pre-selected modes of operation in a familiar pattern even though they knew the situation was far from a typical response. Pre-selected modes of operation served as a starting point for the World Trade Center response and helped establish the early command-and-control systems; as the situation unfolded, however, the decision-making models would change as responders faced even more unfamiliar situations.

Initial strategic options at the World Trade Center reflected a comparative evaluation as the designated decision-makers—the initial commanders—compared strategies, including the rescue and evacuation of occupants, while considering firefighting operations. Ultimately, they settled on rescuing people and confining the flames to the upper floors.[119] The decision to evacuate the buildings centered on the need to clear space for firefighting operations on the floors directly below the fire, ensuring that as many people as possible exited the structures.[120] Given the gravity of the event before incident commanders and the perceived time constraints, weighing the strategic options resulted in satisficing for the quickest option—to engage in firefighting and to support evacuations as crews met occupants coming down. The comparative evaluation on the first floor of the north tower had determined the strategy for the initial hours of the response. It reflected a

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[117] Pfeifer, *Ordinary Heroes*, 13.

[118] Dearstyne, "The FDNY on 9/11," 211.

[119] Pfeifer, *Ordinary Heroes*, 13.

[120] McKinsey and Company and Fire Department of New York City, "FDNY Fire Operations Response on September 11," in *Final Report of the FDNY Response* (New York: McKinsey and Company, 2002), 28, https://www1.nyc.gov/assets/fdny/downloads/pdf/about/mckinsey_report.pdf.

group-based consensus among all the chief officers that the evacuation and rescue of those in the building allowed for firefighting operations.

Evacuating the building represented a novel solution for the FDNY, which had never been forced to make such a decision in the department's history. No one on scene had ever been presented with a fire of this scale or complexity, so there were no established frameworks to rely on.[121] Incident commanders ordered the evacuation after the collapse of the south tower.[122] With thousands of people and hundreds of firefighters in the north tower, the FDNY had never in the history of the organization ordered an evacuation for a fire under these conditions.[123] The evacuation order was not taken lightly or without measured evaluation of the conditions present—it was unorthodox. It went against everything the FDNY had worked toward in response to the towers. The novel solution of a complete evacuation of the building, including firefighters, was not in the original decision matrix as fire crews arrived on scene. The additional information about catastrophic changes in conditions necessitated the wholesale change to evacuation. The lack of information and the inability to gain situational awareness affected the information available to the initial incident commanders; a novel solution was enacted once the first catastrophic event occurred.

A lack of full situational awareness affected the decision-makers' ability to utilize RPD during the initial response to the World Trade Center. The response resulted in silos of information and situational awareness, which otherwise could have provided details about the status of the buildings.[124] The limitations of communications equipment at the incident were the result of technological issues and physical damage to radio systems, which led to poor communication with firefighters and outside agencies.[125] Agencies remained closed off to partners to insulate the decision-making process, thus limiting the

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[121] Pfeifer, *Ordinary Heroes*, 18.

[122] McKinsey and Company and Fire Department of New York City, "FDNY Fire Operations," 33.

[123] Pfeifer, *Ordinary Heroes*, 46.

[124] Pfeifer, 24.

[125] Dearstyne, "The FDNY on 9/11," 34.

use of other disciplines' knowledge of the situation.[126] Moreover, the massive scale of the incident and the sheer number of responders meant that deciphering information and developing a clear operational picture of the incident were nigh impossible. RPD expects that the decision-maker has a relatable framework for the responder and that the responder can envision the option being carried out to success.[127] The lack of situational awareness about the structural stability of the building limited the incident commanders' ability to use RPD, forcing them to react to changes in the environment and rely on novel solutions. The decisions made on the morning of September 11, 2001, saved thousands of lives and were based on the conditions present for the career firefighters who had decades of experience. The overwhelming scope and scale of the situation and the inability to gain adequate situational awareness limited the use of RPD, forcing the decision-makers to rely on options rarely considered.

E. CONCLUSION

Firefighters and emergency responders make decisions under time constraints every day. RPD enables the responder to make decisions quickly by utilizing past experiences and comparing the current conditions to past events, ensuring that the best outcome is selected quickly.[128] The two case studies presented here demonstrate that at a certain point, the use of RPD limits the responder, particularly when the conditions of an incident do not align with recognizable patterns. As the situation unfolds, the decision-maker must transition away from the everyday use of RPD and select a new course of action, which may include novel solutions or unfamiliar tactics. The next chapter identifies components of cross-disciplinary leadership that can support a new model of decision-making in complex situations by incorporating perspectives from other industries and expertise.

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[126] Pfeifer, *Ordinary Heroes*, 211.

[127] Klein, *Sources of Power*, 12.

[128] Klein, "Naturalistic Decision Making," 30.

IV. COLLABORATION AND COMPLEX INCIDENTS

In 2010, two events made headlines around the world and changed their respective industries. On April 20, 2010, an explosion off the shore of Louisiana on the Deepwater Horizon oil platform resulted in the deaths of 11 crew members and injured 17 more. The resulting oil spill was one of the most significant disasters of its kind, affecting the entire Gulf of Mexico ecosystem. Four months later, in August 2010, a mining collapse at Mina San Jose in Chile trapped 33 miners underground with no escape. Both events demonstrated the problem-solving abilities of cross-disciplinary groups coming together to solve complex problems. This chapter explores the factors that contributed to the success of this team-based approach in solving complex problems during mining disasters. Such success requires a leadership structure that accepts nontraditional ideas and encourages broad diversity of problem-solving using multi-disciplinary teams.

This case study analysis explores the impact of cross-disciplinary groups on complex problem-solving. This chapter first establishes a relationship between mining emergencies and the fire service, defining common priorities such as life safety, incident stabilization, and property conservation. Then, each case is presented with an analysis of the following factors: sensemaking, teaming, communication, and leadership (see Table 2).

Table 2. Decision-Making Factors

Sensemaking	What tools or techniques were employed to determine situational awareness and the status of the incident?
Teaming	How were teams formed, and what characteristics were found to increase or decrease the likelihood of team success?
Communication	How did teams communicate together and throughout the overall response structure? What was the impact of communication on the outcome of the incident?
Leadership	What leadership structure existed, and how did the interaction between decision-makers and problem-solving teams inhibit or support the overall incident?

This chapter ends with a comparative analysis of the two events vis-à-vis the impact of the four group dynamics on the overall outcomes of the incidents. It finds that cross-disciplinary teams significantly affect the overall success of complex problems—when strategic-level decisions encourage cross-disciplinary approaches and leaders embrace outside-the-box thinking and suggestions. Additionally, this analysis demonstrates the importance of communication across the entire response domain, encouraging real-time information and operational-picture sharing of the incident.

A. EMERGENCIES AS LIFE-SAFETY EVENTS

Fire departments routinely encounter emergencies large and small using tactics to achieve strategic goals; energy companies and mining organizations employ the same system for emergencies outside their routine operations. In order of importance, the fire service relies on the following four strategic objectives to minimize threats to the public: minimizing risk to life safety, stabilizing the incident, preserving property, and minimizing risk of damage to the environment.[129] The priorities of the offshore mining industry for spill containment differ slightly in their order, but the principles remain the same. The effects of offshore oil spills are measured by their economic, environmental, public health, and social and community impacts.[130] Offshore oil spill incidents are frequently difficult to access, or the affected area of concern involves coastal lands and inland waterways. The mining industry, on the other hand, is more accessible and more connected to emergency services. The life-safety priorities of mining incidents align more closely with emergency services' priorities than do energy companies, focusing on life safety and incident stabilization.[131] Mining incidents, much like offshore incidents, require interagency cooperation and communication among various groups.

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[129] National Fire Protection Association, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, NFPA 1710 (Quincy, MA: National Fire Protection Association, 2020), 11, https://codesonline.nfpa.org/.

[130] Pu Li et al., "Offshore Oil Spill Response Practices and Emerging Challenges," *Marine Pollution Bulletin* 110, no. 1 (September 2016): 6–27, https://doi.org/10.1016/j.marpolbul.2016.06.020.

[131] Sofia Karlsson, "Saving Lives during Major Underground Mining Incidents: Becoming Prepared for a Collaborative Response" (PhD thesis, Umeå University, 2020), http://urn.kb.se/resolve?urn=urn:nbn:se:umu:diva-174292.

All three industries adopt similar priorities during catastrophic events, each prioritizing life safety, incident stabilization, and property conservation. While not all incidents may be comparable among these industries, the Deepwater Horizon oil spill and the trapped miners in Chile both provide lessons learned for the fire service because their strategic goals demonstrate shared objectives that are familiar and applicable to the fire service.

B. DEEPWATER HORIZON OIL SPILL

In February 2010, BP began drilling on the Macondo Prospect in the Gulf of Mexico, 41 miles offshore of Louisiana. On April 20, 2010, an explosion rocked the Deepwater Horizon platform, killing 11 and injuring 17. The resulting oil spill was one of the largest on record, releasing nearly five million barrels of oil into the Gulf.[132] The response to the incident demonstrated not only an international conglomeration of help but also a coordinated trial-and-error process to ebb the flow of oil and lessen the ecological impact to the area.

BP secured the rights to drill on the Macondo Prospect in 2008 and leased the Deepwater Horizon drilling platform from Transocean.[133] The platform was moved into position, and drilling commenced in February 2010. The drill depth at this location was approximately 5,000 feet below sea level, with the anticipated well depth ending at 18,360 feet below sea level. This drilling site was an exploratory well to determine oil production rates and explore the sea floor geology in this newer region for BP. After drilling the well, the plan was to plug it, so it could be accessed later as an oil-producing well.[134]

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[132] Committee on the Analysis of Causes of the Deepwater Horizon Explosion, Fire, and Oil Spill, Marine Board, Board on Environmental Studies and Toxicology, National Academy of Engineering, and National Research Council, *Macondo Well Deepwater Horizon Blowout: Lessons for Improving Offshore Drilling Safety* (Washington, DC: National Academies Press, 2021), ix, https://doi.org/10.17226/13273.

