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Anthony J. Masys *Editor*

Disaster Forensics

Understanding Root Cause and Complex Causality

Springer

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Introduction

Recently the global threat landscape has seen the emergence of high-impact, low-probability events. Events like Hurricane Katrina, the Great Japan Earthquake and Tsunami, Hurricane Sandy, Super Typhoon Haiyan, global terrorist activities, aviation and critical infrastructure disasters have become the new normal. Extreme events challenge our understanding regarding the interdependencies and complexity of the disaster etiology and are often referred to as Black Swans. As described in UNISDR [31] '…between 2002 and 2011, there were 4130 disasters recorded, resulting from natural hazards around the world where 1,117,527 people perished and a minimum of US$1195 billion was recorded in losses. In the year 2011 alone, 302 disasters claimed 29,782 lives; affected 206 million people and inflicted damages worth an estimated US$366 billion.' This book opens the black box of disasters by presenting 'forensic analysis approaches' to disaster investigations and analysis, thereby revealing the complex causality that characterizes them. In so doing it identifies 'new and innovative' strategies in analyzing accidents and disasters.

The anatomy of disasters and accidents depicts an etiology that reflects an inherent complexity that involves elements beyond the temporally and spatially proximate, thereby supporting a holistic or systemic view of disasters and accidents. A systems perspective of accident etiology recognizes, as Hollnagel [13] remarks '… how functions depend on each other and can therefore show how unexpected connections may suddenly appear.' Urry [32] describes how complexity recognizes the emergent properties that result from the dynamic interaction within a system, thereby developing collective properties that are not reflected in the individual components. As such, complexity argues against reductionism. As noted in Styhre [30], the complexity perspective recognizes that changes result from a multiplicity of interconnected causes and effects. Within the context of understanding accident etiology, the systems approach as a guiding methodology informed by complexity theory facilitates a break from '…mechanistic, linear, and causal methods of analysis towards viewing interdependence and interrelation rather than linearity and exclusion' [8: 140]. To capture and address the complexity inherent within socio-technical accidents, Dekker [6: 78] argues '…it is critical to capture the relational dynamics and longer term socio-organizational trends behind system failure.'

As argued in Dekker [4: 103], 'Were we to really trace the cause of failure, the causal network would fan out immediately, like cracks in a window, with only our own judgment to help us determine when and where to stop looking, because the evidence would not do it for us.' Accident analysis utilizing fault/event-based approaches tends toward an explanation of the etiology with a concentration on the proximate events and actors immediately preceding the loss [16].

Leveson [16: 25] characterizes event-based models as best suited for component failures rather than explaining systemic factors such as '…structural deficiencies in the organization, management deficiencies, and flaws in the safety culture of the company or industry.' Leveson [16: 25] argues that 'new models that are more effective for accidents in complex systems will need to account for social and organizational factors, system accidents and dysfunctional interactions, human error and flawed decision making, software errors, and adaptation.'

Perrow [24] coined the phrase 'systems accident' to describe an etiology that resides within complex relationships between elements comprising a system. The complexity that resides in current systems creates what Perrow [24] refers to as 'normal accidents.' Perrow [25: 12] remarks that:

> We have produced designs so complicated that we cannot anticipate all the possible interactions of the inevitable failures; we add safety devices that are deceived or avoided or defeated by hidden paths in the systems. The systems have become more complicated because either they are dealing with more deadly substances, or we demand they function in ever more hostile environments or with ever greater speed and volume.

In what Perrow [24] classifies as high-risk systems, accidents are inevitable or normal stemming from the way failures interact and tie a system together. His introduction of the term 'normal accident' refers to the inherent characteristics of the system.

Understanding such complex disaster and accident etiology thereby requires novel and innovative approaches to analysis.

Forensics

The Integrated Research on Disaster Risk (IRDR) strategic plan (2013–2017) identifies 'reducing risk and curbing losses through knowledge-based actions' as a key goal. Building upon that, the Forensic Investigations of Disasters (FORIN) project proposed an approach that aims to uncover the root causes of disasters through in-depth investigations that go beyond the typical reports and case studies conducted post-disaster events [14]. The evidence-based approach is rooted in the traditional conceptualization of Forensics where in the early twentieth century, Dr. Edmond Locard, a forensic science pioneer in France, formulated the theory which states, 'Every contact leaves a trace.' This became known as Locard's exchange principle and is the basis for all forensic science as we know it today.

FORIN [10: 6] asks the question: why, when so much more is known about the science of natural events, including extremes, and when technological capacity is so much stronger, are large-scale and even small- and medium-scale disasters apparently becoming more frequent and the losses continuing to increase at a rapid rate (IRDR 2009; White et al. 2001)?

1. Understanding Disaster Etiology

As part of the Springer book series: Advanced Sciences and Technologies for Security Applications, this edited volume, **Disaster Forensics: Understanding Root Cause and Complex Causality**, introduces novel perspectives and innovative approaches that reveal the complexity associated with disaster etiology.

The 16 chapters in this book reflect contributions from various experts and through case studies and research reveal many perspectives, tools, and approaches to support disaster forensic analysis. The value added through disaster forensics can enable resilience and help support disaster mitigation, prevention, response, and recovery efforts.

2. Content

Polinpapilinho F. Katina in his Chapter 'Individual and Societal Risk (RiskIS): Beyond Probability and Consequence During Hurricane Katrina' argues that, individuals can have varying understanding of risk which in turn affects their decisions and actions. The varying understanding and actions stem from deep-seated fundamental assumptions (i.e., beliefs and predispositions). However, deep-seated fundamental assumptions are often not included in traditional risk measures of probability and consequences. This chapter attempts to close this gap by developing a risk framework, RiskIS, that includes individual and society measures influencing decisions and actions. These measures are developed by examining literature and contrasting the resulting measures with a well-known event: Hurricane Katrina in New Orleans. A synthesis of this research provides a wider array of measures that influence decisions and actions (i.e., norms and personal attitudes, organizational structures, knowledge base, and social context, degree of connectivity, race and ethnicity, mass media, and national ideology). The proposed framework provides a basis for inclusion of a contextual frame of reference that influences actions beyond probability and consequence. Implications for those involved in disaster management are provided.

Ivan Taylor in his Chapter 'Application of Problem Inversion to Cascading Critical Infrastructure Failure' argues for the need to prepare for frequent future natural disasters and find ways to mitigate the potential death and destruction they cause. This chapter will discuss a novel method for making preparations to avoid the problem of cascading disasters created by a single natural event. This approach will adapt a knowledge-based technique from manufacturing, called Ideation Failure Analysis™, to correct deficiencies in critical infrastructure. The technique involves a number of approaches that are combined into a comprehensive process.

