COMPLEXITIES OF MASS FATALITY INCIDENTS

IN THE UNITED STATES:

EXPLORING TELECOMMUNICATION FAILURE

by

Melissa L. Brown de Gerena

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Disaster Science and Management

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ABSTRACT

Mass fatality incidents (MFIs), by definition, overwhelm the capacity of resources available to a local jurisdiction. An example of surge that a locality may experience is the increase of calls or contacts to the 911-system or center. This information surge may result in a measurable increase of contacts (911 calls or texts) beyond normal day-to-day capabilities, calls being dropped or unanswered or other types of telecommunication infrastructure failure. There is currently no means to anticipate the potential information surge or infrastructure failures following a mass fatality incident in the United States. Current assumptions on this type of data are anecdotal and based on only a small number of incidents. This lack of anticipatory knowledge has led to a major gap in the current understanding regarding the capabilities of the 911 system after a mass fatality incident, along with the resulting implications on technology and personnel resources. There is little existing research on the topic.

This dissertation explores the nuances and intricacies of mass fatality incidents (MFIs) and examines how those complexities may contribute to infrastructure failure through the examination of published documents, such as After-Action Reports (AARs). A mixed methods approach is employed, utilizing events listed in a mass fatality Excel database compiled by the Harris County (TX) Institute of Forensic Sciences (HCIFS). This is the same database that is currently being used by the National Institute of Standards and Technology (NIST) Organization of Scientific Area Committees (OSAC) for Forensic Science's committee on Disaster Victim

Identification (DVI). It contains mass fatality incidents in the United States and U.S. waters in which 4 or more individuals died in any single event from January 1, 2000 to December 31, 2018. Published data of infrastructure failure from the large scale (10 or more fatalities in one event) incidents in the database, occurring between 2010 and 2018 were then collected, along with demographic data surrounding the incident location and population, resulting in the creation of a new Enhanced Mass Fatality Database. This new database was then used to create statistical analyses and anticipatory models to explore potential telecommunication failures following mass fatality incidents in the United States.

This exploratory research develops the relationship between telecommunication failure(s) occurring during and immediately after mass fatality incidents occurring in the United States. It allows local medicolegal jurisdictions, emergency management, first responders and governments, access to the scientifically-based data and knowledge to develop more informed planning documents, as well the evidence to attain, create or build the appropriate capabilities and infrastructure needed to manage the potential for an influx of communication or telecommunication infrastructure failures during and following a mass fatality incident. Accurate expectations of data contribute to determining more efficient, effective and true means of managing incident data and resources, ultimately resulting in rapid response capabilities following a mass fatality incident. This project also serves as a model for confirming and expanding upon the findings in future domestic and international studies.

GLOSSARY AND ACRONYMS

AAR	After-Action Report
ABFO	American Board of Forensic Odontology
Antemortem (AM)	Performed or occurring before death
ARC	American Red Cross
Closed Population	A population for which the individuals are known (for example, where a manifest exists)
CDC	Centers for Disease Control
CODIS	Combined DNA Index System
CT	Computed Tomography
Dead	No longer alive
Deceased	A person who has died; no longer living
Decedent	A person who has died
DHS	Department of Homeland Security
DMORT	Disaster Mortuary Operational Response Team
DNA	Deoxyribonucleic Acid (genetic material)
DRC	Disaster Research Center (University of Delaware)
DVI	Disaster Victim Identification
EMFD	Enhanced Mass Fatality Database
ESD	Exploratory Sequential Design
ESF	Emergency Support Function
FARS	Fatality Analysis Reporting System
Fatality	An occurrence of death
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FS	Forensic Science
IAFIS	Integrated Automated Fingerprint Identification System
Information Surge	The increase in information received by a jurisdiction beyond the normal capacity
HCIFS	Harris County (TX) Institute of Forensic Science
HHS	Department of Health and Human Services
MDKAP	Mass Disaster Kinship Analysis Program (for DNA profiles)
ME/C	Medical examiner and coroner
Medicolegal	Medical jurisprudence; relating to both medicine and the law
MFI	Mass Fatality Incident

MOU	Memorandum of understanding
MSCT	Multi Slice Computer Tomography
NFDA	National Funeral Directors Association
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NMFI	National Mass Fatalities Institute
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
Open Population	A population for which the individuals are unknown
OSAC	Organization of Scientific Area Committees
PSAP	Primary Safety Answering Point/911 center
Postmortem (PM)	Performed or occurring after death
Recovery	The location and removal of dead bodies from the event site
TWG	Technical Working Group
UVIS	Unified Victim Identification System
VIP	Victim Identification Program
WINID	WindowsID – dental identification software

Chapter 1

INTRODUCTION

1.1 Mass Fatalities Incidents in the United States

As of January 1, 2019, there have been approximately 4000 incidents across the United States where multiple fatalities (4 or more decedents, or dead bodies) have occurred in the same event, since the beginning of 2000 (HCIFS, 2019).

Several large-scale mass fatality incidents have occurred in recent years and there seems to be either an increase in number or more awareness of the occurrence of these events, thanks, in part, to practically instantaneous technology alerting the public to the incident (Perera & Briggs, 2008; Bassendale, 2009). Natural events like Hurricane Katrina (1,400+ deaths), Hurricane Maria (between 60 and 2,900+ deaths total), the California wildfires (80+ deaths), acts of terrorism such as the events on September 11, 2001 (2,900+ deaths), and mass shootings like the Orlando Pulse night club shooting (49 dead), the Las Vegas Harvest festival shooting (58 dead), or the Stoneman-Douglas High School shooting (17 dead) have raised awareness for the need to prepare for both large-scale and smaller events (Kishore et al., 2018; HCIFS, 2019). It is essential to recognize the threat of these types of events occurring and to understand that their dynamic nature has the ability to, and does, affect more than just the medicolegal agencies responding to the event, including the potential to cause telecommunication failures. This presents a need to strengthen the existing planning and response to increase preparedness in the face of potential telecommunication surge and infrastructure failure following a mass fatality incident (MFI). A higher than normal day-to-day operation of calls and data received by a jurisdiction can and does occur in numerous areas following a mass fatality incident, potentially overwhelming the infrastructure supporting the local communications; however, this dissertation emphasizes the data that corresponds to various levels of infrastructure failure connected to the 911 system, which relates to the potential needs in staffing 911 centers, increasing capacity for telecommunication system infrastructure, and creating and maintaining memorandums of understanding (MoUs) with neighboring municipalities for support during these types of events.

This dissertation explores the current state of mass fatality incidents in the United States, including the complexities of the medicolegal system used and how that affects response to MFIs, the status of research on MFIs nationally, along with a literature review discussing the planning and identification processes employed in MFIs and the lack of accurate data being collected nationwide. Focusing on telecommunication failures in mass fatality incidents, the dissertation seeks to understand the nature and prevalence of such failures in a holistic manner. Telecommunication failures are interpreted broadly to include failure of the physical infrastructure, the service failure and operational failures. A discussion of the methodology, phases of research and exploration of the data set, creation and analyses of a new database, statistical findings and comparison of those findings in reference to past and current mass fatality incidents along with a survey to address validation from those individuals who participated in the response to these MFIs, complete the dissertation.

1.2 Governance of Mass Fatality Incidents

The United States Department of Homeland Security's National Response Plan

> "is an all-discipline, all-hazards plan intended to establish a single, comprehensive framework for managing domestic incidents...Its premise is that while the combined expertise and capabilities of all levels of government will likely be required in the prevention of, preparedness for, and response to domestic incidents, the primary management of an incident should occur at the lowest possible geographic, organizational, and jurisdictional level (TWG MFFI, 2005; US DHS, 2007)."

Emergency Support Function (ESF) # 8, the Health and Medical Services Annex of the National Response Plan, states that Federal assistance to supplement State and local mass fatality resources will be coordinated by the Department of Health and Human Services, the primary agency for ESF #8. The scope of ESF #8 includes: public health, medical, mental health services, and mortuary services, all of which have a role in mass fatality management (TWG MFFI, 2005; US DHS, 2007). The death investigation system in the United States is currently comprised of a combination of medical examiners and coroners, or a mix of the two, varying by state. A medical examiner is a public official who investigates by inquest any death not due to natural causes (for instance, a potential suicide, murder, accident or unknown cause of death), is a qualified physician, often with advanced training in forensic pathology (the application of medical knowledge to questions of the law) and is usually an appointed position. A coroner is a public officer whose primary function is to investigate by inquest any death thought to be of other than natural causes. More specifically, the medicolegal death investigation system in the United States has coroner-only systems; medical examiner-only systems; mixed systems (some counties are served by both coroners and medical examiners); some only have a state medical examiner and others employ referral systems, in which a coroner refers cases to a medical examiner for autopsy. Identifying the medicolegal death investigation system in a jurisdiction and determining who is responsible for mass fatality management is critical to initiating mass fatality management planning and resource allocation, as they *serve as the lead organization* when a mass fatality incident occurs and are *responsible for the overall management* of the incident. As there are no national standards governing mass fatality incidents, it is often at the discretion of the ME/C to maintain MOUs, and to determine what data is collected, how it is recorded and what outside resources might be needed during a MFI. A lack of minimum reporting standards can result in a lack of data and consistent data being collected during these types of events. There is also very little standard training for mass fatality incidents, due to their unpredictable nature, and most agencies only have access to minimal federal training provided by the Federal Emergency Management Agency (FEMA). There is currently only one class or training for mass fatality incidents through FEMA, G-386 Mass Fatalities Incident Response, which wholly focuses on the collection and identification of the dead, without discussion of how a mass fatality incident impacts other sectors involved the response to the incident or systems used by those agencies (FEMA 2012).

1.3 Status of Current Research on Mass Fatality Incidents in the United States

The National Institute of Standards and Technology (NIST), funded by the United States Department of Commerce, is a non-regulatory agency tasked with the goal of ‘working with industry and science to advance innovation and improve quality of life (NIST, 2019).’ In 2014 NIST, in partnership with the U.S. Department of Justice, created the Organization of Scientific Area Committees (OSAC) for Forensic Science. The goal of the OSAC is to ‘strengthen the nation’s use of forensic science by facilitating the development of technically sound standards and promoting their adoption by the forensic community (NIST OSAC, 2019).’ The OSAC comprises a community of roughly 560 members, having expertise in 25 specific forensic disciplines, as well as general expertise in scientific research, measurement science, statistics, law and policy. The standards that are posted on the OSAC Registry have passed a review of technical merit by forensic practitioners, academic researchers, statisticians and measurement scientists in order to define the minimum requirements, best practices, scientific protocols and other guidance to help ensure that the results of forensic analysis are reliable and reproducible.

Of the five major committees in the OSAC, the Crime Scene/Death Investigation committee contains a subcommittee for Disaster Victim Identification (DVI) which ‘focuses on standards and guidelines related to fatality management of a mass fatality incident that involves the scientific identification of human remains (OSAC DVI 2018).’ The DVI subcommittee has presently identified three research and development needs that they deem essential to fill gaps in the research and literature regarding mass fatality and disaster victim identification. Of those three, the 2016 identified research need directly related to this body of work focuses on the modeling of MFI missing person and victim data. It states:

> “There is currently no means to anticipate the volume and variety of data that result from and must be managed following a mass fatality incident. The existing assumptions are anecdotal and based on a small number of incidents. The volume of data (missing persons call centers, victim information centers, hospitals, law enforcement etc.) available from previous incident after action reports should be used to systematically develop reliable expectations for medicolegal operations (OSAC DVI, 2015).”

As there is very little current research being conducted on the topic, it presents a major gap in the current knowledge surrounding preparedness for mass fatality incidents. The current chair of the DVI subcommittee is Dr. Jason Wiersema, a forensic anthropologist who is also the director of Forensic Emergency Management at the Harris County (Houston, TX) Institute of Forensic Sciences. As chair of the DVI subcommittee and practitioner in the field, Dr. Wiersema has an in-depth knowledge of both the requirements to act during an event and what is needed to recover from mass fatality incidents, as well as firsthand experience responding to numerous MFIs throughout his career. It is this insight that prompted the HCIFS to create and log variables surrounding mass fatality incidents in the United States beginning on January 1, 2000 into a single database. This database provides the primary source of incidents for the dissertation research discussed within.