[133] “Central Gulf of Mexico Planning Area Lease Sale 206 Information,” Bureau of Ocean Energy Management, March 19, 2008, https://www.boem.gov/oil-gas-energy/leasing/central-gulf-mexico-planning-area-lease-sale-206-information.

[134] Committee on the Analysis of Causes of the Deepwater Horizon Explosion, Fire, and Oil Spill, Marine Board, Board on Environmental Studies and Toxicology, National Academy of Engineering, and National Research Council, *Macondo Well Deepwater Horizon Blowout*, 19.

Drilling into the rock bed revealed a high-pressure zone where hydrocarbons built up between the oil and the porous rock formations beneath the ocean. To balance the pressure of the oil with the pressure from drilling, miners use a mix of mud and oil circulated through the drilling bore.[135] The balance of pressure in the mud slurry is a technical process maintained by valves and processes at the drill site. If the pressure in the mud is too low, gas and sediment can enter the drilling area and create a "kick" whereby pressurized oil is released into the adjacent rock formations, and the product is lost.[136] Additionally, placed atop the wells are blowout preventers that consist of valves that function as a safety device for the drillers at the wellhead. A crucial component of the blowout preventer is the blind sheer ram, which is designed to cut horizontally through the pipe in the event of an emergency and seal the well.[137]

At 18,360 feet, the drilling had to stop due to the pressure of the hydrocarbons and the counterpressure of the mud being used to balance the drilling system. Engineers at the site determined that this depth optimized the balance between the two and determined that the well depth had been set. BP had located a reserve of oil estimated to be at least 50 million barrels.[138] Engineers then sought to cap the well with a production casing in a specially formulated cement mixture, which had been developed by Halliburton in close coordination with BP engineers. Once the cement cap was put in place, the next process was to close the drilling operation and prepare to transition from the large, costly Deepwater Horizon platform to a smaller, cheaper platform that would finalize the well capping.

Two tests were performed on the well: one positive pressure test to evaluate its integrity and one negative pressure test. The well passed the positive pressure test, holding pressures up to 2,500 PSI. During the negative pressure test, however, a substantial

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[135] Don Williams, "Defining Drilling Fluids," *Oilfield Review* 25, no. 1 (2013).

[136] "Kick," Schlumberger Energy Glossary, accessed February 16, 2022, https://glossary.oilfield.slb.com/en/terms/k/kick.

[137] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling* (Washington, DC: National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011), 91.

[138] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 91.

problem developed. The team was concerned about readings and ended up conducting the test using other methods, through a process known as the kill line. Even with the minor setback, the team decided to move ahead with capping the well in preparation for their move to another rig. Later that evening, after a series of odd readings on pressure gauges, the crew experienced a kick at about 9:45 p.m. Within minutes, a blowout became evident to the crew as mud flowed back up the drill pipe, pressurized by hydrocarbons flowing from deep under their feet. The first explosion occurred at approximately 9:49 p.m. Neither the blowout preventer on the seafloor nor the automated shutoff systems onboard the Deepwater Horizon could stop the flow of hydrocarbons, and they erupted out of the drill pipe, exploding and taking 11 lives in the ensuing fire.

What followed in the next 85 days was an international and interdisciplinary display of problem-solving to tackle three major dilemmas. The first and most pressing was the burning Deepwater Horizon, which smoldered for a full day before it sank on April 22, 2010. The next problems would not solve themselves—as the fiery hulk of a rig did when it succumbed to the waves. Second, the well continued to spew oil into the Gulf of Mexico, so the wellhead needed to be capped 5,000 feet below sea level. Third, oil recovery efforts needed to be initiated to stop the spread of the oil and the impact to the ocean's ecological systems.

As with most sea emergencies, the U.S. Coast Guard was one of the first governmental agencies to respond to the explosion and assist with the search and recovery of the Deepwater Horizon crew. Captain Joseph Paradis was the first federal incident commander on scene and formed the initial response plan for the burning vessel, the potential fuel stores onboard Deepwater Horizon, and the leaking oil. All these actions were within the National Contingency Plan, whose regulations guide responses to oil spills and hazardous materials.[139] Private supply ships attempted to extinguish the fire while the Coast Guard conducted search-and-rescue operations to locate the missing crew members.

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[139] "National Oil and Hazardous Substances Pollution Contingency Plan (NCP) Overview," Environmental Protection Agency, March 25, 2022, https://www.epa.gov/emergency-response/national-oil-and-hazardous-substances-pollution-contingency-plan-ncp-overview.

During the search, several Coast Guard personnel noted a growing sheen on the surface of the ocean.

As the Deepwater Horizon slipped beneath the waves, the Coast Guard set out to establish command posts in Louisiana and at BP's corporate headquarters in Houston, Texas. The Coast Guard established a unified area command to oversee all operations related the Deepwater Horizon spill. This unified area command consisted of the Coast Guard, the Environmental Protection Agency, and BP—the responsible party in this case. In all, 16 governmental agencies would have a role in the process of mitigation and recovery from this event. In the coming weeks, the commandant of the Coast Guard, Admiral Thad Allen, would assume the role of unified incident commander.

Initial actions to stem the flow of oil from the leaking well were initiated by BP. Remote vehicles descended to the blowout preventer and attempted to activate the blind shear ram, and initially it looked as though the efforts would pay off. However, it was soon discovered that oil was flowing from several locations along the pipe still attached to the wellhead. Once these efforts had been defeated, the next option was for BP to drill a relief well, a process that would likely take months to complete. In the interim, a team of scientists and BP engineers set to work to develop alternatives to stop the flow of oil until the relief wells could reach effective depths. Ideas began to flow about how to contain underwater spills at such extreme depths. New technologies were designed and tested, including underwater cofferdams and chemical dispersants.

The first attempt to contain the oil spill was to use a cofferdam developed for shallow-water oil leaks. The cofferdam would collect the oil and concentrate it through pipes up to pumping vessels at the surface. The oil would then be processed and sent ashore through tankers. This process, however, had not been tested at such depths, and its progress was thwarted when hydrates—ice crystals from a mixture of methane gas and water—formed in the line. The cofferdam idea was abandoned and the device discarded to the sea floor. On the heels of this failure, BP and the unified command team found a small victory in the use of a riser insertion tube tool, which fit on the end of the riser and carried up smaller volumes of oil, collecting merely 22,000 barrels of oil in nine days of use.

Moving beyond the cofferdam, the federal government became more involved in day-to-day problem-solving, supporting BP engineers in finding a solution that could quell the spread of oil and protect lives and the environment. While Russian engineers recommended a sub-surface nuclear detonation, which was quickly discarded by experts, the BP engineers worked to stop the well with a top-kill tactic, designed to pump mud and cement into all available pipes and tubes, in hopes of overcoming the pressure of the oil and creating a plug in the well itself. Unfortunately, the flow of oil was too great, and the top kill was unsuccessful after several attempts. BP once again resorted to other mechanical means to divert any amount of oil into collection vessels and placed a top hat on the blowout preventer at the seabed. While the top hat did not collect all the oil, it did siphon off some, thus lessening the amount free flowing into the Gulf.

By mid-May, the team assembled to work with BP engineers had developed roles and was working cohesively to determine the best options for capping the well and stopping the flow of oil. The group assembled consisted of public, private, and university scientists and engineers working alongside government officials from the Department of the Interior, Department of Agriculture, the Coast Guard, and others. Additionally, and against the wishes of BP, the assembled group also sought advice from industry experts, including competing companies.

Finally, on July 9, 2010, with the approval of President Obama, the federal on-scene commanders approved the use of a capping stack on the well. The concern with using the capping stack was the amount of oil flowing behind the stack. If too much oil pushed behind it, the oil might back up into the adjacent rock and leak from around the area. Government scientists and BP engineers monitored closely as the process of capping the well was undertaken deliberately. It was determined that the cap was holding, and the procedure had been a success. BP then took steps to fully kill the well by pumping a plug into it. Heavy drilling mud was pumped into the well beginning on August 2, 2010, and the well was officially closed, bringing an end to the largest oil spill in history.

1. Sensemaking and Situational Awareness Tools

The Deepwater Horizon incident was an outlier event in terms of size and total flow of oil from the leaking well. The event was the largest oil spill in world history, resulting in an estimated 200 million gallons of crude oil spilled into the Gulf of Mexico.[140] The Deepwater Horizon was not the first well-drilling blowout event on a drill barge; however, it was one of the most deadly, costing the lives of 11 platform workers and wounding 17 more.[141] It took nearly two months to contain the spill and years to clean up the ecological damage to the Gulf region. Given the size of the problem, sensemaking or situational awareness was challenging to coordinate. The process of solving this complex issue was derived from the workflow of an interagency and interdisciplinary approach to problem-solving.

The onset of the event resulted in a heavy presence by the Coast Guard and a limited presence of BP and Transocean personnel. Situational awareness from the start of the incident relied on traditional tools used by the Coast Guard, such as aerial surveillance and visual search. The first priority of the incident response was to utilize search-and-rescue techniques to find survivors and remove them from the waters around the drilling platform.[142] Secondarily, the fire on the drilling platform had to be addressed to stop the threat of continued burning. To accomplish this feat, BP and the Coast Guard relied on contractors deployed to the area to fight the fire.[143] Attention then turned to the extent of the oil flow after the initial response to the fire and the search-and-rescue operation.