First, a simple direct approach is attempted with the assistance of a knowledge base. If the problem cannot be resolved in the direct manner, then an indirect approach is suggested. A detailed Failure Analysis Questionnaire is used to assist in model building. A model of the failure network is developed. However, instead of working directly toward failure correction, an inversion process is conducted. That is, in order to facilitate greater creativity, the analysis team is asked to imagine ways to produce the failure. The creative work is then assisted by a knowledge base. The analysis team is able to prioritize the likelihood that a cause might have resulted in the failure. The next step is to find ways to prevent, eliminate, or reduce the impact of the failure. Again to assist the creative process, a knowledge base provides suggestions for correction techniques that can be prioritized in a hierarchical fashion. Finally, the results are evaluated to avoid negative side effects or drawbacks in the suggested ways to correct the failure. This chapter will conclude by providing some recommendations and an evaluation of the potential value of this technique.

Jonathan Gao and Sidney Dekker in their Chapter 'Heroes and Villains in Complex Socio-technical Systems' highlight how the history of efforts to reduce 'human errors' across workplaces and industries suggests that people (or their weaknesses) are seen as a problem to control [2, 11, 17, 26] (Woods and Cook 2002). However, some have proposed that humans can be heroes as they can adapt and compensate for weaknesses within a system and direct it away from potential catastrophes [26]. But the existence of heroes would suggest that villains (i.e., humans who cause a disaster) exist as well [2] and that it might well be the outcome that determines which human becomes which (Baron and Hershey 1988). The purpose of this chapter is to examine whether complex socio-technical systems would allow for the existence of heroes and villains, as outcomes in such systems are usually thought to be the product of interactions rather than a single factor [16]. The chapter will first examine if the properties of complex systems as suggested by Dekker et al. [7] would allow for heroes and villains to exist. These include the following: (a) synthesis and holism; (b) emergence; (c) foreseeability of probabilities, not certainties; (d) time-irreversibility; and (e) perpetual incompleteness and uncertainty of knowledge, before concluding with a discussion of the implications of the (non) existence of heroes and villains in complex systems for the way we conduct investigations when something goes wrong inside of those systems.

Anthony J. Masys in his Chapter 'Patient Safety and Disaster Forensics: Understanding Complex Causality Through Actor Network Ethnography' argues that human error is often cited as a major contributing factor or cause of incidents and accidents. For example, in the aviation domain, accident surveys have attributed 70 % of incidents to crew error citing pilot error as the root cause of an aviation accident [12: 781; 29: 60, 34: 2]. Similarly in the healthcare domain, medical errors are reported to be a major cause of morbidity and mortality. Aggarwal et al. (2010: i3) argues that '…an increasing awareness of medical injuries has been paralleled by the rise in technology, and the increasing complexity it causes.'

According to Woods et al. [34], human error can be characterized either as a cause of failure or as a symptom of a failure. The label 'human error' as reported by Woods et al. [34] is considered prejudicial and unspecific. They argue that the label 'human error' retards rather than advances our understanding of how complex systems fail and the role of the human in both successful and unsuccessful system operations. This is contextualized and further supported in the healthcare domain (clinical encounters) by Artino et al. [1]. A systems view of the problem space regards human error as a symptom of '…contradictions, pressures and resource limitations deeper inside the system' [3: 2]. Actor Network Theory provides a conceptual foundation and lens to facilitate a systems-thinking-based analysis [19, 33] to examine the key dynamics that reside in the black box of human error pertaining to patient safety.

This chapter frames patient safety and human error through the lens of Actor Network Theory by leveraging insights from accidents and disasters such as the 2003 US/Canada Blackout [20] and the Uberlingen mid-air crash [18]. An example of the medical errors associated with the use of an Emergency Department Information Systems (EDIS) in a clinical situation is given. This ANT facilitated 'disaster forensic analysis' reveals a complex causality that is rhizomal rather than linear thereby challenging our notion of human error and highlights where intervention strategies can be focused to support patient safety.

Allan Bonner in his Chapter 'The Fog of Battle in Risk and Crisis Communication: Towards the Goal of Interoperability in the Digital Age' conducts a 'forensic' examination of disaster communications in the effort to unearth key gaps and contradictions. He argues that clear communication which produces an attitudinal or behavioral change is crucial in business, government, and politics. Selling products, providing entitlements, and obtaining consent from voters rely on communication. This is more crucial when communicating about a risk or during a crisis—recalling product, providing health information, or preparing an urban area for an emergency, for example. The risk communication literature provides guidance in these crucial cases.

Dorte Jessen in her Chapter 'Disaster Forensics: Governance, Adaptivity and Social Innovation' seeks to contribute to the discourse on disaster forensics, by arguing that the root cause and complex causality is ultimately governance, ideally cultivating the collective ability to navigate disasters rather than to command control. The focus will be on the social dimension and its impact on disasters. Governance theory, combined with complex adaptive systems theory [9], will provide the analytical foundation for the examination of Hurricane Katrina and the Fukushima Daiichi nuclear disaster. The theoretical deconstruction will reveal that the traditional virtues embedded in the social amplification of risk [15] remain at the heart of complex causality. With this insight, it is observed that social innovation, with its inherent positive connotation [23], is expanding the horizon for how social divisions, vulnerabilities, and resilience are measured. Optimistically, it is suggested that social innovation, driven by civil society, may prove a vital component in the creation of a new social narrative.

Simon Bennett in his Chapter 'Disasters and Mishaps: The Merits of Taking a Global View' examines the case of the Germanwings Flight 4U9525. On March 24, 2015, Andreas Lubitz, the First Officer of Germanwings Flight 4U9525, committed suicide by aircraft. Following the disaster, there was a 'rush to blame,' with Lubitz painted as the sole villain. Few reviewed the wider circumstances. While accepting the primacy of Lubitz's actions in the destruction of Germanwings Flight 4U9525, this chapter scans the horizon for contributory factors. In doing so it demonstrates the contribution systems-thinking can make to understanding failure in complex, transnational socio-technical systems (like commercial aviation). The chapter offers a counterweight to the fundamental attribution error. It offers an antidote to blamism. It references the work of Ross, Reason, Turner and Fiske and Taylor. While blame and punishment satisfy our baser instincts (the urge to hurt those who have hurt us is hard to resist), they generally undermine safety. The chapter argues that, from a safety standpoint, blamism is an inappropriate response to mishap and disaster.