1.4 Harris County Institute of Forensic Science's Mass Fatality Database

The Harris County (Houston, TX) Institute of Forensic Science (HCIFS) has compiled an on-going database of all mass fatalities in the United States beginning in 2000. By their definition, a mass fatality incident is any incident, man-made or natural, in which there is a minimum of four decedents ($F \geqslant 4$), across the 50 states, including any MFI in open American waters. It was determined through interviews with and surveys of medicolegal investigators by the HCIFS that local jurisdictions are often 'taxed' beyond available resources when the death-toll for a single incident is larger than four bodies. This is especially true if the incident happens in more rural locations, with limited resources, and does not warrant state or federal funding for additional resources, such as the Disaster Mortuary Operations Response Team (DMORT). DMORT is a federal resource group of medicolegal professionals from around the country who can mobilize and assist in MFIs by providing additional personnel and equipment who specify in different means of identification (for example, anthropologists who can identify bones or odontologists who use the teeth and jaws for identification). This, in part, is due to normal medicolegal functions having to continue throughout the MFI process, and the nature of local jurisdictions as relatively small operations with few resources (for example, employees, transport vehicles, morgue capacity).

The HCIFS Mass Fatality database has current information on mass fatality incidents from a period of January 01, 2000 through December 31, 2017, with sporadic additional information on large scale incidents from 2018 only if there was national media attention. In an early 2019 discussion with personnel at the HCIFS, it was stated that database management has ‘passed hands numerous times,’ primarily being researched by a revolving door of interns, and ‘other projects have taken precedence, resulting in incomplete event documentation for 2017 to the present (HCIFS, 2019).’ Incidents in the database were acquired from published data from various government websites and databases, such as the National Transportation Safety Board (NTSB), the Federal Bureau of Investigation (FBI), the National Oceanic and Atmospheric Administration (NOAA), the Fatality Analysis Reporting System (FARS) from National Highway Traffic Safety Administration (NHTSA), the National Institutes of Health (NIH), and additional state websites. Data collected include: the date of the incident, type of MFI (natural/manmade, see Figure 1.1), location (city, state, county, geographical region), population at time of incident, population as of 2013, number of injuries and fatalities, the MFI subtype (for example, criminal/ accident/weather related, etc., see Figure 1.1), the specific type of event or sub-subtype (for example, shooting), if DMORT responded and if there was a federal disaster declaration.

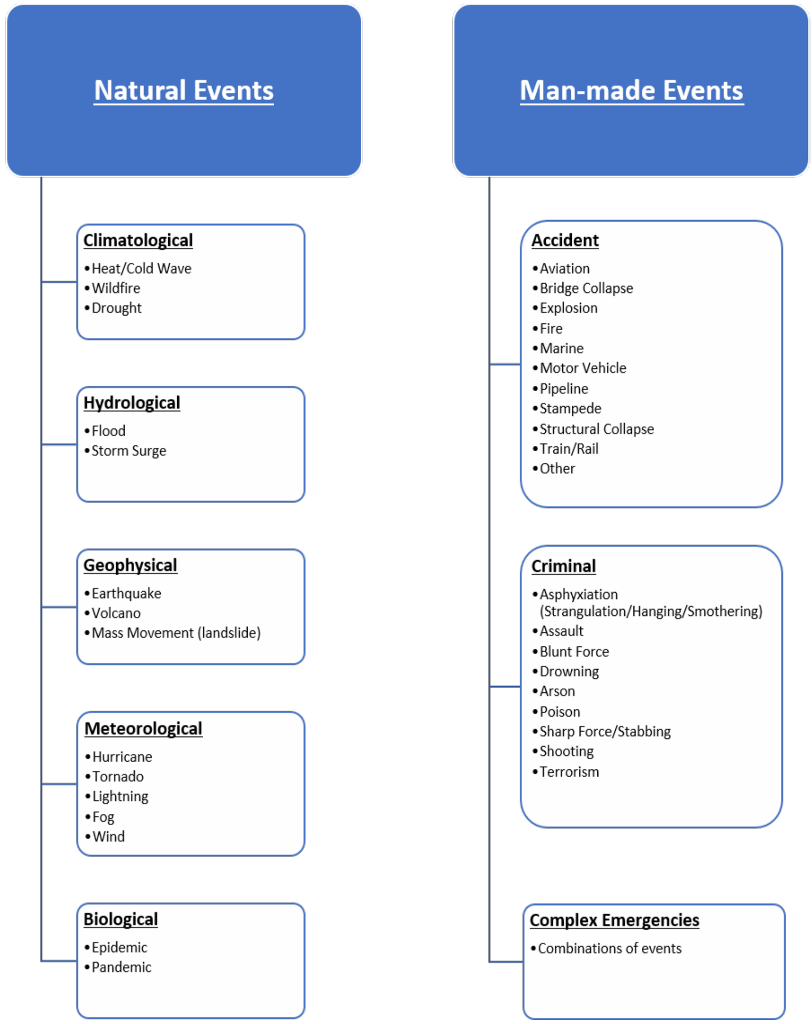

Figure 1.1: MFI types, subtypes and sub-subtypes (HCIFS, 2019).

From the years 2000-2018, a total of 3,748 incidents were recorded, however several events may have been dispersed over multiple locations (for example, hurricane and tornado deaths crossing state or county borders) and therefore the same event may be listed multiple times. Medical outbreaks (for example, SARS, the flu), large scale environmental events (for example, the Flint Michigan water crisis) and the lingering disaster death numbers (for example, deaths due to lack of electricity, fresh water or suicides following Hurricane Maria) have not been included in the database due to the prolonged period of time that the event occurred over and difficulty in determining an exact start or end period. It is unrealistic to assume that the HCIFS MFI database is inclusive of all mass fatality incidents across the country for this time period, but it is the most comprehensive list for data purposes at this time and offers the same information that the DVI subcommittee is currently utilizing. The data supporting missing events is evidenced by significantly lower numbers of MFIs found in 2017 and 2018 as compared with previous years (see Figure 1.2).

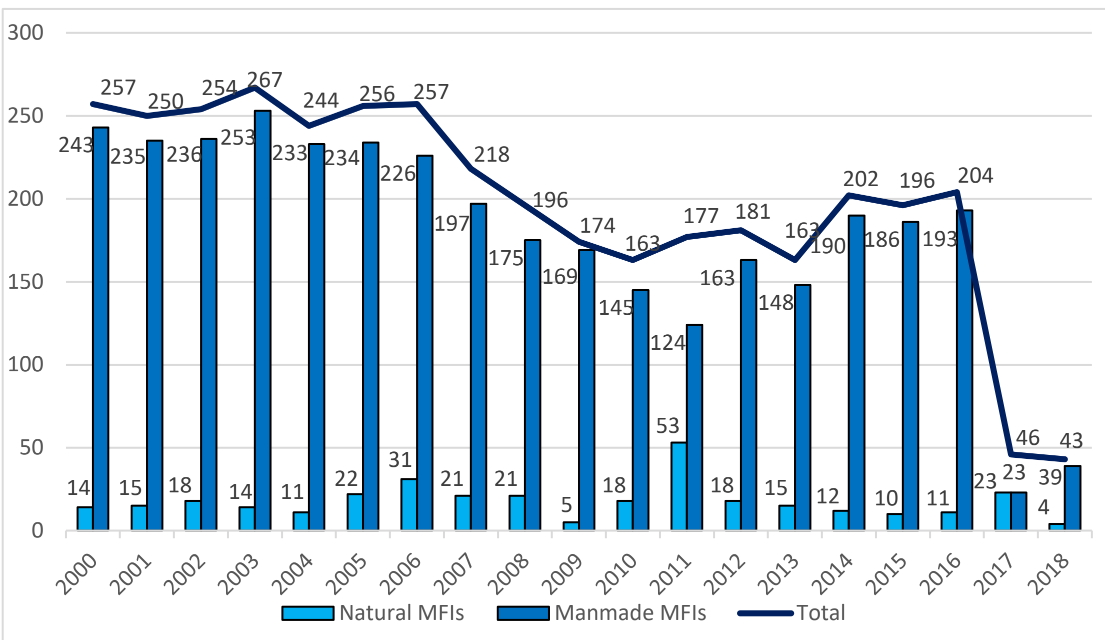

Figure 1.2 HCIFS 2000-2018 MFI totals by year and type (HCIFS, 2019)

It is important to acknowledge the use of the terms ‘natural event’ and ‘manmade event’ throughout this body of work, as in the midst of contemporary gender and climate change discussions, even those events that would be considered to be natural, such as hurricanes or wildfires, likely have human or anthropogenic influences compounding their occurrence (Kelman, 2018; Gill and Malamud, 2017). The use of the term ‘manmade events’ is utilized within this dissertation, as it reflects the verbiage utilized by both FEMA’s National Response Framework (2020) and in the United Nation Sendai Framework for Disaster Risk Reduction (2015-2030) and is inclusive of events defined in the original HCIFS database (FEMA, 2020; United Nations, 2015). The use of the term ‘event’ as opposed to the term ‘hazard,’ is employed, as the various definitions of a mass fatality incidents utilize ‘event’ in their definitions, for example, ‘an event where the number of decedents exhausts and exceeds the capabilities and/or resources of the local medicolegal team (Jensen, 2000; Black et al., 2011; Gursky et al., 2012; Teahan, 2012; Rocha et al., 2017).’ It can be noted that several of the aforementioned documents utilize the terms ‘event,’ ‘hazard’ and ‘incident’ interchangeably depending on if the event was planned or anticipated, as well as the occurrence and severity.

1.5 Goal of Research

Building on the OSAC DVI subcommittee’s problem statement, the broader objectives of this research encompass the overarching research needs in the disaster victim identification field, specifically in mass fatality incidents: *Can infrastructure failure and the need for additional resources immediately following a mass fatality incident be anticipated based on the data from past MFIs in the United States? Can these models be utilized to better prepare responding agencies, and create more* *capable infrastructure and employees is and when a mass fatality incident does occur?* Therefore, the specific research questions are:

1) When a larger scale mass fatality event occurs, is there evidence of the 911 system being overwhelmed? Is there evidence of failures in the telecommunication infrastructure?
2) What data do public archives, such as After-Action Reports (AARs), provide regarding the various types of infrastructure failures to the 911 system during and after a mass fatality incident? What types of variables affect these issues? Is it dependent on the categorical type of incident or some other qualitative or quantitative factor(s)?
3) Can 911 infrastructure failure surrounding a mass fatality incident be anticipated?

1.6 Overview of the Research

This dissertation discusses evidence of various 911 telecommunication failures that a municipality, county, jurisdiction or state may incur during and immediately following large-scale mass fatality incidents (MFIs), through the examination of published documents, such as After-Action Reports (AARs). This information is then used to examine the correlation between variables collected around each mass fatality incident in order to explore and model the infrastructure failure following a mass fatality incident that, potentially, could occur anywhere in the country. This research is directly related to the National Institute of Standards and Technology's (NIST) Organization of Scientific Area Committees for Forensic Science (OSAC-FS) Disaster Victim Identification (DVI) subcommittee's identification that there is currently no means to anticipate the amounts and types of data that result from, and must be managed, following a mass fatality incident in the United States. This lack of anticipatory knowledge has led to a major gap in the current understanding regarding the amount of data received after a mass fatality incident and has resulted in little existing research on the topic. Current assumptions on this data are anecdotal and based on only a small number of incidents.