The size of the incident limited the responders' ability to understand the gravity of the situation. BP engineers and project managers had not envisioned a spill of this

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[140] Jonathan Ramseur, *Deepwater Horizon Oil Spill: The Fate of the Oil*, CRS Report No. R41531 (Washington, DC: Congressional Research Service, 2011), 1, https://crsreports.congress.gov/product/pdf/R/R41531.

[141] BP, *Deepwater Horizon Accident Investigation Report* (Washington, DC: BP, 2010), 9, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/sustainability/issue-briefings/deepwater-horizon-accident-investigation-report.pdf.

[142] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*, 130.

[143] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 134.

magnitude and did not have technology available to address deep-water well-blowout situations.[144] A spill this size and this complicated had never been encountered before. It required rapid development of new technology to develop situational awareness, just to make sense of the scale of the incident.[145] To create the tools necessary to understand the scope of the problem, government officials and BP engineers needed to identify the flow rates from the wellhead over a mile under the ocean's surface.[146] On-scene commanders and regional leaders developed plans to incorporate an interdisciplinary approach to problem-solving, which could identify the level of risk and provide accurate time information about the status of the oil spill.

Decision-makers needed to develop real-time situational awareness to select the best course of action; they required sensemaking tools that could gauge how the situation was progressing and evaluate the results of the various methods to stop the flow of oil. Unified commanders relied on government and non-government scientists and engineers working in cooperation to develop resources for informed decision-making.[147] Collaboration between the BP teams assembled, academic-based science teams, and government-formed teams did not always go as planned. The result of the efforts was the development of tools and procedures that eventually provided monitoring and potential solutions to stop the flow of oil.[148] The coordinated efforts of private industry, academia, and government scientists led to success following this incident. They allowed incident commanders to receive intelligence on the progress of the effort and ultimately the cessation of oil from the Mercado well.

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[144] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 132.

[145] Jane Lubchenco et al., "Science in Support of the Deepwater Horizon Response," *Proceedings of the National Academy of Sciences* 109, no. 50 (2012): 20213, https://doi.org/10.1073/pnas.1204729109.

[146] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*, 147.

[147] Gary Machlis and Marcia McNutt, "Black Swans, Wicked Problems, and Science During Crises," *Oceanography* 24, no. 3 (2011): 319, https://doi.org/10.5670/oceanog.2011.89.

[148] Marcia K. McNutt et al., "Applications of Science and Engineering to Quantify and Control the Deepwater Horizon Oil Spill," *Proceedings of the National Academy of Sciences of the United States of America* 109, no. 50 (2012): 20227.

2. Team Formation and Dynamics

The organizational structure of the Deepwater Horizon was established by statute based on lessons learned from national and international events. Originally developed through the Oil Pollution Act in 1990, the response framework has been modernized through federal doctrine to address modern response practices. The U.S. response to oil spills is framed in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP).[149] The NCP establishes the national response system (NRS) along with national response teams and regional response teams, which all form a stratified approach to oil spill response.[150] The NRS is chaired by the Environmental Protection Agency and vice-chaired by the Coast Guard.[151] A key position is the on-scene coordinator (OSC) role, the federal representative at the incident with the overall authority to make decisions and approve strategic and tactical approaches.[152] The initial on-scene commander for the Deepwater Horizon spill was Captain John Paradis; eventually, Admiral Thad Allen assumed the role when he was designated the national incident commander.

Throughout the Deepwater Horizon spill response, there was friction between the various teams established to solve problems and resolve the largest spill in history. As the spilling agency, BP was initially responsible for all oil recovery costs and established teams at BP headquarters to end the spill, limiting the cost of the recovery process.[153] The top-down structure of the response led to confusion about who was in charge, even resulting in Homeland Security Secretary Janet Napolitano stating publicly on CNN that BP was not a partner in the response. On May 2, 2010, she admonished that BP was, in fact, a "responsible party, they [were] going to pay for it. But they [were] also responsible for getting this well and getting it to shut off with oversight by the Coast Guard and other

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[149] Ramseur, *Deepwater Horizon Oil Spill*, 22.

[150] Ramseur, *Deepwater Horizon Oil Spill*, 23; Oil Pollution Act, 33 U.S.C. §§ 2701 et seq. (1990).

[151] Ramseur, *Deepwater Horizon Oil Spill*, 23.

[152] David Bearden and Jonathan Ramseur, *Oil and Chemical Spills: Federal Emergency Response Framework*, CRS Report No. R43251 (Washington, DC: Congressional Research Service, 2017), 11, https://sgp.fas.org/crs/homesec/R43251.pdf.

[153] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*.

federal agencies."[154] Also, BP was unwilling to reach out to partner companies in the oil industry or collaborate with federally developed teams of engineers and scientists.[155] National teams, such as those from the National Laboratories, were also reluctant to share information with private companies, fearing there was a possible ethical dilemma in having the government solve problems for private companies.[156] Throughout the response, as the situation intensified, there were changes made to adopt outside-the-box thinking, thereby decreasing the fears of ethical violations and increasing information sharing across the entire response.

The success of stopping the oil spill ultimately relied on groups of individuals across the entire response structure developing novel solutions and providing information to decision-makers to adopt these practices. Early in the response, academic, government, and private company teams were established to tackle challenging problems working at such depths. These teams included groups such as Flow Rate Technical Group, the Oil Budget Calculator Science and Engineering Team (Oil Budget Team), the Government-Led Science Team, the Operational Science Advisory Team, and the Joint Analysis Group.[157] The government-led teams, working in cooperation with academia and BP engineers and scientists, sought outside-the-box ideas to develop tools and procedures to provide not only situational awareness but also solutions to stop the flow of oil.[158] The outcomes of Deepwater produced new technologies, such as reservoir modeling and echo sounder flow detection, along with new uses of existing technology, such as estimating the flow rate from atmospheric measurements.[159] Ultimately, through friction and confusion, it can be surmised that the cross-domain approach of government, private industry, and

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[154] "State of the Union: Interview with Secretaries Salazar, Napolitano; Interview with Coast Guard Commandant Thad Allen; Interview with Senatorial Candidate Marco Rubio," CNN, May 2, 2010, https://transcripts.cnn.com/show/sotu/date/2010-05-02/segment/01.

[155] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*, 162.

[156] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 149.

[157] Lubchenco et al., "Science in Support of the Deepwater Horizon Response," 20213.

[158] McNutt et al., "Quantify and Control the Deepwater Horizon Oil Spill," 20222.

[159] Lubchenco et al., "Science in Support of the Deepwater Horizon Response," 20217.

academia led to breakthroughs and successes, allowing the flow of oil to stop and the clean-up of the Deepwater Horizon spill to begin.

3. Information Sharing throughout the Incident

Information sharing throughout the Deepwater Horizon disaster was difficult due to the geographic expanse of the incident and the complex needs of each team to communicate quickly and efficiently. Communications during the incident were problematic from the onset, through the immediate response to the search-and-rescue operation of the Coast Guard and the firefighting efforts of the contractors on the scene.[160] The mechanical communications of marine band radios were complicated by confusion regarding priorities at the incident site. The Coast Guard focused on the search-and-rescue mission, believing it was the primary issue, and the contractors focused on firefighting; meanwhile, BP remained relatively quiet about the oil spill.[161] Problems with radio communications were brought up numerous times throughout the incident beyond the initial response, including difficulties with private vessels communicating with federal vessels and contractors during the clean-up phase of the incident.[162] Communications across the broad expanse of the response area were complex; such complexity was even more prevalent throughout the incident command structure developed by federal policy, spanning the entire Gulf of Mexico.

Communication across the command structure required coordination of accurate information across public, private, and academic bodies in near real-time.[163] The response structure required the federal OSC to decide on tactical responses to various issues, such as initializing the blow-off preventor or utilizing the cofferdam; all decisions were left to the OSC.[164] The Deepwater Horizon was the first oil spill in U.S. history to receive the

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[160] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*, 130.

[161] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 131.

[162] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 143.

[163] Lubchenco et al., “Science in Support of the Deepwater Horizon Response,” 20217.

[164] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*, 135.

spill of national significance (SONS) declaration, which further complicated information sharing because it was the first such procedure overseen by the first national incident commander (NIC), who assumed responsibility for decision-making from the OSC.[165] Communication across the multiple command posts, research bodies, and the national incident command team was difficult, and daily conference calls were often chaotic, resulting in little information sharing.[166] Those in the science community often could not rely on the information from daily conference calls; instead, they relied on news releases to learn what other teams were accomplishing.[167] The NIC needed accurate science-based ideas to make effective decisions and implement appropriate strategies quickly, especially as the event drew on and thousands of barrels of oil poured out daily.

The science community developed processes to share information throughout the event. Initially, the scientific response to the event was disjointed and resulted in a lack of communication among the teams working to cap the well and stop the oil flow.[168] The National Oceanic and Atmospheric Agency and the University of New Hampshire developed a tool to overcome challenges in communications and information by creating a tool called the Environmental Response Management Application (ERMA). ERMA relied on open-source mapping tools to share real-time information among the science teams working to solve the problems associated with the Deepwater Horizon.[169] For the first time, ERMA provided a space where teams could exchange data in the lab or the field, creating common areas for private, government, and academic scientists to share and collaborate.[170] Tools such as ERMA changed the trajectory of response for the national

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[165] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 126.

[166] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 160.

[167] Lubchenco et al., "Science in Support of the Deepwater Horizon Response," 20214.