Dmitry Chernov and Didier Sornette in their Chapter 'Dynamics of Information Flow Before Major Crises: Lessons from the Collapse of Enron, the Subprime Mortgage Crisis and Other High Impact Disasters in the Industrial Sector' present an analysis of the two largest financial disasters in the USA so far in the first decade of this century—the collapse of Enron in 2001 and the subprime mortgage crisis of 2007–2008—suggests that the huge scale of these disasters stemmed from a lack of timely information. Chernov and Sornette present extensive evidence that regulators, investors, and associates were not informed of the conditions and risks associated with the activities of Enron management in the first case, or with the assessment and underwriting of collateralized debt obligations (CDOs) in the second; and with little understanding of the 'whole picture' of risks, they could not intervene decisively to prevent or minimize disaster. Moreover, Chernov and Sornette identify similar obstacles to the transmission of reliable risk information in past cases such as the Barings Bank Crash, the Deepwater Horizon Oil Spill, the nuclear accidents at Chernobyl, and Fukushima Daiichi as well as in the current development of the US shale energy industry. Based on the careful observation of events before the moment of collapse in three financial events (Barings, Enron and subprime crisis), one mixed financial-industrial case and three industrial catastrophes, Chernov and Sornette document and discuss how the inadequate transmission or outright concealment of risk information constitutes a powerful engine of disasters.

Ross Prizzia in his Chapter 'Climate Change and Disaster Forensics' relates and applies forensic theory, insight, and analysis to disaster-related research and practice. It explores, describes, and explains human causality of climate change-related disasters and their impact on human and environmental losses. The chapter also identifies and describes new and innovative methodologies and strategies to analyze climate-related disasters, reduce disaster risk, and improve disaster mitigation, adaption, and management. Emphasis is given to vigilant monitoring and assessment of Intended Nationally Determined Contributions (INDC) to reduce greenhouse gas (GHG) emissions to limit global warming to 2 °C by 2030, a critical target set to prevent some of the worst impacts of climate change.

D. Elaine Pressman in her Chapter 'The Complex Dynamic Causality of Violent Extremism: Applications of the VERA-2 Risk Assessment Method to CVE Initiatives' describes the complexity inherent within radicalization. Attacks by violent extremists have been occurring with increasing frequency over the past years from a spectrum of ideological objectives. Incidents have occurred in the USA, Canada, the UK, Spain, France, Denmark, Norway, Australia, Pakistan, Iraq, Afghanistan, and other countries around the globe. In 2013, more than 9700 terrorist incidents were recorded in 93 countries. These incidents claimed more than 18,000 lives and 33,000 injured. In 2014, a rise in lone offender attacks was observed. Many of these attacks were inspired by ISIL, Al-Qaeda, and other extremist groups. Others do not appear to have been specifically directed by a terrorist organization, extremist group, or their affiliates. In the future, centralized leadership of terrorist organizations may be less important than the radicalization process itself, the individual identity of the perpetrator, and the narratives believed. This chapter examines the dynamic causality of violent extremism through the application of the VERA-2 method.

Gisela Bichler and Stacy Bush in their Chapter 'Staying Alive in the Business of Terror' examine the domain of terrorism. As it pertains to terrorists, they argue that staying alive (and at large) is a career advantage when you manage an insurgent group. If instead, your objective was to detonate a suicide bomb, success would be measured differently. These divergent goals must be considered when examining the social network within which individual actors are embedded, as each outcome may require a different supporting structure, warranting the application of different theory and associated metrics. Breaking from the extant literature that is principally concerned with assessing the cellular structure of attack groups and the centrality of actors, this chapter applies a business model of competitive advantage to examine how varied egonet structures correlate with the operational success of command staff—here the objective is to stay alive. Investigating the utility of Burt's (1992; 1997) theory of structural holes, we find that the communication patterns of central leaders of Al Qa'ida and the Islamic State of Iraq (ISI), who were active since 2006 and survived at-large until November 2015, involved smaller egonets that had fewer non-redundant ties, lower density, and were significantly less likely to involve reliance on a central actor for information. In short, less social capital and lower constraint improved the likelihood of survival.

Anthony J. Masys in his Chapter 'Counter-Terrorism and Design Thinking: Supporting Strategic Insights and Influencing Operations' describes how the recent terrorist attacks in Paris and Jakarta, Ankara, Ivory Coast, and Brussels in 2015 and 2016, respectively, highlight the complexity and challenges associated with counter-terrorist operations. The words of Rosenhead and Minger [28: 4–5] resonate with the complex space of counter-terrorism and these recent incidents. They argue that we '…are not confronted with problems that are independent of each other, but with dynamic situations that consist of complex systems of changing problems that interact with each other.' Such a complex problem space can be viewed as ‘wicked problems’ or ‘messes’ [27]. Rosenhead and Mingers [28: 4–5] describe ‘messy problems’ as that which have inherent complex interdependencies and dynamic complexity. They argue that ‘Individual problems may be solved. But if they are components of a mess, the solutions to individual problems cannot be added, since those solutions will interact.’

Within the context of counter-terrorism, deep uncertainty is the source of surprises and shocks in a system and the main cause of discontinuity in the strategic space of a system. Regions in the EU have been identified as key nodes of radicalization and violent extremism. It highlights the complex social factors that require an empathic approach to uncover the connectivity and processes [22] supporting this convergence of violent extremism. The problem space transcends domain-specific analysis to require a more inclusive approach that draws upon insights from sociology, economics, political science, humanities in the problem framing [21]. New methods and methodologies have evolved to address such inherent complexity in problem spaces. This chapter examines the counter-terrorism problem space leveraging the epidemiological model to illustrate how design thinking can be applied to develop analysis methodologies and intervention strategies to support counter-terrorism and resilience.

Jason Levy, Peiyong Yu and Ross Prizzia in their Chapter ‘Economic Disruptions, Business Continuity Planning and Disaster Forensic Analysis: The Hawaii Business Recovery Center (HIBRC) Project’ propose that modern disaster forensics can reduce supply chain disruptions, enhance disaster resilience, and promote a more robust economy. This chapter examines the root causes of economic disruptions by presenting ‘forensic analysis approaches’ to disasters that impact the economy of the US island state of Hawaii. Supply chain disruptions and investigations pertaining to business disruptions are undertaken with an emphasis on modeling, understanding, and characterizing the complex causality that defines them. In so doing this chapter uncovers creative, timely and important strategies for analyzing accidents and disasters that impact the economy of Hawaii. In order to promote business continuity planning and disaster forensics in Hawaii, the twenty-eighth Hawaii State Legislature enacted, and the Governor of Hawaii has signed, House Bill (HB) 1343 which provides funds for new state-of-the-art Hawaii Business Recovery Center (HIBRC), a joint partnership between the State of Hawaii Emergency Management Agency (HIEMA), the State of Hawaii Department of Business, Economic Development and Tourism (DBEDT), the State of Hawaii State Procurement Office (SPO), and the University of Hawaii West Oahu (UHWO). This designated business recovery hub will provide both outreach and dissemination of business recovery resources in addition to serving as a center for presenting disaster forensics approaches to disaster investigations in Hawaii, thereby uncovering the complex causality that underlies them. The center will help inform businesses of the importance of disaster preparedness, assist with post-disaster business recovery efforts, and create a robust business recovery network that shares the highest-level of management and governance with business leaders and strives for best disaster management practices and continuous improvement.