A mixed methods approach to research and data was employed throughout this project. An Excel database, compiled by the Harris County (Houston, TX) Institute of Forensic Science (HCIFS), that includes mass fatality incidents where over 4 decedents were killed in any single event from January 1, 2000 to December 31, 2018, provided the initial source of MFIs in the United States (HCIFS, 2019). The state of Rhode Island, which as of the end of 2018, only had one occurrence of a defined MFI per the database, the Station Nightclub fire in 2003, was used as a preliminary pilot to establish a very rudimentary baseline to estimate amount of time needed to collect and examine the data, however, it was determined that the record keeping from earlier events may not provide suitable data to represent the surge of data nor the telecommunication infrastructure failures in relation to events that occur in the present or future (see Appendix A). While the entire data set being utilized covers the time period of 2000 through 2018, major mass fatality incidents that have occurred after the dates in the database are considered as events to examine and were utilized to test the regression model(s) created for accuracy in the future. The entire set of mass fatality incidents was not fully examined; however, a substantial subset was assessed. Additional narrowing of scope of the events chosen was required, and utilizing the HSIFS database, recent (2010-present) and larger scale (10+ decedents) events were highlighted for this study based on the immediate aims of the research. Evidence of data surge from 911-call centers and telecommunication infrastructure failure of those selected events were compiled using published After-Action Reports (AARs); data surrounding these events was then quantified and tabulated in a new Excel database, and used to conduct statistical analyses, show relationships and formulate regression models to anticipate the possibility of telecommunication failure in order to determine resource needs. Variables that are shown to be statistically significant in exploring the relationship between MFIs and telecommunication failure (for example, type of incident or number of decedents) were subjected to sensitivity testing utilizing SPSS Statistics version 25 (IBM) statistical program for further analysis.

This exploratory research develops and provides reliable expectations for the surge in calls and potential for telecommunication and infrastructure failure following various types of mass fatality incidents occurring in the United States. The overarching goal of this research is to provide local first responders and governments, along with medicolegal jurisdictions, the scientifically-based data and knowledge to develop more informed planning documents and to attain, create or build the appropriate capabilities and infrastructure needed to manage the influx of 911 calls after a mass fatality incident. Accurate expectations of data will contribute to determining more efficient, effective and accurate means of managing incident data, ultimately resulting in a 911 system that is capable of handling the surge following various mass fatality incidents. This project may also serve as a model for confirming and expanding upon the findings in future domestic and international studies.

1.7 Outline of Dissertation

This dissertation is organized as follows:

Chapter 2 encompasses a literature review discussing various themes relevant to the central topic of mass fatality incidents. It begins with an introduction to the topic, followed by a review of the planning surrounding MFIs. This chapter concludes with a discussion of how data is collected and used in events, and the current status of MFI preparedness in the United States, all of which highlight the collective need for the research aims of this dissertation. Appendices examine the historic and present practices for the identification of victims, as it pertains to the original source material for this project.

Chapter 3 is a discussion of the methodology utilized throughout the dissertation. It is broken down by both phase of research, as labeled per the three research questions, and total research tasks. Chapter 4 describes the new Enhanced Mass Fatality Database (EMFD) compiled of those events from the HCIFS database occurring from 2010-2018 where 10 or more decedents died. It discusses each of the event and demographic variables collected and provides basic descriptive statistics on each variable, along with a brief discussion of the overarching themes in the data. Chapter 5 provides more in-depth statistical analyses of the Enhanced Mass Fatality Database using the IBM SPSS program. It also compares the events utilized in the EMFD from 2010-2018 to MFI events that occurred in 2019, and closes with a discussion of the results of a survey sent to agencies that responded to those identified MFI incidents from 2016 to 2019 for confirmation of findings. Chapter 6 concludes the dissertation with closing thoughts, contributions and potential future research ideas. Appendices provide supporting documentation of preliminary analyses and related programs.

Chapter 2

LITERATURE REVIEW

2.1 Introduction to Mass Fatality Incidents

A mass fatality incident (MFI) has traditionally been defined as 'an event where the number of decedents exhausts and exceeds the capabilities and/or resources of the local medicolegal team (Jensen, 2000; Black et al., 2011; Gursky et al., 2012; Teahan, 2012; Rocha et al., 2017).' These low-probability, high-consequence events may be the result of a variety of causes: natural hazards (hurricanes, tornadoes, earthquakes, tsunamis), accidents (plane crash, train derailment, car accident), technological and structure-based (nuclear or chemical event, bridge collapse, fire), public health (infectious illness, pandemics or epidemics), or criminal-related (terrorist attack, mass shooting, genocide) events. Consequently, there is no minimum death count designated as a 'mass fatality incident,' as communities and their resources vary in size and capability.

Mass fatality incidents, by nature, are complicated systems that require a variety of independent disciplines working in a unified matter to achieve the same goal: to respectfully find and identify the deceased in a timely fashion. This involves a large amount of competency and understanding from numerous professionals, each with their own sets of expectations and training, who must be able to organize and extrapolate data into, and from, a cohesive system or database. As the topics surrounding mass fatality incidents and the data from them is diverse and circumstantial, so is the literature. This literature review covers several topics, mimicking the type and amount of data accrued from a mass fatality incident. The physical data sources have changed throughout time, as has the discussion of how mass fatality incidents require adequate capacity for both infrastructure and logistical planning purposes.

2.2 Planning for Mass Fatality Incidents

Prior to the events that occurred on September 11, 2001, most medical examiner/coroner (ME/C) offices, and local, county and state jurisdictions, lacked plans that included mass fatality incidents; or if they included any discussion of the topic, it primarily focused on instances such as a commuter plane crash, in which it was assumed that a federal organization, like the National Transportation Safety Board (NTSB), would come in and manage the situation (Gilliland et al., 1986; Morlang, 1986; McCarty et al., 1987; Scanlon, 1998; Mittleman et al., 2000; Biesecker et al. 2005). The majority of early historical research on the handling of mass deaths and the societal response to mass fatality incidents was published through the Disaster Research Center (DRC) at the University of Delaware (Hershiser, 1974; Blanshan, 1977; Hershiser and Quarantelli, 1976, 1979). Early articles discuss the role of the funeral director and other medicolegal death 'specialists' as the primary people responsible for identification of the dead, however, while more of the recent emergency management and disaster literature addresses specific types of mortality and morbidity that may happen following various types of events (Pine, 1974, 1979; Auf der Heide, 1989; Quarantelli, 1998; Godschalk et al., 1999; Bouque et al., 2007). Information specific to identification practices can be found in Appendices B-D.

The late Joseph Scanlon, Professor Emeritus at Carlton University and a University of Delaware Disaster Research Center affiliate, spent the latter half of his career examining mass death, specifically the differences and similarities among pandemic and other events resulting death events and the multiregional and international response to identification of the dead. In reviewing the changing patterns in dealing with dead bodies, he suggested that the separation in planning for disaster deaths and pandemic deaths is pointless and an all-hazards approach to death planning would be more appropriate (Scanlon, 1998, 2006a, 2006b, 2008; Scanlon et al., 2007). There is a great benefit, both in practice and in fiscal terms, to the planning for and practicing of mock events, including those that may result in mass deaths; this is especially true when a situation occurs that may be beyond the original scope of any planning, and in which emergency management and other medicolegal personnel are forced to blindly improvise their response to the event (Blanshan and Quarantelli, 1981; Morlang, 1986; McCarty et al., 1987; Eyre, 2002; Pretty et al., 2002; Bedore, 2007; Sledzik and Kauffman, 2008). Recent global MFI events have highlighted the need for all-hazards event planning and preparedness and the importance of multidisciplinary and multi-locational response and cooperation to successfully identify the dead from these events (Scanlon, 2006a, 2006b; Tsokos et al., 2006; Tyrrell et al., 2006).

2.3 Data in Disaster Events

Inadequate record keeping, and inaccurate or incomplete data collection adversely affect the preparation for and response to disaster-type events, especially those that involve mass numbers of casualties and/or fatalities. These inadequacies abound both in the basic collection of data and record keeping and in the anticipation of and processing of the information surge during and after an event.

The San Francisco earthquake of 1906 was thought to have resulted in fewer than 500 deaths for over 80 years, before Gladys Hansen, a museum curator began meticulously going through coroner reports and other official death records in the mid-1980s. By the end of her research, it was determined that in fact over 3,000 lives were lost in that event (Hansen, 1987; Hansen and Condon, 1989). These errors in death counts are not uncommon in mass fatality incidents both here and internationally. Reasons may include: the dead may be fragmented; identification may be nearly impossible due to a lack of antemortem (AM) records to compare with; a manifest may be lacking; bodies may be moved and 'disconnected' from the event; and data collection may be non-existent in that location. In summary, there are numerous reasons for there not to be a singular data repository for information when all hell has literally broken loose (Brondolo, 2004; Tun et al., 2005; Sledzick and Kauffman, 2008; Bassendale, 2009; Interpol, 2018).

Similar trends have been found by McEntire (2002) when studying the emergency response to recent events such as the March 2002 Fort Worth tornado in which five people were killed. The excess of information, both in the form of 911 calls and people, both civilians and professionals, inundating the area to help, created processing delays, resulting in uncoordinated information exchanges between emergency management personnel (McEntire, 2002). This failure to compile data and the decisions made during and post the MFIs underscore the opportunities to improve anticipation of data surge and data collection, and information sharing and reduce the chance of repeating errors made in other events (De Winne, 2006; Morgan et al., 2006; Bassendale, 2009).

2.4 Current Status of MFI Preparedness in the United States

September 11, 2001 is a prime example of the need for not only national, but also international, planning and infrastructure needs when faced with a mass fatality incident. While most people think of the events of that day as an American terrorist event, since it occurred on American soil, in fact there were over 2,700 decedents from 60 countries that perished in those attacks. The logistics of the recovery and identification of bodies and highly fragmented body parts was overwhelming and required experts from local and federal resources, taking over 5 years to be considered 'complete,' while some decedents still remain unidentified 18 years later. The NYC Office of Chief Medical Examiner, the largest governmental forensic organization in the country, undertook the MFI with their own fully-staffed departments for biology, anthropology, odontology and imaging. They still required not one, but two DMORT regional teams to assist in that process. The local telecommunications infrastructure did not fare any better; New York City local telephone service providers lost over 300,000 voice access lines, 4.5 million data circuits and left ten cellular towers inactive (Argenti, 2002). This loss of infrastructure also deprived over 14,000 businesses and 20,000 residential customers of service. The 911 system itself was also overwhelmed, with documentation of callers either not being able to reach an operator or receiving messages of 'all circuits busy (Argenti, 2002).'

A substantial amount of information can be generated in mass fatality events: beginning with the first 911 call, through the various response agencies and their tracking of personnel and resources, to ante and post mortem data on victims and missing persons, through to the after-action report(s) supplied by various local, state federal, and contracted agencies. This information comes from the examination by various types of experts, and many more professionals who may be involved in the

MFI. Unfortunately, there is currently no national repository to collect event data on mass fatality incidents in the United States and data is left in the silos of individual agencies without an understanding of the larger picture and how that data can be used as a baseline for future events across the country.

Furthermore, smaller municipalities and counties have an “it won’t happen to us,” or “someone will come in and take over” mentally that prevents them from thinking about or preparing for a mass fatality incident. This, ironically, fatalistic view prevents them from planning for these situations and often times, being unaware of what federal and state assistance is available to them, both before a potential MFI, like an impending natural event situation such as a hurricane or tsunami, and after an unexpected situation becomes a disaster, like a terrorist attack or plane crash.

As mass fatality incidents continue to occur, potentially more frequently and on a larger scale, the amount of data associated with the incidents increases as well, further complicating the data-comparison process. Unfortunately, many local medicolegal personnel as the lead agency, have the assumption that they are going to be able to rely on emergency responders and other medical professionals during a MFI; however, they fail to consider that a mass fatality incident can also be a mass injury or casualty event and those responders will be busy tending to the living (US IM, 2010). Several studies published by Gershon et al., (2011) and Merrill et al., (2015) queried respondents representing national members of medical examiners, coroners, the death care industries, faith-based organizations and OEMs. Respondents were asked about their readiness for mass fatality incidents. Only 51% felt that at least half of their capabilities for preparedness and response were in place (Gershon et al., 2011; Merrill et al., 2015). The second half of the Gershon et al., 2011 study, published in 2014, focused on an additional 122 medical examiners and coroners in the United States (there are approximately 2,500-3,000 medical examiners and coroners in the United States as of 2016). Forty-two percent of those respondents claim that fewer than 25 additional fatalities above their normal workload would exceed their response capabilities and create a surge situation (Gershon et al., 2014; Merrill et al., 2015). This aligns with the original HCIFS concern, that even a “smaller” MFI might severely disrupt local capabilities, while not even addressing the additional needs of infrastructure, planning, training and funding. Emergency and first responders, including the 911 system, will likely be overwhelmed with the surge from the incident and not able to provide relief to the medical examiner or coroner staff during the onset of the incident. Nor might they have the necessary training or awareness to assist medical examiners and coroner staff due to not having standard operating procedures, and an overall lack of training, likely from a lack of funding or even the idea of money for a MFI seeming unimportant to higher levels of local government.