[168] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*, 149.

[169] Michele Jacobi et al., "Environmental Response Management Application (ERMA)—Web-Based GIS Data Display and Management System for Oil Spill Planning and Environmental Response" (presentation, Coastal Response Research Center, Myrtle Beach, SC, March 5, 2009), https://scholars.unh.edu/ccom/506.

[170] Lubchenco et al., "Science in Support of the Deepwater Horizon Response."

incident response team and allowed information to flow better across agencies that were spread across a wide geographic area.

4. Impact of Leadership Structures on the Response

The federal response structure for the Deepwater Horizon event followed U.S. statutes and included the first-ever establishment of a SONS. The NCP outlines the response framework for oil spills, establishing a tiered response system of local, regional, and national responses similar to the National Response Framework developed in Homeland Security Presidential Directive 5.[171] The federal OSC has the ultimate authority over the response and the final decision-making authority in response and clean-up efforts.[172] The incident grew in size and complexity over the ensuing days, eventually being declared the first SONS and requiring the first-ever NIC, Coast Guard Admiral Thad Allen.[173] The top-down leadership approach mirrors structures such as the incident command structure, whereby supervisors are identified and communication pathways visualized on wireframe organizational charts.

The top-down framework established early in the incident created leadership confusion and impeded progress on the incident rather than work as intended. Initially, BP unified in a command role with the Coast Guard because it was the responsible party for the event.[174] Three command posts were established, one of which was set up at BP headquarters in Houston, Texas.[175] As the response continued, however, lines of authority blurred—individuals in private industry were found supervising government employees, entities had been left off organizational charts, and reporting lines were confused across

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[171] Ramseur, *Deepwater Horizon Oil Spill*, 22–23.

[172] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, "Decision-Making within the Unified Command," Staff Working Paper No. 2 (Washington, DC: National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011), 4, https://permanent.fdlp.gov/gpo19655/Updated%20Unified%20Command%20Working%20Paper.pdf.

[173] Bearden and Ramseur, *Oil and Chemical Spills*, 12.

[174] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*, 131.

[175] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 132.

the three command posts.[176] Additionally, since the NIC role had never been deployed before, there was confusion about his level of authority and responsibility in making decisions.[177] Given the size and scale of the incident structure developed to respond to the Deepwater Horizon, many activities occurred outside the command structure. Many perceived the response framework as an oversight body rather than a decision-making body.[178] The rigidity of the response framework affected not only those working directly at the tactical level of operations in the field but also the science teams in place to solve some of the most challenging problems throughout the response.

Decision-makers at the Deepwater Horizon oil spill needed scientifically valid information on all suggested solutions to stop the flow of oil and protect the Gulf's ecosystem. Many of the scientific teams established to solve fundamental problems on the Deepwater Horizon incident were not explicitly identified in the response framework and thus had no reporting lines to communicate with decision-makers.[179] Within the response framework, for example, both the Department of Energy and the Department of Health and Human Services had no pre-identified roles in the response—roles that decision-makers soon found to be very important.[180] Ultimately, however, the interdisciplinary science teams provided the critical information to decision-makers to end the spill and provide for proper clean-up measures in the Gulf area.[181]

C. COPIAPÓ MINING ACCIDENT

The events of August 5, 2010, put the country of Chile on the front page of newspapers around the world, as word spread quickly of an unimaginable disaster within a copper mine near the city of Copiapó in the northern Chilean desert. Around 2:00 p.m. local time, a 700,000-ton boulder fell from the mine ceiling, completely blocking the access

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[176] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 134.

[177] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, "Decision-Making within the Unified Command," 3.

[178] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 9.

[179] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 9.

[180] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 10.

[181] McNutt et al., "Quantify and Control the Deepwater Horizon Oil Spill," 20223.

road and trapping 33 miners deep within the mine.[182] The trapped miners were subjected to an intense wave of pressure, dust, and wind as the mine closed in around them.[183] The miners immediately sought to free themselves by backtracking up the road system, only to find it blocked; in trying to use escape ladders in the ventilation shafts, they saw that these, too, were blocked by debris or lacked the required ladders. The 33 sought shelter in a break room area with meager food supplies and limited freshwater. They would be stranded for the next 69 days while an international team of experts sought ways to accomplish the deepest rescue of miners ever attempted.

Copper is one of the most essential elements of modern society. Copper is everywhere and is foundational in many industries, including clean energy, electricity transmission, and even urban development. Chile produces 28 percent of the world's copper reserves and is the largest producer of copper.[184] The copper industry in Chile employs 6 percent of the population, and Chilean miners are some of the highest-paid mining employees in South America.[185] The copper mine located at Mina San Jose has been in operation since 1889 and is considered small compared to other Chilean mines. San Esteban Mining Company operates the mine, and annual sales out of the mine are nearly $20 million.[186] The company has a record of poor compliance with safety regulations and has had many injuries in their mines, even several deaths.[187]

The initial response to the Mina San Jose collapse consisted of miners who had previously escaped the mine.[188] Once the miners realized the road was impassible, they

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[182] Marc Aronson, *Trapped: How the World Rescued 33 Miners from 2,000 Feet below the Chilean Desert* (New York: Atheneum Books, 2011), 3.

[183] Jonathan Franklin, *33 Men: Inside the Miraculous Survival and Dramatic Rescue of the Chilean Miners* (New York: Penguin, 2011).

[184] "Chile," Nations Encyclopedia, accessed April 18, 2021, https://www.nationsencyclopedia.com/economies/Americas/Chile.html.

[185] Nations Encyclopedia.

[186] "Derrumbe en la mina San José" [Collapse in the San José mine], Deportespe, accessed April 18, 2021, https://www.webcitation.org/6EpRA924k?url=http://deportespe.terra.com.pe/shared/pop/noticias/mina-san-jose/mina_san_jose.html.

[187] Pascale Bonnefoy, "Poor Safety Standards Led to Chilean Mine Disaster," The World from PRX, August 29, 2010, https://theworld.org/stories/2010-08-28/poor-safety-standards-led-chilean-mine-disaster.

[188] Aronson, *Trapped*, 21.

sought help from a highly specialized police rescue team known as the *Groupo de Operaciones Policiales Especiales* (Special Police Operations Group; GOPE). GOPE is dedicated to all manner of special tactical operations, including anti-terrorism, search and rescue, and technical procedures, such as scuba and high-angle rope operations.[189] GOPE officers searched the mine for access to the trapped miners for hours after they arrived on scene by traversing roads, walking mine shafts, and traveling ventilation shafts looking for ladders down to the miners. Despite their efforts, they could not locate a viable way to the miners, finding the ventilation shafts lacking the federally required ladders.[190] Mining officials on site and initial responders realized the situation was beyond their capacity and reached out to the government for assistance in leading the rescue operation.

Chilean President Sebastián Piñera was elected in 2010, following a poorly led government response to a significant earthquake and tsunami in February 2010 by his predecessor. He quickly assumed control of the rescue operation at Mina San Jose. He declared that the government would be responsible for the overall rescue of the miners because the San Esteban Mining Company could not take on such a task alone.[191] President Piñera assigned Laurence Golborne, the minister of mining, to the task and set out to find a mining expert to lead the overall operation. André Sougarret, a mining engineer from state-owned mining company Codelco, was selected to lead the search for any survivors and remove them from the refuge area, nearly 2,300 vertical feet from the top of the mine.[192] Initial evaluations of the mine and the task ahead identified that more help would be needed, and an international call went out to the mining industry to help retrieve the 33 buried in the earth.[193]

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[189] "Comandos en Operaciones Especiales y Antiterrorismo de La Policía Nacional—COPES" [Commandos in Special Operations and Antiterrorism of the National Police], Colombian National Police, December 30, 2015, https://www.policia.gov.co/especializados/copes.

[190] Franklin, *33 Men*, 44.

[191] Franklin, 44.

[192] Franklin, 76.

[193] Don Cohen, "Applied Knowledge: NASA Aids the Chilean Rescue Effort," *ASK Magazine*, January 31, 2011, 8.

Initially, nine drills were brought to the site from around the country and worldwide. The shifting soil, complex geology of the hillside, and antiquated maps from the mining company all complicated drilling as teams sought to drill into areas where miners were believed to have survived. Kelvin Brown, a mining expert from Australia, brought a drill and a precision measuring system known as reflex technology, which assisted local miners in precision targeting the first initial borehole to reach the trapped miners on day 17 of the rescue effort.[194] Brown quickly established himself as a leader at the drill site and frequently worked among the drills to ensure coordination and cooperation. Government officials, families, and miners all rejoiced when the drill bit emerged from the earth with a note saying that all 33 were alive and in a safe area.[195] Once the miners had been found, two questions emerged: How would the miners get out, and how would the rescuers keep them alive for however long that might take?

While plans were being developed to remove the miners, a team of psychologists and submarine officers developed strategies to keep the men in the mine alive and in good spirits. By the end of the rescue, the life support team grew to over 300 personnel, including dietitians, psychologists, physicians, and engineers from the U.S. National Aeronautics and Space Administration (NASA).[196] A local professor from the Universidad del Mar in Copiapó, Miguel Fortt, developed a system called *Palomas* (doves) to carry goods down to the men through 10-inch-long cylinders sent up and down one of the three bored holes to the rescue area.[197] NASA provided information collected from space missions about human behavior in extreme conditions such as confined spaces and situations under extreme stress.[198] Renato Navarro, a commander from the Chilean submarine force, also contributed to the life support of the men isolated from their families through his

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[194] Lloyd Jones, "Aussie Driller Helping Chile Mine Rescue," *Sydney Morning Herald*, August 24, 2010, https://www.smh.com.au/national/aussie-driller-helping-chile-mine-rescue-20100824-13ity.html.