Jason Levy in his Chapter 'An Event-Driven, Scalable and Real-Time Geospatial Disaster Forensics Architecture: Decision Support for Integrated Disaster Risk Reduction' examines water resources disasters and their impact on humans, the built environment and natural systems. The chapter also identifies and describes timely and innovative decision support architectures to analyze climate-related disasters, enhance emergency preparedness, reduce disaster risk, promote disaster resilience, and improve disaster mitigation, adaption, and management. The root causes of water resources disasters are explored, and a distributed, scalable and real-time disaster forensics architecture with event-driven messaging and advanced geomatics engineering capabilities is put forth. Emphasis is given to vigilant monitoring, assessment, response, and recovery of floods and oil and molasses spills in the US state of Hawaii. The decision support and situational awareness advances found in this chapter complement the recent success of water resources disaster risk management and disaster forensics in Europe and elsewhere. The herein proposed disaster forensics architecture helps managers uncover creative, timely and important strategies for analyzing water resources accidents and disasters. In this manner, professionals have additional tools to model the complex causality of disasters and are better equipped to apply disaster forensics theory to the promotion of a more holistic, sustainable relationship between society and the environment. Specifically, this contribution provides theoretical insights and practical examples to manage water resources disasters under uncertainty.

Jason Levy and Peiyong Yu in their Chapter 'Advances in Economics and Disaster Forensics: A Multi-criteria Disaster Forensics Analysis (MCDFA) of the 2012 Kahuku Wind Farm Battery Fire on Oahu, Hawaii' illustrate how the discipline of economics and its many sub- and closely related disciplines offer valuable modeling techniques to relate and apply forensic theory, insight and analysis to disaster-related research. We herein propose advances in economics and disaster forensics to also reduce disaster risk and assess the direct and indirect impacts of disasters. This chapter constitutes a landmark attempt to address, comprehensively and in-depth, many timely and important issues associated with using the field of economics to build a culture of disaster prevention and to understand the root cause and complex causality of disasters. In particular, advances in microeconomic, macroeconomic, and forensic analyses are used to assess the causes and consequences of energy-related disasters. A timely, original and valuable Multi-Criteria Disaster Forensics Analysis (MCDFA) approach for the forensic analyses of disasters is put forth, and the 2012 battery room fire at the Kahuku wind energy storage farm on Oahu, Hawaii, is used as a case study to illustrate the proposed approach. Modeling identifies dynamic volt-amp reactive (D-VAR) technology as a preferred alternative over lead acid batteries for the Kahuku Wind Farm.

Jason Levy in his Chapter 'Complexity and Disaster Forensics: Paradigms, Models and Approaches for Natural Hazards Management in the Pacific Island Region' assesses and applies complex systems theory, modeling and analysis to disaster forensics policy and research. To better understand the root cause and complex causality of disasters, complex systems theory, with roots in the fields of statistical physics, information theory, and nonlinear dynamics, and systems analysis, is applied to help communities and nations achieve important social development goals, reduce institutional brittleness, and increase disaster resilience by promoting positive transformations in the coevolving and mutually dependent human-environmental condition, and by capitalizing on opportunities provided by human creativity, diplomatic openings, technologic capacities and environmental change. The case studies, investigations and models outlined in this chapter collectively demonstrate the quality, breadth and depth of complex systems and disaster forensics methodologies. Game-theoretic ('Small World') decision analyses and complex systems ('Large World') models of mutually interactive game design are put forth to capture the complexity of climate-related disasters and to reduce the threat of climate refugees in the Pacific Island region. The resulting risk management lessons learned were applied to communities in the Pacific Island of Vanuatu, the most natural disaster-prone country in the world.

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Individual and Societal Risk (RiskIS): Beyond Probability and Consequence During Hurricane Katrina

Polinpapilinho F. Katina

Abstract The classical definition of risk revolves around probability and consequence. However, individuals can have varying understanding of risk which in turn affects their decisions and actions. The varying understanding and actions stem from to deep-seated fundamental assumptions (i.e., beliefs and predispositions). However, deep-seated fundamental assumptions are often not included in traditional risk measures of probability and consequences. This chapter attempts to close this gap by developing a risk framework, RiskIS, that includes individual and society measures influencing decisions and actions. These measures are developed by examining literature and contrasting the resulting measures with a well-known event: Hurricane Katrina in New Orleans. A synthesis of this research provides a wider array of measures that influence decisions and actions (i.e., norms and personal attitudes, organizational structures, knowledge base, and social context, degree of connectivity, race and ethnicity, mass media, and national ideology). The proposed framework provides a basis for inclusion of a contextual frame of reference that influence actions beyond probability and consequence. Implications for those involved in disaster management are provided.

Keywords Hurricane Katrina · Individual · New Orleans · Risk individual—society (RiskIS) · Society · Traditional risk

1 Introduction

Hurricane Katrina has the distinction of being the "costliest and one of the five deadliest hurricanes to ever strike the United States" [24, p. 1]. The damages associated with Hurricane Katrina are estimated to have been 108 billion dollars (US) with

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over 1800 deaths [24, 49]. It is natural to stop and reflect on why there was so much damage and loss of life from a hurricane which had been publicized with prior warnings by federal, state, and local levels/authorities especially related to aspects of making landfall and potential consequences for the city as well as the residents of the city of New Orleans [4]. Arguably, a response might be found in the notion that past experiences should not be the basis for accurate prediction of future events. More succinctly, this notion suggests that "experiences of the past, encourages anticipation of the wrong kind of risk" [6, p. 330]. The irony is in the fact that there is a pervasive use of past information in many aspects of decision and actions in human-life. Certainly this is the case when someone decides to 'ride-out' a storm since they weren't harmed by a previous storm. This form of thinking is often tacit and therefore difficult to be made explicit and almost impossible to quantify. When one revisits this situation from a perspective of risk, the conclusion is easily reached by assuming that the probability of occurrence associated with an impending disaster and the related consequences will have the same outcomes as in previous similar situations.