In order to ensure funding for training and resources, mass fatality incidents have to be made a priority, and that can only be ensured by proving, via evidence, that this information, training and data to support needed resources are necessary. Evidence can be provided through steering committees or working groups compiling data and making both short term and long-term recommendations that are appropriate to the field and can be implemented nationwide (Sledzik, 2002; Ousley et al., 2016).

2.5 Synthesis

Research on MFIs continues to evolve as the research community begins to understand the challenges presented by such events, and as they increase in numbers, especially in the United States. While there is a recognition that information and communication are critical elements in any event, there is limited research on telecommunication failures related specifically to mass fatality incidents. It is imperative that key medicolegal stakeholders, emergency managers and technology integration specialists are present at emergency management meetings and are actively participating in the planning and training drills and exercises for a mass fatality event so that all parties are aware of the scope and ability of the local staff and resources to handle any number of mass fatalities or a complex fatality situation. As evidenced by the HCIFS database, less than 1% of the total events resulted in a federal disaster declaration occurring and/or DMORT teams coming to assist local responders (HCIFS, 2019). This emphasizes the fact that the immediate response falls on the local jurisdiction, first responders and the emergency management team to address the needs of the event, including the potential telecommunications system failures or a surge in calls resulting from individuals calling 911, to either report or gain information about the event, potentially straining the confines of the system and large-scale infrastructure failures.

Chapter 3

METHODOLOGY

3.1 Overview of Methodology

In order to fully explore the topics discussed in this dissertation, a pragmatic approach to theory is being utilized as the three goals of this research actively try to seek practical and useful direction in addressing the concrete and complex problems of mass fatality incidents in the United States and how to better prepare and recover from them. The intricate nature of mass fatality incidents (the type, time, location, breadth and scope of the incident, the people/groups affected, if criminal in nature then the people/groups committing the act, the amount of damage, the number of decedents, who is in command of the incident, etc.) in the United States provides a unique and conditional context in which to collect data.

Pragmatism informs both qualitative and quantitative research by first inquiring into practical questions in search of useful and actionable answers and by making decisions while conducting inquiry or research based on real-world constraints of limited time and resources (Seale, 2012; Morgan, 2014; Patton 2015). As mass fatality incidents have and will continue to happen, and as the data from each event further informs us of their nuances and resource requirements, a pragmatic approach allows for that new data to continually change how we respond to future events. As Patton (2015) suggests, this research will create a sense of “practical consequences and useful applications” in that ultimately it will highlight the complexities surrounding mass fatality incidents and provide concrete data to localities regarding the needs and resources required to respond to the surge in communication following these types of event.

The inquiry discussed in this dissertation adopts a mixed methods approach, as it has been proven that utilizing both quantitative and qualitative approaches provides diverse perspectives on and triangulated insights into the problem being studied, recognizing that all methods have a variety of strengths and weaknesses (Creswell 2009, Morgan 2007). By employing mixed-methods, a more holistic view of the telecommunications struggles occurring during mass fatality incidents is developed; with the hope that looking at these events across the United States will form a more comprehensive view of telecommunication infrastructure needs, as opposed to the anecdotal single event data that currently exists.

An exploratory sequential design (ESD) method is employed, focusing on qualitative and then qualitative approaches to address the research questions (Figure 3.1). Exploratory sequential design allows for the collection and analysis of qualitative data, in the form of published research documents and archives, into an examination of the intricate set of variables associated with 911 capabilities and failures in MFIs, followed by quantitative analysis in the form of statistical analyses and regression models, both of which are designed from the results of the qualitative findings. ESD also allows for a conscious movement back and forth between the parts and the overall incident, aiming to understand specific variables and dimensions, while also capturing the complex, interwoven fabric of mass fatality incidents as a whole. In order to address the three research questions, each question will constitute its own phase as represented in Figure 3.2.

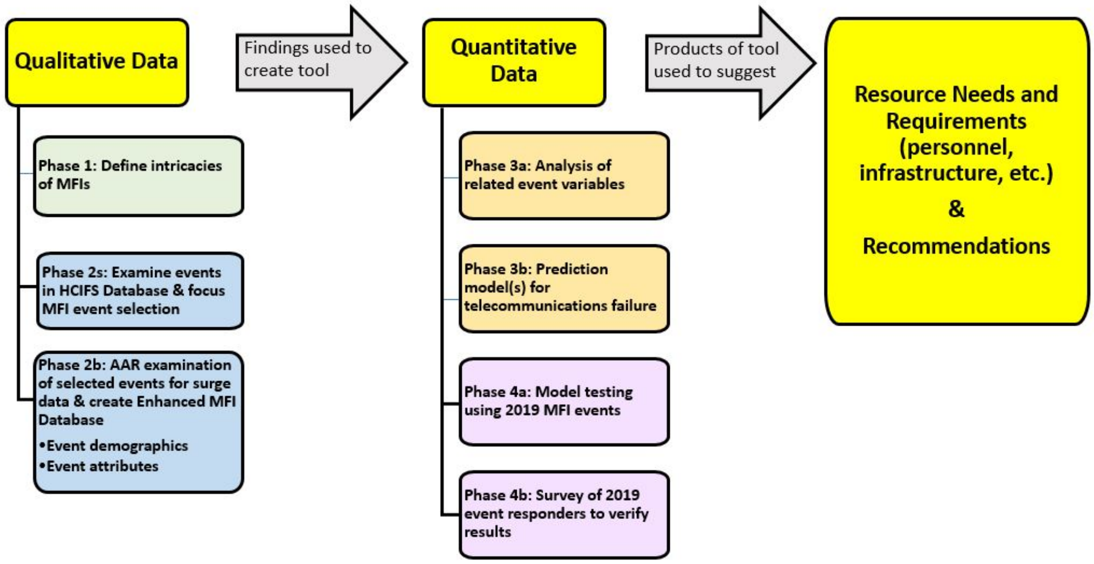

Figure 3.1: Exploratory sequential design

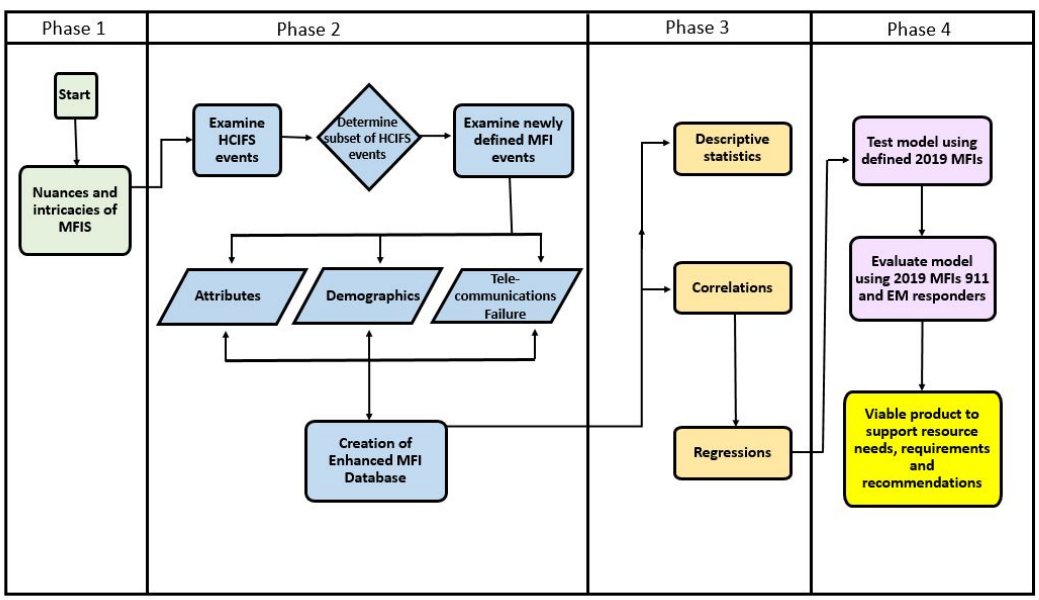

Figure 3.2: Research by phase

3.2 Research Tasks

3.2.1 Phase I: Addressing the Nuances of MFIs in the US

Phase I of this dissertation includes identifying, defining and addressing the nuances and complexities surrounding mass fatality incidents in the United States. This involves an in-depth look at past research, primarily in the medicolegal literature, on mass fatality incidents to determine who assumes 'command' for an incident and what steps are taken from the moment an event starts to when it is determined to be 'finished,' and who aids in and how fatalities are recovered and identified. These complexities add to the difficulty in finding holistic research on mass fatality incidents, specifically those looking at the surge in calls, which may strain and complicate the telecommunication infrastructure in place. Results of Phase I can be found in Chapter 1 and Chapter 2 of this work.

3.2.2 Phase II: Collecting Public Archive Data from National MFIs

Phase II of the dissertation starts to look at the actual data from mass fatality incidents in the United States. It begins with an in-depth examination of the Mass Fatality Incident database created by the HCIFS to determine which of the almost 4,000 MFIs should be considered for additional analysis. Basic exploratory data analysis was performed to create a baseline for time needed and data for variables examined in order to aid in the narrowing of events chosen for further in-depth document examination. Those incidents that are selected were then subjected to additional document analysis utilizing any reputable published document from governmental and direct first responder sources (i.e., After-Action Reports, 911 and emergency management reports), with all variable and data information being compiled into a new MFI database. It is expected that more recent and larger-scale incidents will provide the most detailed data. In order to test this theory, a pilot study was attempted using Rhode Island's Station Nightclub Fire in 2003.

Referencing the 2003 Rhode Island Station Nightclub fire pilot, it was determined that 'older' events lacked the amount of data collection to prove useful to this dissertation (See Appendix A). Due to these results, the current selection of events from the HCIFS database has been further narrowed to only focus on events where 10 or more individuals died in any one incident, from years 2010 to 2018, in order to coincide with and utilize the latest U.S. Census data available from 2010.

Evidence of information or call surge post mass fatality and mass casualty events is not commonly published in After-Action Reports, except for those high-profile, larger-scale events, which may be highly scrutinized due to publicity of the incident. For instance, the AAR published regarding the 2012 Aurora, CO movie theater shooting in which 12 individuals died, referenced the 'Public Safety Communications Department handling 6,000 calls instead of the 1,500 calls on a regular day (TDD SPC, 2014).' Unfortunately, this specificity in the 911 call surge is not typically the case for most of the mass fatality events from this time period.

3.2.2.1 Data Collected on the Attributes of Event

When examining the HCIFS MFI database, it was important to note the sheer size of the database and the distinct variation between the numbers of natural versus man-made events (see Figure 1.2). The original attributes of events in the HCIFS database included the 'start' and 'end' dates of each event, location, status of federal disaster declaration and DMORT response, number dead and injured, and type, subtype and sub-subtype of MFI. Additional information, specifically demographic and 911 center data, was collected on each incident, as it is expected that these variables will aid in the ability to anticipate telecommunication failure. These new variables equate to the complexity of MFI events through a variety of attributes relating to the event, such as the number of days over which the event unfolded, the type, subtype and sub-subtype of MFI, state and FEMA region, the percentage of child deaths associated with the event, county-level demographic attributes related to population density, income, and commute distance, number of hospitals and number of 911/PSAP call-centers and the types of defined 911 infrastructure failure from the AARs of each event (see Appendix E).