[195] Aronson, *Trapped*, 46.

[196] Franklin, *33 Men*, 157.

[197] Franklin, 33 Men, 85; Aronson, *Trapped*, 78.

[198] Franklin, *33 Men*, 155.

experience as a submarine officer.[199] The group of specialists would have to focus on the physical and mental well-being of the men and the intergroup dynamics both in the mine and through interactions with those above it. While the men below were being cared for, a complex plan was developed to remove them from deep within the mine.

The road into the mine was too unstable to use as an escape route, and any attempt to clear the debris increased the likelihood of further collapse. Therefore, three drilling plans were developed to rescue the men: A, B, and C.[200] Plan A was nicknamed the turtle and used a Canadian-operated Strata 950 drill to bore out an escape shaft. Plan B involved a Schramm T130XD air core drill used to widen one of the boreholes for the Palomas. Finally, plan C used a Canadian RIG-421, a drill for oil.

Plan A was a two-phase drilling process whereby a pilot hole would be drilled to the men in the rescue chamber. A raised boring machine would then be used to bore out a wider hole, following the path of the pilot hole.[201] While the Strata could drill in a straight line and bore a hole wide enough to send down a rescue capsule, the drawback was its drilling speed and drilling process—the Strata bored from the bottom of the pilot hole back up to the surface. Canadian engineers developed a solution to help overcome the bottom-up complications while the pilot hole began boring. There were only six Strata 950 boring machines in the world, and in a positive turn of events for the Chilean authorities, one was in the country and could be moved to the site. The best estimated completion for the Strata hole was three to four months, thus the turtle plan nickname.[202]

A small mining firm from Pennsylvania proposed its solution for the Chilean authorities. After several conversations, the Center Rock company, in cooperation with the United Parcel Service, moved seven heavy drills halfway around the world. The drill used for plan B was a percussion-hammer water-well drill, quickly nicknamed the rabbit.[203]

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[199] Franklin, 157.

[200] "Another Look at Plan B—The Effort That Rescued 33 Chilean Miners," *Engineering and Mining Journal* 211, no. 9 (November 2010): 62.

[201] Marcia A. Lusted, *Chilean Miners' Rescue* (Edina, MN: ABDO Publishing, 2011), 48.

[202] Aronson, *Trapped*.

[203] Aronson, 97.

Plan B was built on speed and required a drilling crew to take over one of the three Palomas. The biggest concern with the Schramm was whether a drill designed to operate in a vertical position could follow the Paloma at an angle to reach the miners.[204] The Center Rock crew arrived on September 4, nearly a month after the miners had been trapped in the collapse. An international team came from around the world to assist in the operation of the drill.

Plan C took a completely different path, enlisting a mammoth Rig-421, traditionally used to drill for oil. Given the size of the drill and the number of trucks used to deliver it, the team named Plan C "the transformer."[205] The transformer was the largest drill on the site and could bore a single hole big enough to transport all the men out of the mine at one time. The last drill to start digging, the transformer began drilling on September 19. The greatest struggle with the largest drill was aiming for a tiny target deep within the earth.

While drilling continued day and night at the mine, a key piece of equipment needed to be engineered and built. A specialized basket needed to be made to fit the narrow hole being drilled while carrying a man and essential life support systems. A diverse group of engineers, including academics, government engineers from Chile, and NASA engineers, developed such a system and named the device Phoenix.[206] The Chilean navy manufactured the device; it weighed 900 pounds and housed six and a half feet of interior standing room.[207] It was painted the colors of the Chilean national flag and delivered to the drill site on September 25, 2010.[208]

The Center Rock team reached the miners on October 9, 2010, after drilling 2,040 feet into the mine. This astonishing feat opened the door for the miners' rescue and marked nearly 10 weeks from the time they were trapped in the mine. It was time to lift the men from the mine to a sea of loved ones and an international audience anxious to watch their

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[204] Aronson, 76.

[205] Aronson, 84.

[206] Cohen, "NASA Aids the Chilean Rescue Effort."

[207] Franklin, *33 Men*, 197.

[208] Aronson, *Trapped*, 96.

rescue broadcast live on thousands of news channels. On October 13, after 69 days underground, the men finally emerged from the earth, all alive and in good spirits.

1. Sensemaking and Situational Awareness

Sensemaking at the Chilean mining collapse comprised two phases. The first phase of situational awareness sought to determine the status of the miners. The second phase monitored the miners after they had been found and tracked the progress of the rescue efforts. These phases required technology and interactions among various groups rarely encountered in the history of copper mining or mining collapse rescues.

The first critical piece of situational awareness in the Chilean mining disaster was determining whether the miners were still alive after the collapse. For the first 17 days of the event, mine bosses, government leaders, and family members did not know the status of the trapped miners.[209] Leaders planned three boreholes to determine how many miners were alive and what their health status was.[210] Absent these boreholes, there was no way of determining the status of each miner, and without this knowledge, the rescue mission would not be necessary. This first key piece of data formed the basis for decisions moving forward.

A critical roadblock in gathering information was the mining company, San Esteban Mining. San Esteban did not have a good working relationship with the government before the collapse and had a long history of safety violations.[211] The mining company initially failed to release news of the collapse. It would not notify family members and went as far as prohibiting mine employees from using company phone lines to contact outside agencies after the collapse.[212] Throughout the rescue effort, the company stood by, refusing to accept responsibility for issues at the mine and blaming safety shortcuts and the lack of required equipment on the mine employees.[213] The failure of the mining company

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[209] "Another Look at Plan B."

[210] Aronson, *Trapped*.

[211] Bonnefoy, "Poor Safety Standards Led to Chilean Mine Disaster."

[212] Franklin, *33 Men*, 30.

[213] Franklin, 141.

to help with the rescue delayed early efforts to access the mine and mine employees, potentially extending the first phase of the rescue—determining whether the miners were still alive.

Situational awareness split into two different processes after the miners were found alive: life support and rescue efforts. One of the priorities of the life support staff was to determine the miners' health. A phone and video system was strung down one of the boreholes, and miners could discuss physical and mental health issues with physicians at the top of the mine.[214] Each miner was also equipped with a personal health monitor, which conveyed health measurements such as blood pressure and heart rate directly to physicians.[215] With the physical and mental health tracking of the miners, the physicians and health care providers could adjust strategies to ensure the proper level of life support activities were in place while the arduous task of extrication was planned and executed.

Monitoring the progress of the drilling operation required overcoming technical challenges no single person or group had attempted before 2010.[216] Drilling through the rock and guiding drill bits required precision equipment to move through the layers of rock. With each foot of the drilling, the potential for moving off course was ever-present. Miners relied on lessons learned from each drill site in a shared forum to change and adapt in short-burst learning cycles, a process not usually accomplished in mining operations.[217] Implementing other technologies such as 3D spatial modeling and seismic monitoring also helped develop a complete operating picture while the boreholes and the rescue holes were drilled.[218] The physical feat of finding the miners, let alone rescuing them from their depths, was given only a 2 percent chance of success, yet with constant monitoring and communication throughout the response, this impressive objective was realized.

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[214] Franklin, 126.

[215] Franklin, 4.

[216] "Another Look at Plan B," 64.

[217] Amy C. Edmondson, "How 'Teaming' Saved 33 Lives in the Chilean Mining Disaster," Harvard Business School, January 29, 2018, http://hbswk.hbs.edu/item/how-teaming-saved-33-lives-in-the-chilean-mining-disaster.

[218] "Teamwork and the Chilean Mine Rescue," Sheila Margolis Workplace Culture Institute, accessed August 15, 2022, https://sheilamargolis.com/2010/10/teamwork-and-the-chilean-mine-rescue/.

2. Team Formation and Dynamics

The success of the Chilean rescue effort was the result of an international team of cross-disciplinary experts who worked cohesively to achieve extraordinary results. President Piñera, once on scene at the mine, realized the situation's complexity and recognized the response would be outside the capability of on-scene resources. He sought out experts from around the world, and the effort accomplished an astounding achievement, saving 33 lives from 2,000 feet below the mine's opening.

The government sent out an international call for assistance from anyone who could help within four days of the collapse. President Piñera and Minister Golborne realized early on that their lack of technical expertise would not help the rescue effort; however, their management skills could guide the rescue efforts from an executive standing.[219] Minster Golborne set out to build a team to address the vast array of complicated issues facing the rescue efforts; he first assigned the technical oversight of mining to an expert, André Sougarret.[220] Sougarret, in turn, recruited the first interdisciplinary team as he gathered 32 Codelco staff of various backgrounds and specialties and brought them to the mine site.[221] Eventually, teams from around the world descended on the mine site, contributing in areas such as psychology, nutrition, drilling, claustrophobia, and seismic monitoring.

After the miners were found alive, the mine site was divided into three teams to balance the workload, each focused on a different component of the rescue. The three teams focused on drilling holes to rescue the men, keeping the men alive and well in the refuge area, and determining how to get the men out of the rescue holes.[222] The first team focused on drilling to the miners and getting a big enough hole bored out to allow the men to escape. With Plans A, B, and C in place, each subgroup worked on its respective drill plan, coordinating to share information and learn from the successes and failures of each other. The second team focused on life support and the mental health aspects of living in the

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[219] Ahmed El Hussiny, "2010 Chilean Mining Rescue Team Development" (self-published, 2014), 5.

[220] Franklin, *33 Men*, 72.

[221] Faaiza Rashid, Amy C. Edmondson, and Herman B. Leonard, "Leadership Lessons from the Chilean Mine Rescue," *Harvard Business Review*, July 2013, 115.