Discernibly, this type of thinking has implications on actions and decisions that one makes in association with an impending disaster. For those involved in disaster type-situations (i.e., potential victims and rescuers), one area of concern might be how to incorporate the range of tacit beliefs in risk formulations to enable better decision-making. This issue is especially essential since the traditional formulation of risk [4] considers two measures: (1) probability that an event will occur and (2) articulation of consequences of occurrence of such an event. However, this does not account for tacit and implicit beliefs held by people in a disaster situation. The supposition at hand is that it is possible to make a decision and take actions contrary to what is expected given probability and consequence of a disaster. An examination of *why* that might be the case provides insights and could be instrumental in the development of techniques and tools instrumental in minimizing damage and loss of lives in disaster scenarios.

There is wide recognition of the importance and the role of risk and its measures of probability and consequence. However, these measures alone are not sufficient for decision-making and action-taking for an increasingly emerging low probability high impact events of the 21st century. In these events individuals might make decisions and act based on unarticulated core and tacitly held values and beliefs. It is from this perspective that this chapter is developed to propose a risk-based framework that incorporates individual and society factors influencing decisions and actions. These measures are supported by literature and the events leading up to, during, and after Hurricane Katrina in New Orleans in 2005.

To fulfill the purpose of this chapter, the remainder of this chapter is organized as follows: Sect. 2 explores the concepts of culture, society, and engineering risk. The aim of this section is to indicate how the concept of risk changes based on different contexts. Section 3 uses Hurricane Katrina as a case application. This section contrasts the relationship between classical risk and the core values/tacit knowledge that might have influenced how residents of the city of New Orleans viewed Hurricane Katrina. Section 4 provides an alternative approach for risk incorporating individual and societal measures: RiskIS. The proposed view of risk incorporates several measures that attempt to refine risk and could be used to better understand actions and decisions of those in disaster stricken areas. Future research directions are provided.

2 Foundations: Culture, Society, and Risk

Modern times have been characterized as tumultuous [26, 43]. This characterization is manifested in the ambiguity, complexity, emergency, interdependencies, and the uncertainties of the last three centuries [23]. There is *ambiguity* associated with an increasing lack of clarity and situational understanding, *complexity* associated with large numbers of richly and dynamically interacting complex systems and subsystems with behavior difficult to predict. Moreover, there is *emergence* with respect to the inability to deduce behavior, structure, or performance of current critical systems as a function of their constituent subsystems and elements and *interdependency* associated with mutual influence among different complex systems through which the state of a system influences, and is influenced by, the state of other interconnected systems. Uncertainty appears to be the norm in which there is always incomplete knowledge about situations and therefore casting doubt for decision/action consequences [21–23].

This landscape aligns with the notions of 'messes' [2] as well as 'wicked problems' [37]. The increasing prevalence of these conditions suggests a need to question classical elements of our understanding of how the world operates. With respect to risk formulation, Beck [6] notes that the increasing ubiquitous computing and pervasive computing technologies should force policymakers as well as researchers to abandon how risk has been approached. The call for a revision of the predominant risk paradigm is also evident across areas of disaster management [27], critical infrastructures [8, 25, 48], terrorism and homeland security [10, 19], system of systems [35] and cultural studies [45, 47, 50]. These studies acknowledge that the classical view of risk that past experiences can be quantified and then used as the basis for accurate prediction measures of probability and consequences. However, they also acknowledge that recent events, natural (e.g., hurricanes) or man-made (e.g., the 9/11 attacks), continue to defy and call into question the logic of this classical view of risk.

The need to understand and 'control' risk events fits within the purview of engineering managers and systems engineers. Therefore, there is benefit from examination of risk from this an extended perspective that extends beyond more classical views.

2.1 Engineering Risk

Often associated with risk analysis and decision-making processes, engineering risk is a science of risk and its probabilities based on statistical analysis of available data. From the engineering perspective, the aim of risk analysis is to establish future risk estimates based on independent sampling and past experiences [34]. The term 'engineering' serves as an indicator that one is concerned with an engineered system. Engineered systems are characterized as having been 'designed' by someone [17]. Such systems have "a high degree of technical complexity, social intricacy, and elaborate processes, aimed at fulfilling important functions in society" [11, p. 31]. Examples of engineered systems include healthcare systems (i.e., hospitals), banking and finance, and energy systems [42].

Moreover, there is an increasing realization that the modern world is more integrated. This integration, evident by interdependencies and connectivity among engineered and 'non-engineered' systems creates a situation in which the term 'engineering' is not a necessary requirement in risk analysis. This is especially the case when one considers that there is a need for integration of different disciplines to better understand and deal with risk events in modern times. Coincidentally, the very characterization of engineered systems—existing in the real world, artificiality, dynamic, hybrid state, and involving human control [11], supports this thesis of the limitations imposed by a singular formulation of 'engineering' risk. It is thus obvious that the term *engineering risk* carries multiple connotations in risk analysis that may in fact be limiting given the current state of risks in modern systems.

In this chapter, there is a deliberate effort to move away from risk as defined by any specific field and more towards emerging perspectives on risk [19, 22]. These emerging perspectives suggest risk can arise from designed and natural systems. This might be attributed to system deficiencies, and regardless as to whether such deficiencies are known, unknown, unpredictable, or undetectable, they still have the possibility of generating loss/injury and consequences to system users. A cautionary tale is provided by Beck [6]. His research provides several examples in science, government, business, and defense where this emerging paradigm is evident. He suggests, for example that, the discovery of chlorofluorocarbon (CFC) and its potential benefits should have been examined for known and unknown implications—especially those associated with ozone layer impacts and contributions to global warning [30]. Beck's [6] thesis is that the time is right for modern society to move away from the paradigm of 'science'. This is especially the case based on its assumption that the future is predictable and controllable based on past experience. In the case of CFC, one could argue that the promises of beneficial science have in fact generated threats to the society it had well-meaning intentions to improve.