It was originally thought that the data found in the AARs would provide information on the numbers of 911 calls, requiring defining variables to capture the surge in information which occurs and rises and falls over a predefined time period following a MFI, or a quantifiable increase in calls. After extensive review of the highlighted events in the Enhanced Mass Fatality Database, it was determined that the number of 911 calls and measurable surge of calls that occur during a MFI were either not captured or rarely published unless the event was of exceptional large-scale, such as the September 11, 2001 terrorist attacks in NYC or in the 2012 Aurora, CO movie theater shooting (TDD SPC, 2014). In order to determine telecommunications capability and subsequent failure, new variables had to be created and defined to address if call surge and failure occurred. Published after-action reports and other reputable-sourced reports were reviewed to find evidence of the language associated with various failures related to the 911 system. It is difficult to utilize every term discussing ‘failure’ found in the AARs, as the same type of failure, for instance a 911 call being transferred or dropped may be described using different terms in different events. In order to address the original ‘data surge’ ask by NIST, evidence of failure discussing a substantial increase in the amount of 911 calls resulting in calls being put on hold or dropped, a complete or partial breakdown in the telecommunications infrastructure in the form of busy signals, dropped calls, calls being transferred to multiple PSAPs, or the inability to reach an operator, as well as either the power system, phone lines or cell phone infrastructure being inoperative were documented. This resulted in seven specific categories of failure being defined based on the most common failures found in the AARs.

Data on each of the newly defined MFIs has been compiled into a new database, referred to as the Enhanced Mass Fatality Database (EMFD), and is used to further characterize MFIs and for use in additional phases of this research. Table 3.1 summarizes the data and sources utilized, all of which are publicly available, with no human subjects involved.

Table 3.1 Enhanced Mass Fatality Database data types and sources

Data Type	**Source**	**Notes**
MFI event data	HCIFS MFI database	
Telecommunications surge: 911 call increase, evidence of dropped calls, busy signals, telecommunications infrastructure failure	AARs (Appendix E)	For those events that meet EMFD criteria
Demographics: Location, population, rural/urban status, average annual employment, average travel time to work, hospital and 911 center/PSAP availability	2010 United States Census, 2010 American Community Survey FCC 2019 PSAP Registry Report	All demographic variable data coming from same source for year 2010. PSAP data from FCC Dec. 2019 report.

3.2.2.2 Characterizing Mass Fatality Incidents

Utilizing the Enhanced Mass Fatality Database, exploratory data analysis including descriptive statistics, cross tabs and Chi-squared analysis and charts of basic attributes of each event such as: type (manmade versus natural), subtype and sub-subtype (refer to Figure 1.1), location (mostly urban, mostly rural, completely rural), county population demographics (population density, income, and travel time to work), number of hospitals within the county affected, number of PSAPs or 911 centers servicing the county affected, and number of days from event start to resolution, were examined for trends and patterns.

3.2.2.3 Narrowing Data Collection and Focus

Based on the amount of time and the lack of results from the Rhode Island pilot, a narrowing of focus was required when deciding which mass fatality incidents would be further examined. Given the timeframe, there would not be enough time to look into each of the over 3,700 incidents. By employing purposeful sampling of the incidents, a subset of incidents was identified with data added from the After-Action Reports and other published documentation from those incidents that reflect the increase in 911 calls and infrastructure failure during and post MFI. The requirements for inclusion in Phases II and III of this study resulted in incidents comprised of ten or more decedents from 2010-2018. The minimum of 10 decedents was chosen due to this being the international standard for inclusion as a mass fatality event (Fitzgerald et al., 2016; Rubin and Dahlberg, 2017; NYS 2020); allowing for future international use of this work. This original narrowing of incidents resulted in 59 total events, with roughly equal representation of both natural and man-made events as shown in Figure 3.3.

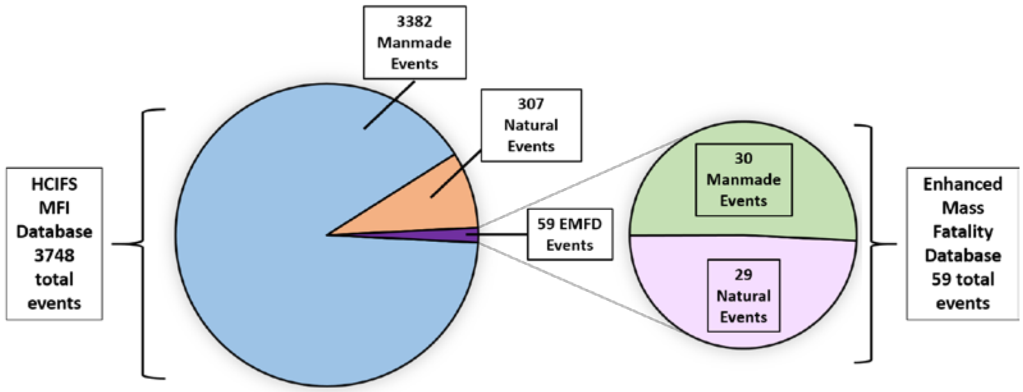

Figure 3.3 Narrowing of events from HCIFS MFI Database to new EMFD

It should be noted that incidents from 2017 and 2018 may not be reflective of all MFIs meeting these criteria, as data for these years in the HCIFS database are not complete as of the time of this writing. Incidents from 2017 and 2018 were noted and included into the HCIFS database sporadically, and likely are only those larger scale incidents that garnered national media attention; unlike the majority of MFIs which were local and consisted of six or less decedents, and primarily motor vehicle accidents (HCIFS, 2019). By utilizing the new MFI definition of ten or more deaths, it allowed for a greater sense in confidence that events occurring during the 2010-2018 period were included in the EMFD, as events of that size and scope were more likely to garner media attention.

3.2.3 Phase III: Development of Predictive Tools

Phase III focuses on the development of the predictive tools used to create anticipatory models that aim to anticipate the surge in communication and potential for telecommunication failure following a MFI. Statistical models, including cluster analysis, linear and logistic regression formulas, are produced using the event, variable and AAR data from the EMFD developed in Phase II, using IBM's SPSS Statistics 25 statistical analysis program. By examining the trends in the variables from MFIs using an analytical predictive model, those variables that are the largest predictors of the types of failure(s) can then be utilized to inform local jurisdictions regarding their preparedness for various types of events.

Cluster analysis was used to group the data into clusters of like events, however due to the small number of total events (59) clustering of the data did not prove useful. This information further identified the need to use a logistic regression model initially, instead of a linear regression. The exploratory data analysis was also used to understand which variables are candidates for the regression model. The dependent variable of telecommunication failure was further analyzed in order to continue the analysis of failure as a result of event and demographic variables, through the use of linear regressions. Regression models are utilized as they are relatively simple, easy to understand tools to use for prediction.

3.2.4 Phase IV: Evaluating the Predictive Tools

Using previously defined attributes for the seven MFI events that occurred in 2019, similar information from the EMFD was collected from available AARs to evaluate the predictive tools. The regression models to anticipate failure and estimations of telecommunication infrastructure failure were tested using these new events to gauge the accuracy of models. A follow-up online survey was disseminated to agencies that participated in identified 2016-2019 MFIs (911/PSAP call-center, first responder and emergency management staff), in order to gauge accuracy of the models and to determine validation and feedback of the research (Sandelowski, 1993; Morse, 1994; Angen, 2000). See Appendix F for the University of Delaware's Institutional Review Board letter of exemption for the survey conducted to validate this research.

Chapter 4

THE ENHANCED MASS FATALITY DATABASE

4.1 Narrowing the Scope of the Original MFI Database

The original Harris County Institute of Forensic Science (HCIFS) database created and updated by members of the DVI subcommittee, includes over 3,700 mass fatality incidents utilizing the standard for a mass fatality set by the Federal Bureau of Investigation (FBI) of a single event in which three or more decedents perished (Investigative Assistance for Violent Crimes Act of 2012). Realistically, smaller events are not as likely to involve a systemic communications failure, and it is important that consistent data is available to develop the final data set analyzed. Therefore, the scope of the data analyzed is more clearly defined in terms of the number of fatalities and the time frame in which the event occurred. By increasing the number of fatalities to 10, which incorporates both the international health and economic standards for a mass fatality incident and the accepted definition of a 'major disaster,' and looking only at those events that occurred from 2010 through 2018, a consistent, systematic approach to the events was employed, as summarized in Figure 3.3 (Fitzgerald et al., 2016; Rubin and Dahlberg, 2017; NYS 2020). Utilizing the timeframe of 2010-2018 provides a single source, with consistent demographic data provided by the latest complete U.S. Census in 2010.

The additional narrowing of scope resulted in a total of 59 events between January 1, 2010 and December 31, 2018, of which 26 (44.1%) showed evidence of the previously mentioned areas of telecommunications infrastructure failure (see Figure

4.1). Telecommunication failures are defined in seven specific categories: (1) evidence of 911 system being overwhelmed or calls not being answered and calls lagging, (2) evidence of 911 calls being dropped, (3) evidence of 911 calls being put on hold, (4) evidence of 911 calls being transferred to multiple PSAPs or 911 centers, (5) evidence of damaged or not functioning telecommunication wires or towers, (6) evidence of interoperability failures or radio issues, and (7) evidence of personnel issues, such as being understaffed. The telecommunication failure category 'evidence of the 911 system being overwhelmed' included evidence of calls going unanswered or not able to go through. It was not uncommon to see multiple types of failure occurring in the same event, for instance, if the system was overwhelmed (1), then evidence of not having enough staff (7) or calls being put on hold (3) may also occur.

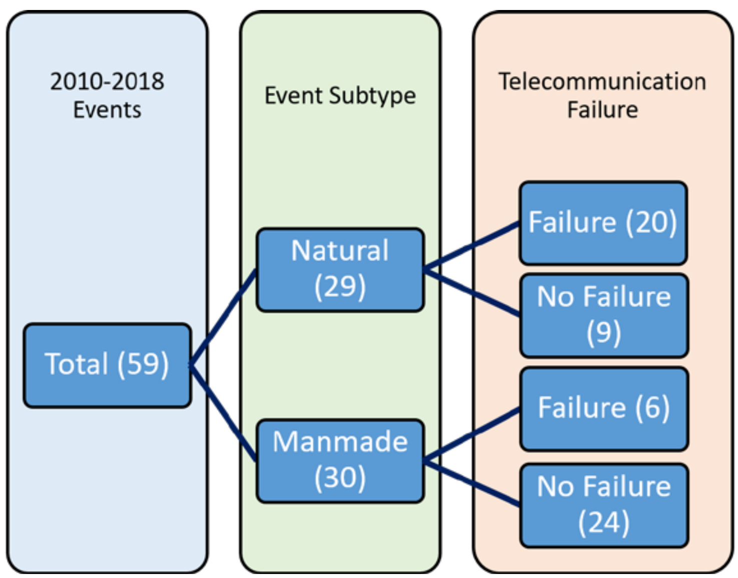

Figure 4.1 Enhanced Mass Fatality Database Failure Breakdown

4.2 Selection of Variables Examined

Original variables from the HCIFS database that were incorporated into the EMFD for analysis include: the event location (state), the total number of dead (including perpetrator in criminal events in which the perpetrator died), the population of the county the event occurred in, if a federal disaster was declared, if DMORT was deployed to aid in locating and identifying decedents, and the start and end date for the event, which was converted to number of days over which the event elapsed. Primary supplementary variables selected for the fifty-nine events chosen for final analysis include demographic information on the county that the event occurred in. This information is publicly available through the 2010 United States Census and American Community Survey. Additional variables added to the EMFD looked at whether more than 1/3 of the victims were children under the age of 18, and the county and FEMA region that the event occurred in. Several county-level demographic variables were introduced to the EMFD, including the number of PSAP or 911 call centers and the number of hospitals within the county, if the county is considered mostly urban, mostly rural or completely rural, the average annual employment and the mean travel time to work in minutes.

The variables representing population, employment and travel time to work were included to reflect a county's change in population during the day, which may result in a higher or lower number of individuals potentially involved in the MFI or calling 911 to report or find information about the event. Employment and travel time to work is also important to local governments, as they derive a portion of their revenues from commercial and industrial tax bases, which in turn, leads to the availability of funding for things like telecommunication infrastructure or additional employees to work in the 911 center. A county with lower population and employment numbers and a longer commute time would suggest that people are leaving the area for work, versus those with larger population and employment number in conjunction with a shorter commute time who likely will still be within the county (Kneebone and Holmes, 2016; Salon et al., 2012; Sultana, 2002; Cervero, 1989; Peng, 1997).