[222] Edmondson, "'Teaming' Saved 33 Lives in the Chilean Mining Disaster."

refuge area. Subgroups from NASA and the Chilean submarine force contributed to the unique issues accompanying individuals in such extreme settings.[223] Finally, the rescue capsule team had to coordinate with drillers, academics, and other engineers to develop a solution to get the men out of the refuge area and up the 45-minute ride through a chute not much wider than their shoulders.[224]

The size of the teams resulted from the leadership at the mine and the commitment of government officials to ensure every effort was made for a successful outcome. President Piñera and Minister Golborne constantly reminded the teams of the risks involved with the rescue and the government's commitment.[225] Along with this focused leadership came a consistent theme of redundancy and multiple options from all levels of leadership.[226] The leadership team of President Piñera, Minister Golborne, and Sougarret was flexible in its approaches to the problems presented at the mining site and sought out information from all available sources.[227] Rather than being the final decision-makers, they were willing to let options develop at all response levels and encouraged outside-the-box thinking to solve complicated problems.[228] Incorporating diverse teams and enabling distributive decision-making undoubtedly led to the operation's success and the procedure's relative speed, thus saving the 33 miners ahead of schedule.

3. Information Sharing throughout the Incident

Open communication throughout the entire response to the Chilean mining incident led to increased efficiencies and positive outcomes for each phase of the response. Miners and engineers at the site found an atmosphere of collaboration and a free-flowing space where successes and failures resulted in a community of shared knowledge. This free flow

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[223] Cohen, "NASA Aids the Chilean Rescue Effort."

[224] Franklin, *33 Men*, 198.

[225] Michael Useem, "The Chilean Miner Rescue: A Lesson in Global Teamwork," Wharton School, University of Pennsylvania, March 27, 2012, https://knowledge.wharton.upenn.edu/article/the-chilean-miner-rescue-a-lesson-in-global-teamwork/.

[226] Franklin, *33 Men*, 46.

[227] Michael Useem, Rodrigo Jordan, and Matko Koljatic, "How to Lead during a Crisis: Lessons from the Rescue of the Chilean Miners," *MIT Sloan Management Review* 53, no. 1 (Fall 2011): 52.

[228] Rashid, Edmondson, and Leonard, "Leadership Lessons from the Chilean Mine Rescue," 114.

of information, along with honest and realistic expectations, led to an environment that supported the rescue efforts and led to the operation's success.

The sharing of technical information assisted each mining company working at the mine site. Both formal and informal channels designed into the response facilitated sharing successes, failures, and lessons learned.[229] The technical leaders for each team held regular meetings with leaders of other teams in a strict meeting cycle; the same strict meeting schedules were also held with media groups and families. These meetings promoted information sharing but were tightly controlled.[230] Informal channels, such as dining areas where miners congregated during downtimes, were also a source of shared information.[231] The shared knowledge and the free flow of collaboration were unique at the mine site, with so many teams working closely together.[232] The open design of the organizational structure encouraged discussion at all levels. It did not silo individuals; instead, it encouraged collaboration and amplified all voices at the drill site.

The physical layout of the drill site was designed to encourage professional dialogue and collaboration among the teams. The security team at the drill site built a restricted access perimeter around the drilling and support areas where media, families, and bystanders could not enter.[233] This physical boundary allowed a particular place where team members could speak freely, without the risk of failure, shaming, or accidental release of information to outside entities, such as news crews. Teams found the physical connection of working on site to be beneficial to the overall effort. For example, once the NASA engineers returned to the United States, they found that not being in Chile prevented them from staying current with the operations and sought to return to the desert site.[234] In addition to building a common operational understanding with physical proximity, being co-located as a team helped break down language barriers that existed with the multi-

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[229] Edmondson, "'Teaming' Saved 33 Lives in the Chilean Mining Disaster."

[230] Rashid, Edmondson, and Leonard, "Leadership Lessons from the Chilean Mine Rescue," 118.

[231] Franklin, *33 Men*, 87.

[232] Useem, "The Chilean Miner Rescue."

[233] Rashid, Edmondson, and Leonard, "Leadership Lessons from the Chilean Mine Rescue," 117.

[234] Cohen, "NASA Aids the Chilean Rescue Effort," 7.

national team.[235] Whether it was solving complex drilling alignment issues or creating inventive ways to transmit information to the miners, the proximity of team members helped with information sharing and contributed to overall incident success.

Leaders were open and honest with communication across all levels of the organization. Officials were straightforward and honest with all those involved from the first day of oversight at the mine; there was no sense of false hope due to inflated communications.[236] Families were presented with realistic information and the potential that rescue operations might not work. Chilean officials did not hold back when speaking to the media either; they were factual and spared no details as they outlined rescue efforts.[237] Sharing information in such a manner put no undue stress on the teams designing solutions for each of the complexities on the drill site. Failure, while not desirable, was accepted as a learning tool and subsequently shared across the teams as learning points.[238] From the onset, President Piñera was open and honest with the teams, the media, and the families about the odds of success in the endeavor to save the 33 miners. In the end, this openness allowed the free flow of information from all team members that contributed to the success of the operation.

4. Impact of Leadership Structures on the Response

The leadership approach at the Chilean mining incident utilized a distributive model, which encouraged free-flowing information and fast, iterative cycles of innovation adoption. Leaders were not bound to operate in a top-down hierarchical structure but instead opted to have teams work through problems cooperatively. The upper echelon of government leadership set the tone. It provided a model of open and transparent communication, sharing facts and presenting an authentic message to the teams, family members, the country of Chile, and the international community watching.

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[235] Cohen, 8.

[236] Franklin, *33 Men*, 74.

[237] Useem, “The Chilean Miner Rescue.”

[238] Edmondson, “‘Teaming’ Saved 33 Lives in the Chilean Mining Disaster.”

The Chilean government adopted a strategy of distributive leadership for the response to the mining collapse. President Piñera and Minister Golborne both had backgrounds in executive leadership, not in the mining industry.[239] André Sougarret, therefore, was given much leeway in the approach to decision-making and working with the many technical experts working on several plans concurrently. Rather than adopting a top-down autocratic system, the leadership team relied on open collaboration whereby decisions were routed to Sougarret for review rather than approval and denial.[240] This approach empowered innovation and allowed for ideas to develop at all levels of the organizational structure.[241] Sougarret, in his role as a leader, could help orchestrate the response rather than get impeded with tactical-level decisions.

The distributive decision-making approach allowed for faster incident resolution by encouraging innovation and alternative strategies. Throughout the entire response, President Piñera was focused on a plan that provided multiple options to achieve positive outcomes.[242] The leaders needed to enable innovation and encourage free-flowing information to work on various strategies simultaneously. The data from successes and failures had to be shared throughout the mine site and then adopted into other strategies to work effectively.[243] Innovative ideas were encouraged at the drill site, especially those that could be implemented rapidly, such as the Paloma delivery system or the use of alternative technologies when teeth from a drill bit became embedded in metal support structures of the mine.[244] Sougarret pushed the drilling teams hard to achieve success in a short time and, in the process, overcame tremendous obstacles. Working in collaboration with the technical experts, the government led the overall effort by keeping the teams focused on the primary goal and relying on an open communication strategy internally and externally.

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[239] Useem, Jordan, and Koljatic, "How to Lead during a Crisis," 51.

[240] Useem, Jordan, and Koljatic, "How to Lead during a Crisis," 53; Irving Wladawsky-Berger, "Lessons from the Rescue of the Chilean Miners," *Irving Wladawsky-Berger* (blog), October 25, 2010, https://blog.irvingwb.com/blog/2010/10/lessons-from-the-rescue-of-the-chilean-miners.html.

[241] Rashid, Edmondson, and Leonard, "Leadership Lessons from the Chilean Mine Rescue," 118.

[242] Franklin, *33 Men*, 46.

[243] Rashid, Edmondson, and Leonard, "Leadership Lessons from the Chilean Mine Rescue," 118.

[244] Franklin, *33 Men*, 85, 170.

In February 2010, just before President Piñera took office, a catastrophic earthquake and tsunami struck the country of Chile, resulting in the deaths of approximately 500 people and affecting the lives of three million others.[245] The earthquake response was a priority for the newly installed president, who took office in March.[246] Government officials knew from the onset that open communication would ensure they maintained the support of the country. The mining incident provided another opportunity for the president and his cabinet to lead through a disaster. Piñera, along with Minister Golborne, selected a course of action that relied on the expertise of mining professionals while maintaining a sense of realism with the families and the international community.[247] The president and the cabinet took responsibility for the rescue from the onset. They continued to maintain a presence throughout the plan iterations, ensuring an open dialogue and honest information.

D. CONCLUSION

Through examining two case studies, this chapter presented the impact of cross-disciplinary coordination and the importance of situational awareness in complex decision-making. The utilization of cross-disciplinary expertise leads to increased creativity in selecting strategies and tactics in unfamiliar and complex situations. The effectiveness of cross-disciplinary teams is enhanced when good communication occurs across the entire response force. Shared situational awareness is enhanced with a deliberate approach to ensuring good communication, allowing for collaboration at all levels of the response framework.

The Deepwater Horizon oil spill was the largest oil spill in recorded history and the first SONS. The incident scale and pre-formatted response framework under U.S. statutes prevented situational awareness even though the National Incident Management System and other doctrines clearly emphasize its importance. Information sharing and oversight

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[245] *Encyclopedia Britannica*, s.v. “Chile Earthquake of 2010,” accessed February 28, 2022, https://www.britannica.com/event/Chile-earthquake-of-2010.