The preceding discussion has implications for the concepts of risk engineering and risk itself. First, it suggests that there is no succinct difference between engineering risk and risk. While most engineering projects deal with engineered systems; such systems interact with natural systems—making them more of *hybrids* in nature. Risk analysis, for such systems, requires a consideration of a system of interest as well as the interacting systems. Second, while the measures of probability of occurrence of an event and the magnitude of the resulting consequences are considered fundamental [4, 20], there are scenarios (e.g., unknown unknowns [33] and black swans [44]) in which these measures are not sufficient to enable 'anticipation' [6] of risk and support for subsequent actions and decisions based on historically based predictions. The consideration of measures of probability and consequences, while necessary, is not sufficient to account for the multitude of measures that influence actions and decisions. The hybrid nature of complex systems, coupled with the increasing unpredictability of such systems supports the need to revisit risk measures and their influence on decision-making.

2.2 Culture and Risk Analysis

One measure affecting decision and action is *culture*. Webster's New Explore Encyclopedic Dictionary defines culture as "a set of shared attitudes, values, goals, and practices that characterizes a company or corporation" [29, p. 442]. When shared, a culture can influence collective action regarding specific issues—including responsive behavior. This issue is well noted in Beck's [6] discussions related to how certain issues are prioritized and addressed. This is the case for terrorism as well as climate change, where global warming is considered a critical issue for the European Union and terrorism as the most pressing issue in the US [6]. Cultural differences are also attributed to establishment of two different risk philosophies for addressing issues. Table 1 draws on Beck [6] to illustrate two different risk philosophies that have been attributed to culture.

In the context of risk analysis and management of risk, culture could be defined as emanating from a *group of individuals who share a set of specific beliefs and those beliefs are manifested in the attitudes, values, goals, visions, and objectives of the group*. This definition comes with a caveat from Schein [38]: culture is one of the most difficult 'organizational' attribute to change. The uniqueness of an

Table 1 Risk philosophies attributed to culture

Applicable philosophy	Description	Risk implications—example
Laissez-faire	It is safe, as long as it has not been proven to be dangerous	Policymakers are inclined to accept genetically modified foods (GMF) without fully understanding the consequences of such foods—a GMF is safe since it has no known bad consequence
Precautionary principle	Nothing is safe, as long as it has not been proven harmless	Policymakers are induced to reject GMFs in favor of more research to establish the fact that they are safe—a GMF not proven harmless renders it unsafe not given definitive evidence to the contrary

organization lies with the concept of culture [31]. Arguably, there is utility in consideration of culture in the articulation of risk events especially as people of the same 'culture' could be expected to have similar approaches and mindsets related to the analysis, modeling, and management of problematic issues.

2.3 Society and Risk Analysis

A related measure that can influence risk is *society*. If one takes the perspective that society is "an enduring and cooperating social group whose members have developed organized patterns of relationships through interaction with one another," then society can be thought of as "a community, nation, or broad grouping of people having common traditions, institutions, and collective activities and interests" [29, p. 1747]. This perspective is portrayed by modern society being characterized by an increasing demand for quality services, long-term sustainability, increasing trans-boundary dependencies, rapid technological changes, shifting to privatization of public sector [46]. Arguably, these characterizations involve having a set of *common interests* which in turn can create and shape society. A good example can be found in the field of critical infrastructures where an increased need for more secure and predictable electrical power infrastructures led to the emerging paradigm of 'electricity plus information' (E + I) in which information is viewed to be as relevant as the electricity itself [18]. This is a realization common in heavily industrialized societies.

In addition to having a set of common interests, societal behavior can also be influenced by a *common tradition*, *institutions*, and *collective activities and interests*. Again, and certainly within the context of the European Union, it has been argued that deregulation, internalization, liberalization, and unbundling of the European Electric Power System can be attributed to interests in use of digital electronics, better measurements, quicker operations, powerful control schemas and broadband access [18]. These perspectives alone seem to indicate that the modern world is interconnected as a result of increasing cooperation which could be attributed to common activities, needs, or demands.

Consequently, the term *society* encompasses traditions and institutional needs, demands, activities, and interests beyond those of a culture, which we have defined within the context of a given organization or a profession. In our current discussion *society* could be defined in terms of *a larger group of people (across time and space) with common traditions, institutions, activities and interests*. In context of risk analysis and management of risk, there is utility in consideration of culture in the articulation of risk events especially as people of the same 'society' are expected to have similar mindsets concerning appropriate approaches related to addressing problematic situations.

The concepts of culture and society are purposefully selected and contrasted to engineering risk to illustrate how the classical view of risk (i.e., measures of probability and consequence) evolve in today's more complex operating landscape.

In this landscape, there is an increasing realization that promises of modern systems free of risk from science, state, business, and defense are failing [6, 16]. Society and institutions themselves continue to change with rapid technological innovations—as a result of increasing demand for cheaper, higher quality, and safer systems as well as higher levels of outputs (i.e., products, goods, and services) from such systems. Moreover, these changes continue to transform society's current penchant for creating systems not bounded by traditional geo-political boundaries. It is from this worldview that engineering managers and system engineers must address the current hybrids of systems, spanning the manmade and natural formulations. In risk and especially disaster-type scenarios, risk based efforts can benefit by consideration of several measures and factors that might influence how people make decisions and take actions in risky-type situations. These measures are the basis of the discussion in the following section.

3 A Review of Literature: The Influence of Culture and Society on Risk Analysis

This section provides a review of literature supporting the supposition that culture and society influence activities and approaches that might be used in dealing with complex situations. Moreover, it has been suggested that how one deals with a situation can be related to deep-seated dispositions, inclinations, and tendencies [22]. This is an issue of extensive research in the social sciences.

In cultural theory it is widely contended that the humanity based environments contain social 'norms' that drive individual and societal perceptions on health, risk, and safety [12, 45]. Cultural theory is essential in risk analysis and management since it can be used in attempts to explain how having shared values, goals, and practices (cultures) and common traditions and interests (society) influences how individuals and large groups approach risk events. Although studies in cultural theory are not known for their attempts to distinguish culture and society, they reinforce the idea that *culture* can be viewed in terms of groups and individuals. The group level is concerned with inside and out of the group while the individual level is concerned with being influenced by or attempting to influence a group from an individual perspective.

Interestingly, discussions about risk in cultural theory are not restricted solely to issues of safety in reducing magnitude and probability. Tansey and O'Riordan [45] suggests that risk is best understood when it is viewed in terms societal issues of *power*, *justice*, and *legitimacy*. This is based in the notion that traditional risk quantification measures of probability and consequences is too simplistic—technically driven, based on utility theory, and heavily intertwined with the assumption that all humans make rational decisions. This issue is supported by McKinnon's [28] research which highlighted weaknesses in one of World Bank's social protection frameworks. McKinnon observed that social risk management for the World Bank did not account for contextual issues "preferencing the primacy of individual responsibility before collective action…[and] challenges the aspirational and redistributive policy agenda of social security in its pursuit of 'social justice' for all" [28, p. 22]. In other words, there is need to consider *irrational* actions of preferencing to act based on self-sacrifice—deferring to the interests of others beyond self.