Data collected also planned to include the average daily 911 call number and increase in emergency calls following each event, for each of the associated county 911/PSAP centers, as well as the average number of 911 call operators and dispatchers. Unfortunately, it became evident that average call numbers and the increase in calls following an event, along with shifts and staffing, are rarely published, and due to the nature of the employment field for 911 centers, are usually not representative of the actual average call and personnel numbers, as 911 centers across the country have been, and continue to be, severely understaffed (Krouse 2018; US BLS, 2018).

To address infrastructure failure, the seven categories or types of failure were established and examined for in any official, published report, such as After-Action Reports, found using a basic Google search of the event. A complete list of the variables, the type of variable (categorical, integer, number, yes/no) and source included in the Enhanced Mass Fatality Database can be found in Table 4.1.

Table 4.1 Enhanced Mass Fatality Database Variables

Variable	Type	Source(s)
Event Data: Days elapsed Location: State Location: FEMA region Number Dead Disaster declaration status DMORT response Event type (natural/manmade) Event subtype (criminal/accident/weather) Event sub-subtype (aviation/boating/ debris flow/explosion/fire/flood/ hurricane/motor vehicle accident/shooting/tornado)	 Integer Category Category Integer Yes/No Yes/No Category Category Category	HCIFS MFI database
Demographic Data for 2010: County population County average annual employment County urban-rural classification (mostly urban, mostly rural, completely rural) County mean travel time to work Number of hospitals within county	 Integer Integer Category Number (mins) Integer	2010 United States Census, 2010 American Community Survey
PSAP/911 Centers servicing the county	Integer	2019 FCC PSAP Report
Telecommunication Failure: Evidence of 911 system being overwhelmed or calls not being answered and calls lagging Evidence of 911 calls being dropped Evidence of 911 calls being put on hold Evidence of 911 calls being transferred to multiple PSAPs or 911 centers Evidence of damaged or not functioning telecommunication wires or towers Evidence of interoperability failures or radio issues Evidence of personnel issues, such as being understaffed.	 Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No	After-Action Reports and other publicly published official documents from each event

4.3 Descriptive Statistics

The Enhanced Mass Fatality Database includes 59 total events from January 2, 2010 to December 31, 2018, with an almost equal distribution of 30 manmade and 29 natural events. Details are provided in Figure 4.1. The following subsections provide detailed descriptive statistics for the variables associated with each of the 59 events in the Enhanced Mass Fatality Database presented in terms of the event demographics, county demographics and response.

4.3.1 Event Demographics

A total of 59 events spanning a total of 9 years (2010 to 2018) are included in the EMFD. The number and subtype of events per year is shown in Table 4.2. They range in number from a low of 4 events per year in 2016 to a high of 12 events per year in 2011, with an average of 6.6 events per year. Manmade events range from a low of one event in 2014 to a high of 7 events in 2018, with an average of 3.3 manmade events each year. Natural events similarly average 3.2 events per year, with a high of ten events in 2011 and a low of no natural events occurring in 2016.

Table 4.2 EMFD 2010-2018 Event Type and Subtype by Year

Year	**Total MFI Events**	**Manmade MFI Events**	**Natural MFI Events**
2010	5	3	2
2011	12	2	10
2012	7	4	3
2013	6	3	3
2014	4	1	3
2015	5	3	2
2016	4	4	0
2017	8	3	5
2018	8	7	1
Average	**6.6**	**3.3**	**3.2**

The types of events are further subdivided by subtypes as shown in Figure 4.2. Of the three major subtypes of manmade events, accident, criminal and complex emergencies, the accident subtype was represented 17 times (56.7% of the manmade events), encompassing marine (1), aviation (3) and motor vehicle (8) accidents, as well as explosions (2) and fires (3), while criminal events were a majority of shootings (12 events, or 40% of manmade events)) and a single event (3.3% of manmade events) of criminal fire (arson). The 29 natural events in the EMFD were composed of four out of the five total subtypes of natural events, with the majority being hydrological (6 events or 20.7% of natural events), and unsurprisingly, meteorological events (21 events or 72.4% of natural events).

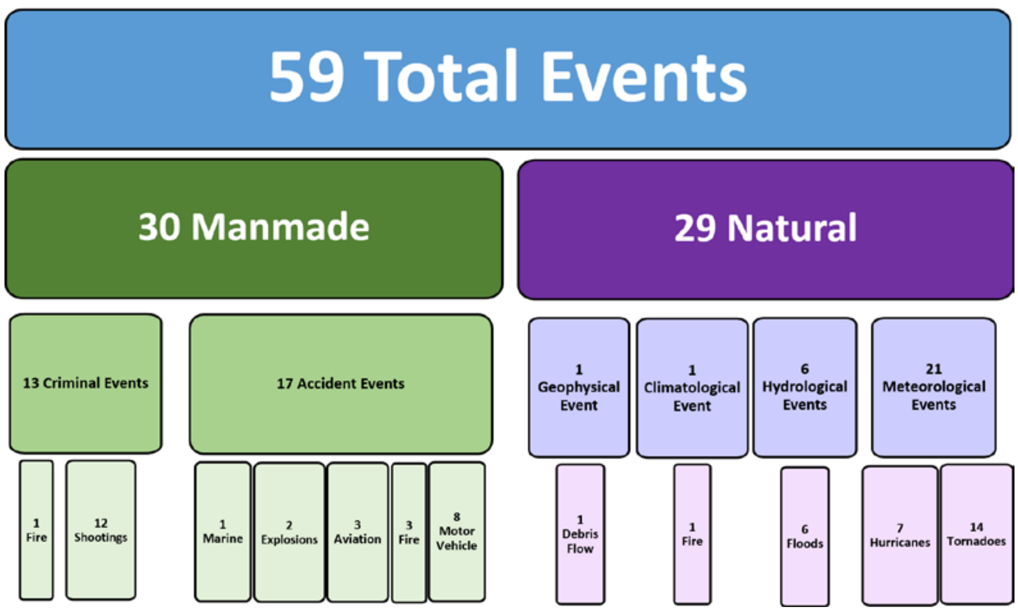

Figure 4.2 EMFD 2010-2018 Breakdown of Events by Type, Subtype and Sub-subtype

The events found in the Enhanced Mass Fatality Database occurred throughout the United States (see Figure 4.3). A total of 23 states and the District of Columbia are represented, with twelve locations (50% of locations) having a single event (Alaska, Colorado, Connecticut, the District of Columbia, Kentucky, Louisiana, North Carolina, Pennsylvania, Oregon, Utah, Washington and West Virginia). Texas experienced the majority of events (10), likely due to being the second largest state in the country and being historically prone to various natural events, such as hurricanes, tornadoes, floods and wildfires. Texas is markedly followed by Alabama (7 events), Florida (6 events), California and New York (5 events each), and Arizona, Arkansas, Mississippi, Missouri, Nevada, Oklahoma and Tennessee (2 events each).

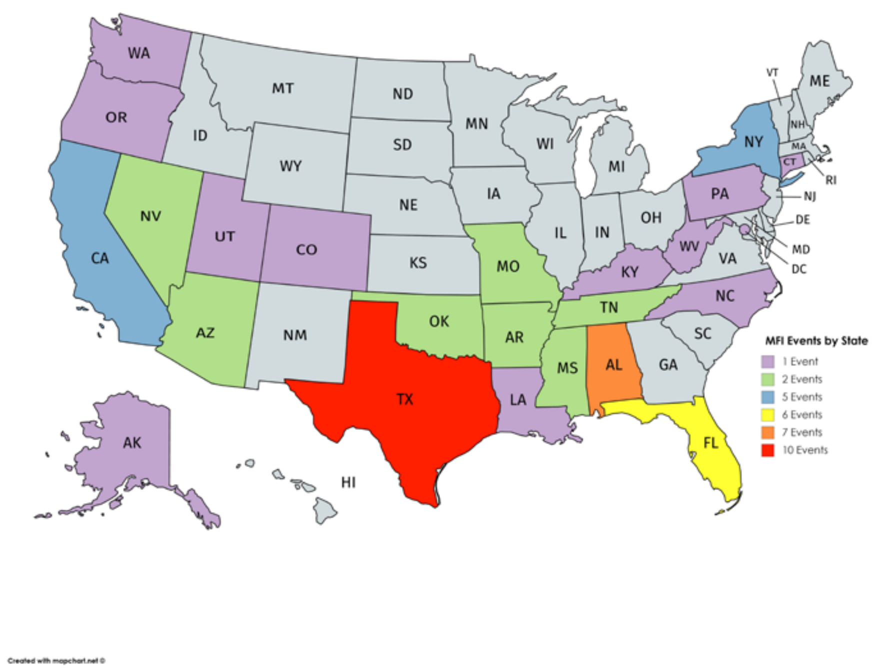

Figure 4.3 EMFD 2010-2018 Mass Fatality Incident by State

Mapping the frequency of events by the Federal Emergency Management Agency (FEMA) regions (see Figure 4.4), shows that Region 4 and Region 6 experience the most MFI events from 2010 to 2018, with 19 and 15 events, respectively. These two regions account for 57.6% of the total events in the EMFD (34 of 59 events) FEMA Region 4 is made up of the Southeastern corner of the US, including Florida, Georgia, Alabama, Mississippi, the Carolinas, Tennessee and Kentucky. This area is especially prone to natural events including hurricanes and tornadoes and has seen an increase in manmade events in the form of shootings, most notably in Florida (NCEI.a, 2020; NCEI.b, 2020). FEMA Region 6 is in the Southcentral portion of the country, including Texas, Louisiana, Arkansas, Oklahoma and New Mexico. Similar to Region 4, Region 6 is highly susceptible to natural events, with hurricanes and flooding being most prominent, but again with an increase in manmade events (NCEI.a, 2020; NCEI.b, 2020). As seen in Figure 4.3, Texas, again, makes up the majority of the incidents for this region, with 10 of the 15 total events occurring in that single state. The FEMA region with the next highest number of cases is Region 9 with a total of 9 events. Region 9 includes the states in the Southwestern border of the country, covering Arizona, California, Nevada and Hawaii. After these three regions, a noticeable decline in cases is seen with every other FEMA region having 5 (Region 2 – New York, New Jersey and the U.S. Territories) or fewer events throughout this time period. Region 1 (the Northeastern corner of the United States above New York) reported only one event, with Region 5 (Ohio, Indiana, Illinois, Michigan, Wisconsin and Minnesota) having no mass fatality incidents in the EMFD.