[246] Franklin, *33 Men*, 43.

[247] Useem, Jordan, and Koljatic, “How to Lead during a Crisis,” 53.

often ran into complications as federal partners and private industry were bound by political and legal factors. Ultimately, the inclusion of outside private agencies and academic workgroups helped to develop novel solutions, and the well was capped months after the situation began. The research suggests that the number of technical attempts by scientific and government teams was appropriate, but the structure of the organization hampered the response because it allowed for conflicts across domains and siloed communications pathways. The case demonstrates that situational awareness and coordination over vast physical space require deliberate strategies, mainly when organizations' structural issues cause conflicts.

The Copiapó mining case presented a different approach to problem-solving, using variations of the strategies demonstrated at the Deepwater Horizon. The international response involved a variety of disciplines, just as the Deepwater Horizon spill utilized a broad scope of disciplines. Copiapó had the benefit of proximity to other drill teams, which facilitated the decision-makers' sharing successes and failures in common areas throughout the camp. The absence of political and private silos allowed for the free sharing of data and other pertinent information. Leaders at the Copiapó mine utilized a distributive leadership model, which also helped each team operate autonomously, allowing for the trial and error of new strategies that were shared with other teams.

The additional variable in each case affecting the response was the amount of time each team had to develop options throughout the incident. The Deepwater Horizon was a spill that lasted nearly five months before being brought under control. The Copiapó mining accident, on the other hand, lasted 69 days. While the factor of duration has not been considered in this thesis, it undoubtedly had an impact on each of the strategies selected for the respective cases. Indeed, time stress increases the pressure on decision-makers and can affect the selected outcomes.

Both cases present valuable lessons in decision-making under complex situations. When decision-makers are unfamiliar with present conditions, they must reach out to other industries and disciplines to make sense of the situation and develop novel solutions. This process must be implemented quickly to limit the potential spread of the incident and minimize the potential for loss of life or continued damage to the environment.

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V. EVOLVING THE MODE OF DECISION-MAKING DURING COMPLEX FIRE EVENTS

Naturalistic decision-making was prevalent at both 9/11 and Mann Gulch; however, it proved to distract responders when they were presented with outside-the-box solutions, such as escape fires and building evacuations. Collaboration with outside agencies was not part of the FDNY's response to the collapse of the twin towers and, by its own admission, could have provided additional information to assist in decision-making. Collaboration with outside groups was a key part of the responses to both the Chilean mining accident and the Deepwater Horizon oil spill. Each of these events demonstrates the power of interdisciplinary teams while highlighting how structural and communication pathways can both empower and inhibit the response. Table 3 details the key findings of these four case studies.

Table 3. Key Findings

	Known or familiar situations	Unfamiliar situations
Decision-making process	Naturalistic decision-making through a reliance on previous experience	Expanded interdisciplinary team to rely on cross-disciplinary knowledge, creatively searching for alternative solutions
Sensemaking and information sharing	Situational awareness collected at the tactical level	Open discussion of ongoing incident status throughout entire response framework; leadership to encourage trial-and-error strategies and innovation
Response framework selection	Reliance on previously developed frameworks (Incident Command System)	Expanded response frameworks inclusive of outside agencies and nontraditional emergency responders
Intergroup communication	Reliance on traditional pathways of communication through command-and-control frameworks	Open pathways for communication and free sharing of success and failures; co-located teams to encourage group communication

Naturalistic decision-making may benefit the emergency responder when time is a considerable factor and a decision needs to be made quickly. Intuition relies on fast processing and the quick development of solutions applied to the situation.[248] RPD allows the decision-maker to rely on the first best option rather than relying on several options and determining the most likely to result in positive outcomes.[249] The use of naturalistic decision-making in extreme situations allows responders to rely on learned and situational expertise—the more experienced the decision-makers, the quicker they apply the solutions.[250] The lighting of the escape fire at Mann Gulch represents an application of RPD, where time was critical and the decision seemingly appeared from Dodge's memory. Thus, there are times when RPD can contribute to a successful outcome, particularly when time constraint is a driving variable and the factors involved are familiar to the responder.

Naturalistic decision-making, however, can create cognitive entrenchment. Individuals who build a career's worth of experience and domain schemas are susceptible to cognitive entrenchment due to a hyper-focus on their domain-specific information.[251] Cognitive entrenchment can limit the decision-makers' ability to identify solutions to problems due to inflexibility within their domain.[252] As experts in emergency fields gain experience in response to situations, it is possible that their expertise may inhibit their creativity to address new situations or decrease the likelihood of their accepting a nontraditional solution. When Wag Dodge stood in the ashes of his safety zone and yelled for the crew to join him, the smokejumpers did not heed his call, opting rather to commit to their own selected option, and they ran away from safety. Leaders need to understand the potential for cognitive entrenchment and the potential impact it can have on naturalistic decision-making and the acceptance of outside-the-box solutions.

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[248] Justin Okoli and John Watt, "Crisis Decision-Making: The Overlap between Intuitive and Analytical Strategies," *Management Decision* 56, no. 5 (2018): 1124, https://doi.org/10.1108/MD-04-2017-0333.

[249] Klein, *Sources of Power*, 23.

[250] Ericsson, Hoffman, and Zozbelt, *Cambridge Handbook of Expertise and Expert Performance*, 406.

[251] Dane, "Trade-Off between Expertise and Flexibility," 579.

[252] Dane, 583.

Furthermore, focusing on known cues, relying on the first selected option, and not accounting for new situational information impact the decision-makers' ability to change strategies and adapt courses of action. The use of RPD by fire and emergency services responders results in the decision-makers' acceptance of the first best option based on past experiences being applied to current conditions.[253] Moreover, the presence of non-anticipated clues, and the absence of expected ones, can affect the decisions made using naturalistic decision-making.[254] Responders to the north tower, for example, immediately noted oddities in the response to a situation that they had deemed was a high-rise building fire, namely that there were burn victims on the first floor, and none of the 90 elevators were working in the expansive building.[255] These clues did not fit the traditional frameworks of a high-rise fire; they indicated that something else was contributing to the problem set. Alerting decision-makers to the additional variables could have contributed to an earlier decision to evacuate the building.

Shifting from tactical- to strategic-level decisions requires a transition from familiar response processes to more dynamic decision-making operations when confronted with complex situations. Relying on intuition and RPD for decision-making at incidents falls into a zero-order capability, an ordinary course of action, or a patterned response.[256] Transitioning away from zero-order capabilities, such as when presented with a complex situation, requires leaders to search for creative alternative solutions and improvisations.[257] Utilizing ad hoc strategies and improvisations relies on the responder's experience as the foundational level of reference, and reliance on these strategies can increase with time pressures such as those found at emergency scenes.[258]

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[253] Klein, "Naturalistic Decision Making," 457.

[254] Klein, *Sources of Power*, 151.

[255] Hanlon, Naudet, and Naudet, *9/11*.

[256] Winter, "Understanding Dynamic Capabilities," 992.

[257] Winter, 992.

[258] Anne S. Miner, Paula Bassoff, and Christine Moorman, "Organizational Improvisation and Learning: A Field Study," *Administrative Science Quarterly* 46, no. 2 (June 2001): 329, https://doi.org/10.2307/2667089.

The research into dynamic capabilities suggests that decision-making at complex incidents is not within the perceived typical framework for fire and emergency service responders. When decision-makers face unfamiliar situations, they need to pivot from normal processes to new modes of decision-making. On 9/11, Chief Pfeifer and other chief officers demonstrated this shift by deciding to move away from standard high-rise firefighting procedures, focusing more on evacuations and moving people out of the dangerous area. Shifting the decision-making away from zero-order operations requires leaders to adopt new strategies, including incorporating cross-disciplinary teams, to achieve overall mission success.

A. THE DECISION-MAKING PROCESS

As decision-making in complex events moves away from tactical-level decisions to strategic ones, leaders need to move toward collaboration by incorporating views outside their domain. Situational awareness is enhanced when additional disciplines are brought in, as each discipline has its own expertise and lens to view the problem. Considering viewpoints from other agencies can lift the information fog and shed light on issues not considered by fire and emergency responders.[259] At 9/11, fire service leaders were not afforded access to law enforcement's situational information, including aerial assessments from helicopters, due to isolated leadership between the two groups with command posts located blocks away and no common communications system.[260] Research suggests that it can be difficult for response groups to share information for situational awareness or changing conditions. Fire and emergency services are limited in capacity and processing when they do not allow other disciplines to join in the decision-making process at complex incidents. As leaders move toward strategic decisions, it is imperative that outside disciplines be allowed to share situational information, thus breaking down silos and encouraging unification of decision-making.

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[259] Giovanni Gavetti and Massimo Warglien, "A Model of Collective Interpretation," *Organization Science* 26, no. 5 (2015): 1278, https://doi.org/10.1287/orsc.2015.0987.

[260] Pfeifer, *Ordinary Heroes*, 210.

- Recommendation 1: Decision-makers should allow cross-disciplinary teams to engage with fire and emergency response leaders when they are presented with unfamiliar situations.

B. SENSEMAKING AND INFORMATION SHARING

The sensemaking process in responses to unfamiliar situations must address the collection and dissemination of information up and down the command structure, ensuring a shared common operating picture with all responders and decision-makers. At its core, sensemaking is about taking information from the environment (cues) and developing a common operating picture from them.[261] Sensemaking needs to support the translation of the information and address the transformation of information from frontline responders and those working remotely from the front lines, often in a virtual presence from command posts or distant locations.[262] Information is not always passed up through the process to decision-makers to effect strategic decisions.[263] This delay can be seen in each of the case studies presented in this thesis but is especially poignant in the response to the Deepwater Horizon oil spill, where delays in communicating spill-related information back to the command post resulted in reduced estimations of oil flow and contributed to the overall response timeframes and severity of the event.[264] A response framework that deliberately breaks down information obstacles and encourages the sharing of data and other important information in real time improves the overall response and ensures a high likelihood of success at the incident. The team structure, thus, is crucial for responding to complex incidents and impacts sharing information and the overall strategic picture.