Personal attitude also influences different approaches to risk. This might be more evident in *modern society* where there exists a belief that science, state, business, and the military have failed to deliver on their promises of a modern world free of risks. Arguably, free will is a major driver in how individuals view risk-related aspects including the identification, mitigation, and communication related to risk. In culture theory, this categorization of risk is defined in terms of *individual risk approach*—how individuals perceive and measure risk events. To illustrate: consider personal interpretations of risks associated with GMF and global warming. These interpretations induce people to view the associated risks in a particular manner. An alternative approach is a *cultural risk approach* in which social solidarities, judgments (about fairness and reliability), and risk communication are more important than the individual view of risk [45]. A cultural risk approach has been instrumental in the emerging worldviews of how to address global risks as suggested by Aaron and Dunlap [1] and Beck [6].

Another issue to consider is *social context*. Tansey and O'riordan [45] note that social context "impose[s] order on reality in particular ways" (p. 73). In other words, the need to maintain social identity might invoke particular preferred approaches to dealing with phenomena. In order to maintain societal identity and reduce risk, Tansey and O'riordan [45] note that some *cultures* may promote certain 'norms' as explained in an example where women are encouraged to avoid contact with cattle for the sake of not causing death. While this approach might appear 'primitive' to some, it turns out that even 'non-primitive' societies are equally influenced by societal 'norms.' Examples in which *culture* influences risk includes issues of "immorality" and "promiscuity" [45], the fight against terrorism, global warning, and GMFs.

Tansey and O'Riordan [45] have also postulated that culture and society affect risk analysis via the *degree of connectivity* which is explained in terms of 'center' and 'border' of an issue at hand. In the 'center' of the culture, Tansey and O'riordan [45] notes that people feel more attached to the beliefs held by the group as opposed to people on the borders. This would then suggest that people in the center of the group will have a higher degree of legitimacy and influence on those on the border. The ones on the border are more susceptible to following the center's approach an issue such as risk and approach [45]. Hence, one can reasonably conclude that a boundary associated with risk, which will be reflected in people and their tendencies, can be a manifestation of influence of a given culture. This idea seems to be supported by Douglas and Wildavsky [13] who suggested that being close to the beliefs of a group plays a major role in evolution, transformation, and quantification of risk. Certainly, this can have a significant implication for how to conduct analysis, modeling, and management of engineered systems. There are two major implications stemming from this discussion: (1) an issue that may have been considered relevant could become irrelevant and largely ignored and (2) the group or individual is able to identify new relevant issues—risk events. To illustrate, consider 'new' risks that are being associated with the field of *critical infrastructures*. This field involves identification and protection of essential systems (physical and/or information) whose destruction can have debilitating impact on public well-being. This emerging view of these systems is bringing to light new risks and vulnerabilities [25]. Moreover, it should be noted that discovering these 'new' risks could also be a basis that creates isolation among groups and individuals especially in scenarios where some groups fail to 'see' the new risks.

McKinnon [28] observed yet another way in which culture and society influences risk: *through powerful organizational structures*. This idea becomes more evident when one examines the role and influence of political powers, organizational agendas, and economic interests of certain entities such as those involved in risk assessment of nuclear energy programs and numerous accidents such as Three Mile Island, Exxon Valdez oil spill, and the Challenger accident. Tierney [47] notes that organizations such as the Atomic Energy Commission, the Joint Committee on Atomic Energy, and the Nuclear Regulatory Commission can influence risk analysis and management by promoting their ideas. For example, despite mounting evidence from the Brookhaven National Laboratory, regarding safety issues in power plants, the Atomic Energy Commission, the Joint Committee on Atomic Energy, and the Nuclear Regulatory Commission "consistently pushed the idea that nuclear power plants were necessary, safe, and economical" [47, p. 223]. Alternatively, political powers and organizational structure use mass media to influence risk and how it should be perceived. Tierney [47] espouses that "people's perceptions on risk are shaped by the ways in which risk-related information is communicated to them by these sources" and that "perceptions are also influenced significantly by the trust people have in organizations, including the producers of hazards, the organizations providing risk information, and the organizations responsible for protecting the public" (p. 234). Recall that the issue at hand is not whether the way of influencing people on risk is 'correct' or 'incorrect,' but rather, a recognition that this is one of the ways factors that influence risk should be noted when addressing how people might view risk. This issue of powerful organizational structure is closely related to Tierney's [47] knowledge base. *Knowledge base* is related to specific means that might be used in the calculations of risk which might involve a knowledge base as established by engineers, scientists, and certain government agencies.

Literature also establishes that *race and ethnicity* can be major influences concerning risk. Using an example of industrial pollution of the 1970s, [47, p. 232] notes that "states, poor, minority, and less politically organized communities end up as the 'hosts' for such [toxic and polluting] facilities." While noting that correlation does not imply causality, Tierney [47] argues that most low-income and minority communities could not simply resist becoming exposed to toxic wastes since they could rationalize the risks in terms of employment provisions. This can be compared to accepting risk, given in terms of freedom, which could be associated with giving up personal freedoms—freedom of expression (e.g., posting a message on WWW) despite possible ruminations.

In the perspective of *national origin*, it is stipulated that people's background can also have an influence on different risk perception. For example, Weber and

Hsee's [51] research illustrates that there are differences in how American students and their counterparts from China perceive risk. After using a survey, Weber and Hsee [51] concluded that since Chinese culture emphasized collectivism and inter-dependence on others in one's family and the community as a whole, there is a tendency to engage in 'risky' behavior. This is the opposite for highly individualized nations like the U.S. In effect, people in the Chinese culture are able to see 'big risks' as small because of their collectivism ideology [51].

A final perspective is that of allocating risk by the default of *prestige*. Beck [6] espouses that this is an issue more prevalent when one does a comparison between the west and east. According to Beck [6], Western nations are always seen to portray a symbol of success and safety because they appear to have succeeded in "bringing under control contingencies and uncertainties" (p. 332) involving issues such as accidents, violence, and sickness. Coincidentally, this view allows developing nations to engage in "lax [rules] or nonexistent land-use regulation, the proliferation of squatter camps in hazardous areas, environmental degradation, insufficient infrastructure to support the population and provide protection should a disaster occur, and governments that are only too willing to allow risks to be imposed on the poor for the benefit of elites" [47, p. 235]. Nations in this category, may see that allocation of risk by the 'elite' nations as the only way forward. After all, when 'amateur' nations are unable to recover toward 'elitism,' they are often considered to be living in pathological conditions, undeserving, and beyond help [28].