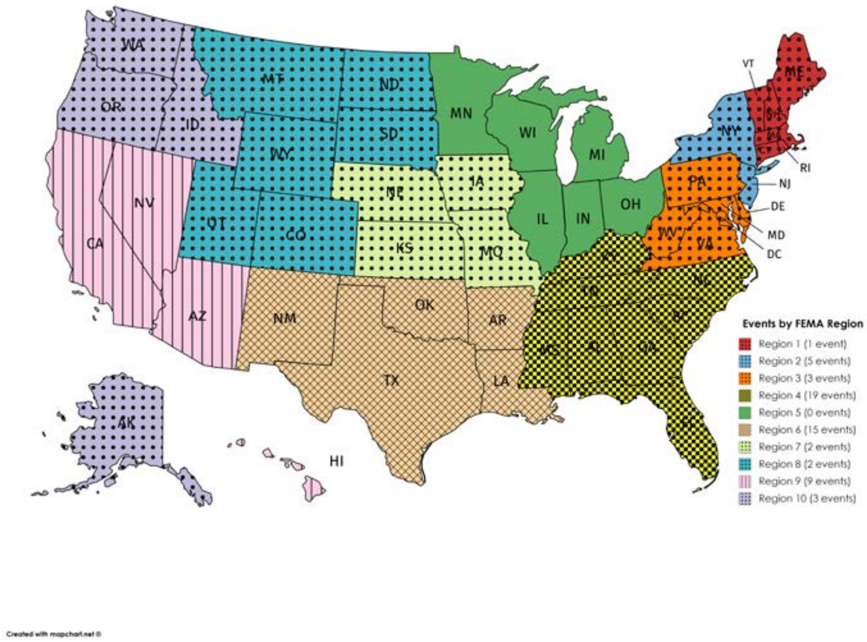

Figure 4.4 EMFD 2010-2018 Events by FEMA Region

When the 59 events in the EMFD are expounded upon by type (natural vs. manmade) we see even more contrast, with natural events coinciding with weather patterns and a seemingly random pattern of manmade events. As seen in Figure 4.5, a total of 13 states have natural MFI events occurring in them from 2010-2018. Alabama has the most natural MFI events (7 events), due to the supercell tornado outbreak of April 27, 2011 in which tornados swept through seven different counties causing widespread death and destruction. Removing Alabama, as an anomaly with a single event showing up in multiple counties, Texas, New York and Florida tie for the highest number of natural events with three each; however, we see similar patterns to Alabama for these locations – Florida has Hurricane Irma (2017) listed for two different counties, and New York has Hurricane/Superstorm Sandy (2012) in all three events. All of the remaining states in which more than one event occurs fall along the Southern border of the country. This pattern mimics data collected by the National Oceanic and Atmospheric Administration regarding states that have experienced billion dollar ‘natural disaster’ events from 1980 to 2019 (NCEI.a 2020; Smith 2020). This arrangement of Southern states being historically subjected to large-scale natural events of various types, mostly tropical cyclones, severe local storms (tornados) and flooding, is also reflected by the mass fatality events in the EMFD, as shown in Figure 4.6. Between 2010 and 2018, a total of six wildfires, eight droughts, ten tropical cyclones, sixty severe storms, five winter storms, 15 flood events and one freeze event caused over $1 billion in damages per event (NCEI.a 2020). In fact, since the 1950’s, the top ten states with the most incidents of natural ‘disasters’ in order of greatest to least include: Texas, California, Oklahoma, Washington, Florida, New York, Colorado, Alabama, New Mexico and Louisiana; seven of these top ten states are represented as having natural MFI events in the EMFD.

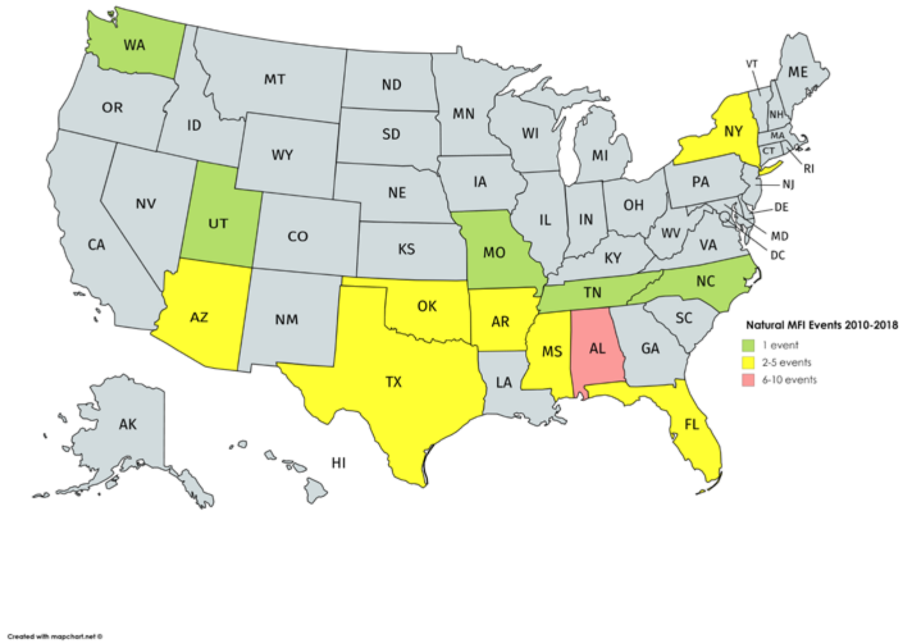

Figure 4.5 EMFD 2010-2018 Natural Events by State

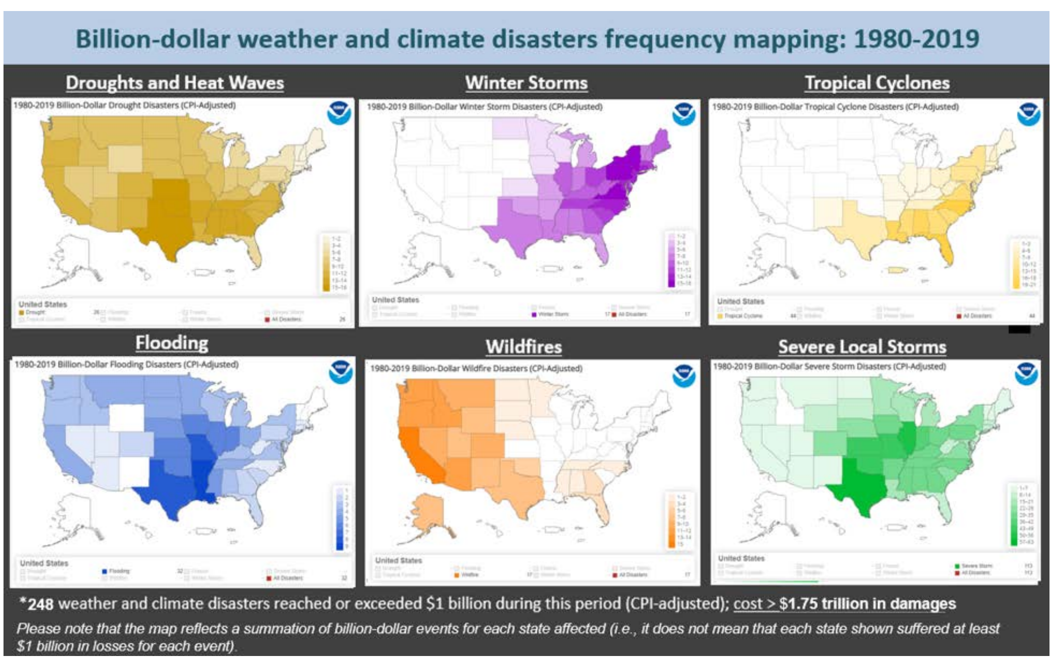

Figure 4.6 NOAA billion dollar natural events 1980-2019 (NCEI.a 2020; Smith 2020)

Manmade MFI events show more variability, occurring throughout the nation, as shown in Figure 4.7. There was a total of 30 manmade MFI events covering 16 locations (15 states and Washington D.C). Texas accounts for the majority of the manmade MFI events, having seven events (23.3%), followed closely by California with five events (16.7%), Florida with 3 events (10%) and Nevada and New York with two events each (6.7% each). The remaining 36.7% of the total manmade events occur in eleven locations, each only having a single MFI event in the EMFD. This pattern might be representative of the sheer size in population of the states represented – those states with the highest populations also have the highest number of manmade MFIs. Per State Population Totals provided by the U.S. Census Bureau, the top ten most populated states in 2010 were California, Texas and New York, followed by Florida, Illinois, Pennsylvania, Ohio, Michigan, Georgia and North Carolina. The order of ranking changed slightly by 2018, with California and Texas again taking the top two spots, followed by Florida, New York, Pennsylvania, Illinois, Ohio, Georgia, North Carolina and Michigan (USCB, 2019). Looking in this direction, it is not surprising that Texas, California, Florida and New York would have the majority of MFI events in the EMFD, as they simply have the most people in them to cause manmade events.

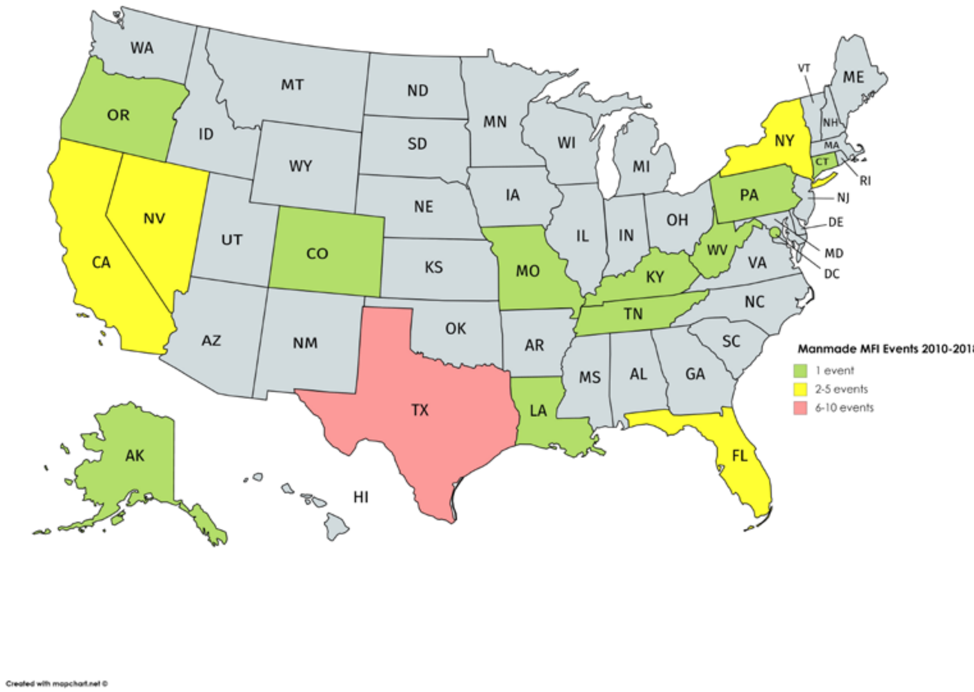

Figure 4.7 EMFD 2010-2018 Man-Made Events by State

Of the 59 total events found in the EMFD, 50 events (84.7%) elapse over a single day as seen in the summary statistics and the box and whisker plot shown in Figure 4.8, with the remaining nine events comprised of two manmade and seven natural MFI events. As the majority of the manmade events are terroristic in nature, it is unusual for them to last more than a few hours, let alone surpass a day from start to end. The manmade events that exceeded this norm include the 2012 Deepwater Horizon fire which lasted for two days and the 2018 California Camp fires that burned in Butte County for 18 days. Natural events, such as tropical storms, are much more likely to last more than a single day, as they ‘stall’ over or near land. This is evidenced in most of the natural events found in the EMFD where Hurricane/Superstorm Sandy pummeled New York for two days in 2012 (again, listed three times for each County effected), and Hurricane Harvey in 2017 stalled over the greater Houston area for four days (listed two times for each County effected). The remaining two natural MFI events in the EMFD include the 2010 Davidson County, TN storm/flood over a four day period and the 2013 Oklahoma County, OK storm/tornado/flood that lasted for two days.

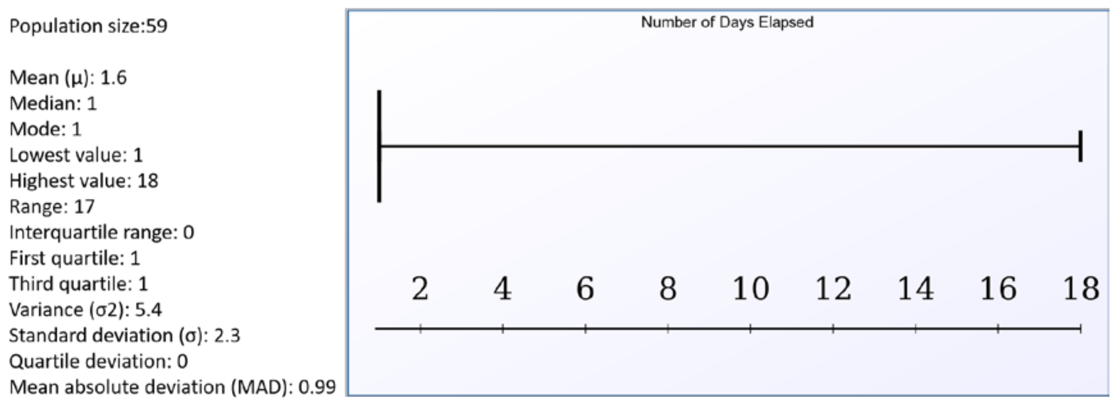

Figure 4.8 EMFD 2010-2018 Total Number of Days Event Elapsed Over

Figure 4.9 shows the summary statistics and box and whisker plot for the number of dead in each event. Understanding that the minimum number of decedents for inclusion in the EMFD was ten decedents in a single event, this only occurred in 10 of the 59 events (16.9%), with a mean of 24 (23.5) deaths, and a maximum death toll in the EMFD of 166 from the 2011 Joplin tornados. Figure 4.10 examines the number of dead per type of event and demonstrates that the majority of events include 25 or less fatalities (76.3% of total events), with a relatively even distribution between natural and manmade events and number of dead. This data verifies the concern of first responders and fatality management personnel in which it was found that even in events with ‘smaller’ death thresholds, their local and regional resources would be quickly overwhelmed.