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[261] Sally Maitlis and Scott Sonenshein, “Sensemaking in Crisis and Change: Inspiration and Insights from Weick (1988),” *Journal of Management Studies* 47, no. 3 (2010): 552, https://doi.org/10.1111/j.1467-6486.2010.00908.x.

[262] Willem Treurniet and Jeroen Wolbers, “Codifying a Crisis: Progressing from Information Sharing to Distributed Decision-Making,” *Journal of Contingencies and Crisis Management* 29, no. 1 (March 2021): 1, https://doi.org/10.1111/1468-5973.12323.

[263] Arjen Boin et al., *The Politics of Crisis Management: Public Leadership under Pressure*, 2nd ed. (Cambridge: Cambridge University Press, 2016), 54.

[264] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*, 132.

Innovation in response to a complex incident requires sharing information and deliberately communicating strategies throughout the response framework. Information sharing may be limited due to compartmentalization of information for security or sensitivity issues.[265] Indeed, information sharing was affected by policies, industry culture, and previous experiences by groups involved in developing new technology, including academics, government scientists, and private companies, in response to the Deepwater Horizon.[266] The ability to interact and coordinate observations and perceptions exists in proximal workstations or work sites to create a shared space and community.[267] Information at the Chilean mine site flowed easily due to physical proximity and shared common areas and eating spaces.[268] Groups working to overcome specific issues in response to complex problems need to communicate and share successes and failures. The ability to share information may be limited by specific political or statutory issues or even be affected by the physical proximity of working groups to one another. Leaders and decision-makers must be aware of communication and information-sharing limitations, creating opportunities and encouraging cross-disciplinary teams to communicate and share information.

- Recommendation 2: Fire and emergency leaders should co-locate command and situational awareness teams to support real-time communication about the incident status.

C. RESPONSE FRAMEWORK SELECTION

A significant factor in the ability to create response frameworks is the simultaneous development of response priorities and strategic objectives, which are developed early in

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[265] Boin et al., *The Politics of Crisis Management*, 28.

[266] Lindley Mease et al., “Designing a Solution to Enable Agency-Academic Scientific Collaboration for Disasters,” *Ecology and Society* 22, no. 2 (2017): 2, https://doi.org/10.5751/ES-09246-220218.

[267] Neil R. Anderson and Michael A. West, “Measuring Climate for Work Group Innovation: Development and Validation of the Team Climate Inventory,” *Journal of Organizational Behavior* 19, no. 3 (May 1998): 238, https://doi.org/10.1002/(SICI)1099-1379(199805)19:3.

[268] Useem, “The Chilean Miner Rescue.”

the response.[269] Many organizations lack the policies and procedures to develop response frameworks that can collect, organize, and disseminate situational information quickly.[270] Responses to federal disasters follow requirements such as homeland security presidential directives, whereby the structure of the response framework is rigid with prescribed roles and responsibilities.[271] Emergency response agencies train and prepare to build response frameworks through established systems, yet other organizations might not have the procedures in place to incorporate response frameworks quickly and efficiently. An improved model of decision-making that incorporates disciplines beyond the traditional modalities of emergency response will require that emergency responders be flexible to work outside the established roles and that outside industries become familiar with federally adopted procedures, such as the Incident Command System. The developed response structure and framework will impact the ability of the overall organization to share information and create solutions to complex issues; deliberately addressing the structure of the response will ensure that all participants can readily participate in the response effort.

- Recommendation 3: Emergency response leaders should prepare to expand the response framework to incorporate entities outside the fire service.

D. INTERGROUP COMMUNICATION

Leaders of cross-disciplinary teams must engage with innovation to allow for new concepts to grow and change throughout the response to the incident. Complex incidents have no pre-determined response frameworks due to responders' unfamiliarity with the given circumstances; as such, response leaders must rely on innovation from experts and

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[269] Treurniet and Wolbers, "Codifying a Crisis."

[270] Boin et al., *The Politics of Crisis Management*, 38.

[271] Tiffany C. Brown, "Just-in-Time Training Considerations for Rural Emergency Operations Centers" (master's thesis, Naval Postgraduate School, 2018), 41, https://www.hsdl.org/?abstract&did=.

interdisciplinary teams to develop solutions.[272] Responses to large-scale incidents, such as oil spills and cave-in situations, therefore, require that new science and innovation be developed and implemented quickly.[273] Innovation within the Deepwater Horizon incident, for example, included academia's assisting private and government scientists to develop solutions for deep-water well-capping, a process only previously attempted in shallow-water wells.[274]

Emergency responders, traditionally the sole decision-makers at complex incidents, need to embrace advancements from industries outside their own to discover potential innovative solutions. Complex situations present the emergency responder with situations not previously encountered, so the responder has no pre-determined response strategies to overcome the incident. Embracing innovation from outside groups or nontraditional responders presents an opportunity for the incident to stabilize more quickly, saving more lives and protecting more property. Fire and emergency services leaders need to adopt leadership strategies that encourage innovation and incorporate outside groups to provide the best chance for rapidly resolving complex situations.

If properly developed and fostered using deliberate leadership strategies, cross-disciplinary response frameworks can foster innovation. Responses to significant events that are complicated and complex require collaboration among agencies of multiple disciplines.[275] Research by Anderson and West reveals that success in the innovative environment requires individuals to interact on a regular or semi-regular basis, that a common goal or outcome drives the teams to action, and a sufficient level of task interdependence ensures that each team is aware of expected patterns of results and shared understandings.[276] Other research demonstrates that leaders who have experience

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[272] Janice Francis Super, "Building Innovative Teams: Leadership Strategies across the Various Stages of Team Development," *Business Horizons* 63, no. 4 (July 2020): 553–63, https://doi.org/10.1016/j.bushor.2020.04.001.

[273] Lubchenco et al., "Science in Support of the Deepwater Horizon Response," 20212.

[274] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water*.

[275] Karlsson, "Saving Lives during Major Underground Mining Incidents," 17.

[276] Anderson and West, "Measuring Climate for Work Group Innovation," 238.

nurturing teams and incorporating innovation will have success pulling together disparate groups or disciplines.[277]

Leaders must anticipate innovation and creative responses to problems when developing frameworks for cross-disciplinary teams, building an environment that nurtures innovation and embraces alternative strategies. There were countless examples of innovation and new technologies to address novel problems throughout responses to the Chilean mining incident and the Deepwater Horizon. Key to the success of this innovation was shared information and the distribution of results and failures, thereby innovating on other teams' projects and progress.

- Recommendation 4: Fire and emergency services leaders must embrace innovation when presented with unfamiliar situations and build command structures that support testing new ideas.

E. CONCLUSION

This thesis aimed to identify an appropriate decision-making framework for the fire service to use in unfamiliar situations. Based on the case study evaluation of various industries, it can be concluded that cross-disciplinary teams should be included in the process of solving unfamiliar problems. The results indicate that the model must also account for and include communication strategies to encourage open dialogue and real-time information-sharing of results. Finally, fire service leaders must embrace innovation and support ideas generated from outside the traditional purview of the fire service.

The case study examination in this thesis focused on traditional approaches by the fire service and potential solutions presented by the mining industry. Numerous other examples could have been examined and presented different factors in the approach to cross-disciplinary teams solving unfamiliar problems. The selected cases, however, present clear examples wherein intuition affected the outcomes and cross-disciplinary teams overcame tremendous obstacles to achieve incident success.

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[277] Super, "Building Innovative Teams," 562.

The analysis reveals that the fire service traditionally relies on RPD, typified by time-critical decisions based on past experiences. When novel solutions have been presented to responders, such as using a burned-out area for responder safety, that do not align with previous experiences, firefighters have opted to rely on their intuition, thus leading to negative outcomes. Additionally, information silos have prevented decision-makers from fully embracing all incident factors, meaning they have made decisions without a complete operational picture.

The case studies from the mining industry provide examples of how interdisciplinary teams developed novel solutions to complex situations. To be sure, cross-disciplinary expertise leads to increased creativity in selecting strategies and tactics during unfamiliar and complex situations because it provides greater depth and breadth of experience to craft creative recommendations. Decision-makers must also embrace innovation in seeking alternative solutions to unfamiliar problems. Communication throughout the entire response framework must be addressed to encourage information sharing and real-time situational awareness. Cross-disciplinary response frameworks can foster innovation if leadership and decision-makers support them.

The 21st century will continue to present new challenges for fire service leaders and first responders. This thesis has provided potential paths for them to follow:

1. Decision-makers should allow cross-disciplinary teams to engage with fire and emergency response leaders when they are presented with unfamiliar situations.
2. Fire and emergency leaders should co-locate command and situational awareness teams to support real-time communication about the incident status.
3. Emergency response leaders should prepare to expand the response framework to incorporate entities outside the fire service.
4. Fire and emergency services leaders must embrace innovation when presented with unfamiliar situations and build command structures that support testing new ideas.

Responding to complex problems requires fire service leaders to adapt the traditional approach to incident management. Pandemics, climate change, and other problems present new problem sets for industry leaders. To address the coming needs of tomorrow, leaders need to prepare today by adopting new decision-making strategies that allow for a smooth transition from known situations to unfamiliar events.

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