This discussion attempts to draw out indicators of *primary influences* of culture and society in the analysis and management of risk in engineered systems. These include individual 'norms' informing personal attitudes, organizational structures (i.e., power, justice, and legitimacy), knowledge base, and social context (i.e., environment). Additionally, degree of connectivity (i.e., being at the 'center' verses being at the 'border' of issues), race and ethnicity, and media and communications affect risk perception. The reviewed literature also suggests that national ideology (i.e., individualism versus collectivism) affects how risk events and incidents are perceived. This includes the amount of risk people are willing to be exposed to—which is related to understanding risk, management, and vulnerabilities.

There are two implications of interest related to our current development efforts concerning risk. First, an engineer and/or policymaker has to realize that in addressing current issues, one cannot simply rely on traditional risk measures of *probability* of occurrence and *potential* of harm. Such an approach assumes that man makes rational decisions. Second, the proceeding section indicates that risk analysis and management approaches should consider contextual issues that might influence actions and decisions. A reflexive modernization philosophy (transformation) in which the society as a whole uses reflex insights to reform and shape its future using principles of adaptability, sustainability, and precautionary principles is suggested by Beck [6]. This is especially the case since "disaster [emerges] from what we do not know and cannot calculate" [6, p. 330]. It is from these insights that the analogy (Fig. 1) of an onion peel level of issues was developed. The accompanying table (Table 2) elaborates on each level attempting to create a relationship between risk, individual, culture, and society.

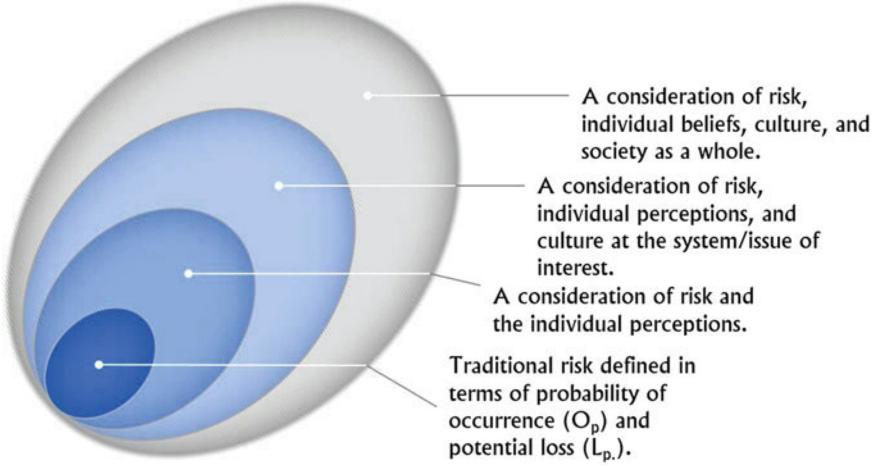

Fig. 1 An onion peel analogy of levels of issues to consider

Table 2 An expanded mapping of different levels to support individual and group perceptions

Level of quantification	Level descriptions	Relevant observations
1: Traditional risk	Founded on the basis of probability of occurrence (O_p) and potential loss ($L_{p.}$)	Besides O_p and L_p, risk calculations may involve measures of exposure, communication, perception, and vulnerability [50]
2: Individual level	A consideration of risk (i.e., $O_{p.}$ and L_p) and influence of individual beliefs	The individual perception measures might involve understanding the role of choice, free will, predispositions, and personal beliefs
3: Culture level	Understanding risk, individual beliefs, and a consideration of culture at the level of the system (organization) of interest	The culture at the location of system/issue at hand may be discerned through ***shared attitudes, values, goals, and practices*** involving organizational structures, knowledge base, degree of connectivity, norms, mass media, and race/ethnicity and dominant ***philosophical paradigms*** (e.g. laissez-faire and precautionary)
4: Societal level	Understanding risk, individual beliefs, culture, and influences at the societal level	Societal influences might be discerned through examination of ***shared attitudes, values, goals, and practices*** at a society level. The scale of operations for societal is at a global level involving elements of time, space and magnitude (e.g., organizational culture versus national ideology)

The proposed risk framework has three phases (i.e., peels) beyond the core which is defined based on classical view of risk. The three ‘peels’ are meant to ensure a more holistic view of risk with each peel providing more structure to understanding through risk analysis. As a framework, it only lays the foundation for understanding and dealing with complex issues. It is not meant as a systematic process to solving complex risk related issues. Rather, it serves as a guide to support the present topic. Moreover, it can offer utility to individuals interested in deeper understanding and appreciation of how their choices and personal beliefs influence how risk is perceived. It also offers a basis for seeing effects of culture and society on individual and risk events. While this framework is not a full-blown methodology, it provides a glimpse into issues that may need to be considered when addressing risk events involving individuals and large groups (i.e., culture and society) with implicit predispositions. The presented framework is only a first iteration and as such must be prone to inconsistencies and incompleteness. Refinement will be achieved through applications. A case application is presented is the following section.

4 Case Application: Hurricane Katrina

4.1 Context of Hurricane Katrina

New Orleans is located in southeastern part of the state of Louisiana, straddling the Mississippi River. The city and Orleans Parish boundaries are extended to parishes of St. Tammany to the north, St. Bernard to the east, Plaquemines to the south and Jefferson to the south and west. City limits also include Lake Pontchartrain (north) and Lake Borgne lies to the east. The geography of New Orleans is dominated by water.

During the 2005 Atlantic hurricane season, New Orleans was engulfed by floods from Hurricane Katrina causing loss of life and huge socio-economic damages. It is also fair to describe the New Orleans area as below sea-level and therefore “prone to flooding from the river, the lakes, and the Gulf of Mexico” [49, p. 35]. Plans to protect the city from flooding have always been in place and they date back to 1927. The Great Mississippi Flood of 1927 led the U.S. Army Corps of Engineers (USACE) to construct the world’s longest levee system under the Flood Control Act of 1928 [5]. Additionally, the New Orleans Flood and Hurricane Protection System was created to protect the city from flooding. It consisted of “350 miles of levees which are embankments, usually earthen, that serve as flood barriers… floodwalls, hundreds of bridges, closable gates, culverts and canals that facilitate transportation in and out of the system. It is comprised of a series of four main compartmented basins designed to limit the flooding impacts on the entire system resulting from individual failures of levees and floodwalls. In addition, large pump stations are used to pump out and redirect water from the city. These pumps are