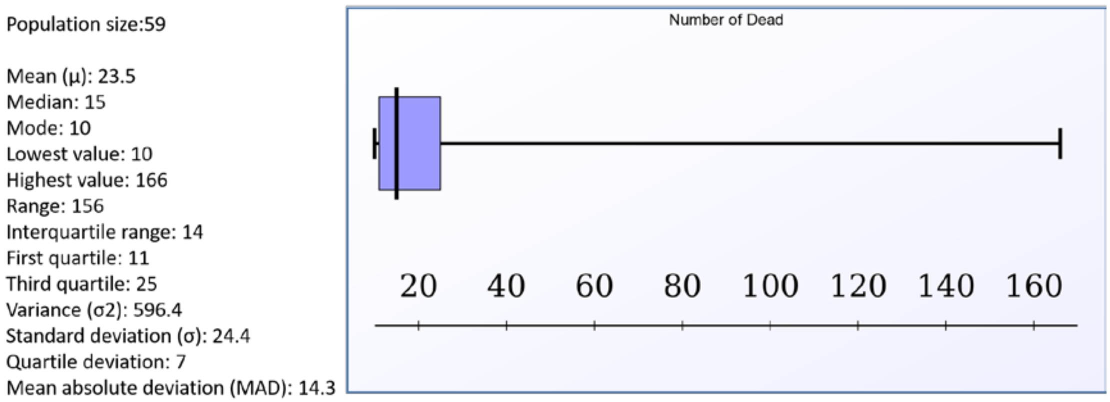

Figure 4.9 EMFD 2010-2018 Total Number of Dead

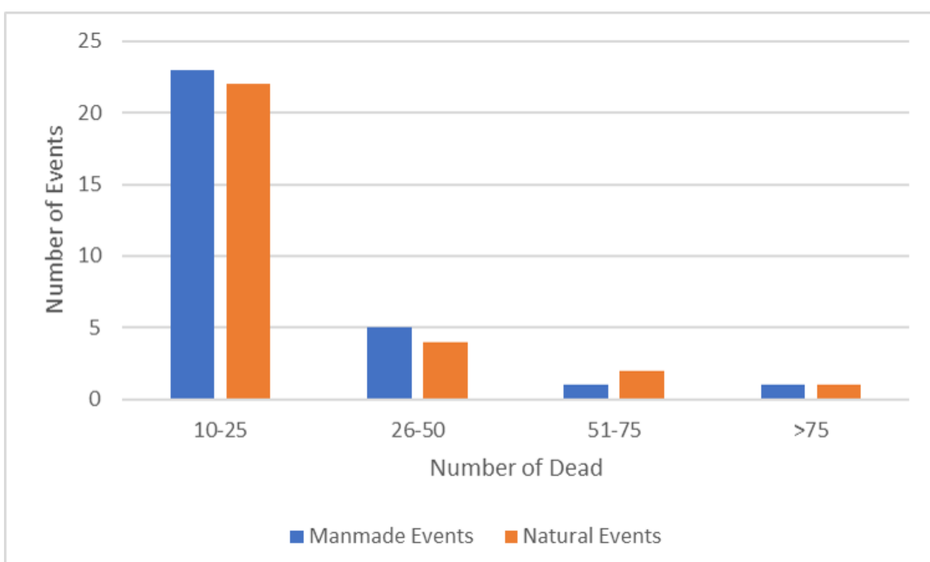

Figure 4.10 EMFD 2010-2018 Breakdown of Number of Dead by Event Type

Additional information collected on each event included: if the President declared the event a federal disaster, if DMORT responded to help retrieve and identify the decedents and if more than one-third of the decedents were under the age of eighteen. A federal disaster declaration is made by the President when requests for assistance from the state/Governor state that the “disaster is of such severity and magnitude that effective response is beyond the capabilities of the state and the local governments and that supplemental federal assistance is necessary (FEMA 2011).” Federal disaster declarations usually occur in natural ‘disaster’ events, which is what is reflected in the EMFD: disasters were declared in 28 total events (47.5%), 26 of which were natural events (92.9%). The two manmade events included the 2018 Camp, CA wildfires (determined to have been started by human activity) and the 2013 McLennan, TX fertilizer plant explosion (determined to be arson). DMORT traditionally responds when there is a large number of decedents, or when the bodies are fragmented, and identification is difficult and requires specialized experts (see Appendix B). DMORT was activated in only nine of the 59 events in the EMFD (15.3%) and included all of the 2011 Alabama tornado supercell counties (7events), the 2011 Joplin tornado response and the 2013 Texas fertilizer plant explosion. A total of eleven events (18.6%) in the EMFD included more than 1/3 of the victims having been under the age of 18. Of these events, only four (36.4%) of them were natural events, primarily flooding (75%) with one tornado event (25%). The seven manmade events (63.6%) in which a third of the deaths were children included three school shootings (42.9%), three accidents (one boat, one plane and one bus accident at 14.9% each) and a house fire (14.9%).

4.3.2 County Demographics: Census Data and Public Safety Answering Points (PSAPs)

As mass fatality events differ and the information collected on them varies, it was important to maximize consistent data across these events. In order to achieve this, descriptive demographic information was compiled on each County that an event occurred in. The EMFD includes events from 2010 to 2018 in order to utilize the most recently published U.S. Census, which was completed in 2010, and the American Community Survey reports, based on the 2010 Census. County data collected included population, urban vs. rural status, average annual employment, mean travel time to work, and the number of hospitals and public safety answering points (PSAPs) or 911 centers within each county. The County demographics, briefly described below, show the largest variability of all variables examined in the EMFD.

The County population where the events in the EMFD occurred in show a spectrum of populations ranging from the low thousands (low of 7,210 in Goliad County, Texas) to the low millions (high of 4,092,459 in Harris County, Texas). Figure 4.11 provides additional descriptive statistics related to the County population across all 59 events in the EMFD. When separated by event type, natural events show a distribution from 9,487 (Montgomery Co., Arkansas) to the overall high of over 4 million in Harris Co., Texas. Manmade events span the overall low of 7,210 from Goliad Co., Texas to 2,035,210 in San Bernadino Co., California.

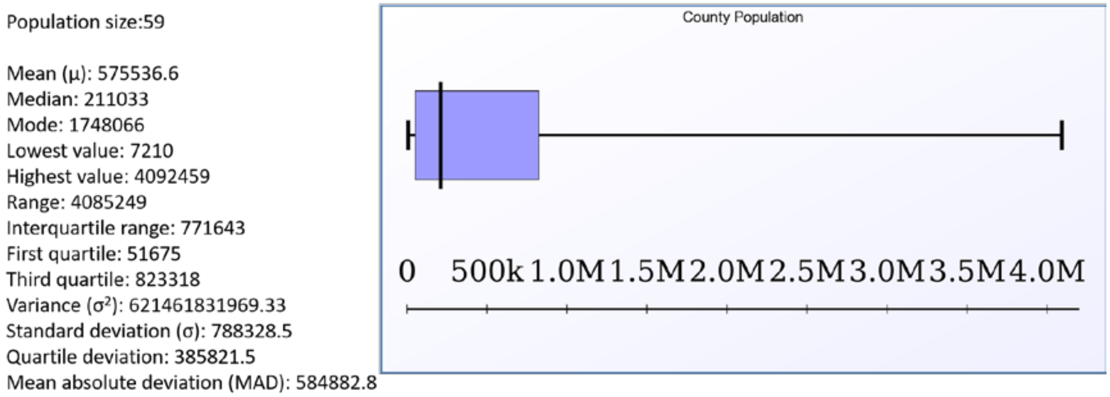

Figure 4.11 EMFD 2010-2018 County-level Population for Events

The County population helps to form the basis of the U.S. Census' definition of urban and rural locations, along with population density, land use and distance from urban centers. Studies using the 2011-2015 American Community Survey, which utilizes the U. S. Census data, show that as of 2015, there were 704 counties in the U.S (22.4%) that met the definition of 'completely rural,' 1,185 counties that were 'mostly rural' (37.7%) and 1,253 counties (39.9%) that qualified as 'mostly urban (Ratcliffe et al., 2016).' Figure 4.12 demonstrates that when applying the urban and rural definitions to the events in the EMFD we see a very different distribution. There is a disproportionally larger number of events occurring in mostly urban counties (74.6%) as compared to those occurring in mostly rural (22%) and completely rural counties (3.4%). The distribution of natural versus manmade events occurring in each category is relatively equal with only slightly more natural events (61.5%) happening versus manmade events (38.5%) in the category of mostly rural counties.

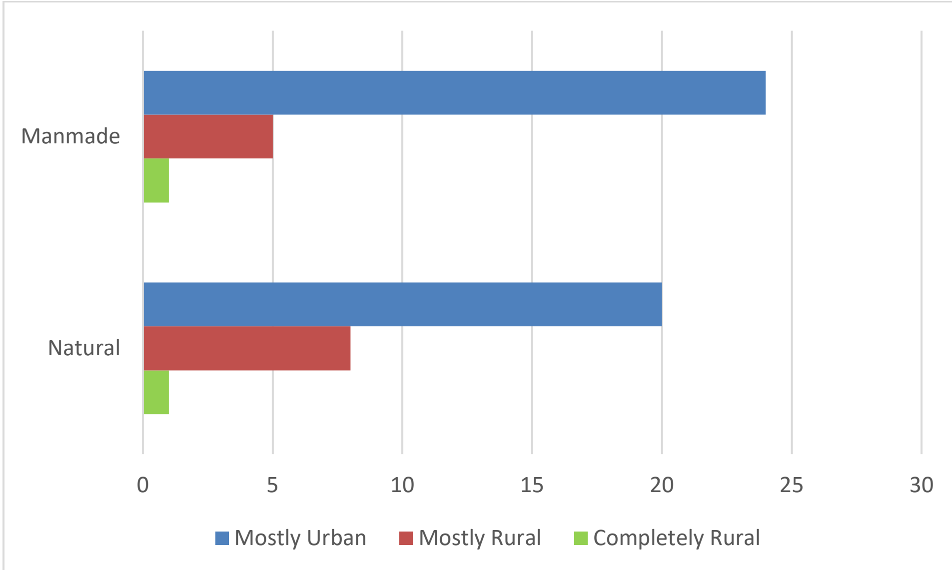

Figure 4.12 EMFD 2010-2018 Urban Versus Rural County Status by Event Type

Additional County demographic variables that correlate to population and rural/urban status include average annual employment and mean travel time to work. These variables are important in that they reflect the amount of movement in or out of the county, which could affect the number of dead and potential for telecommunication failure in any given event, as well as to contribute to the overall revenue streams available to agencies within them – such as first responders, PSAP/911 centers and emergency management. The 15 events that are categorized in counties that are listed as mostly rural or completely rural would suggest that people are moving out of those counties for employment opportunities and similarly that the 44 events that occur in the mostly urban counties would have more people in them at any given time than the county population suggests. Figures 4.13 and 4.14 represent the descriptive statistics and box and whisker plots for the average annual employment and mean travel time to work in minutes for each county that an event from the EMFD occurred in, respectively. These variables work in tandem with county population and rural/urban status in that lower annual employment numbers combined with higher mean travel times are found in those counties that were labeled as completely or mostly rural, and counties with high populations, reflecting mostly urban status, often had high average annual employment numbers, and varied commute times, suggestive of close proximity to work location or high amounts of traffic in congested, urban areas.

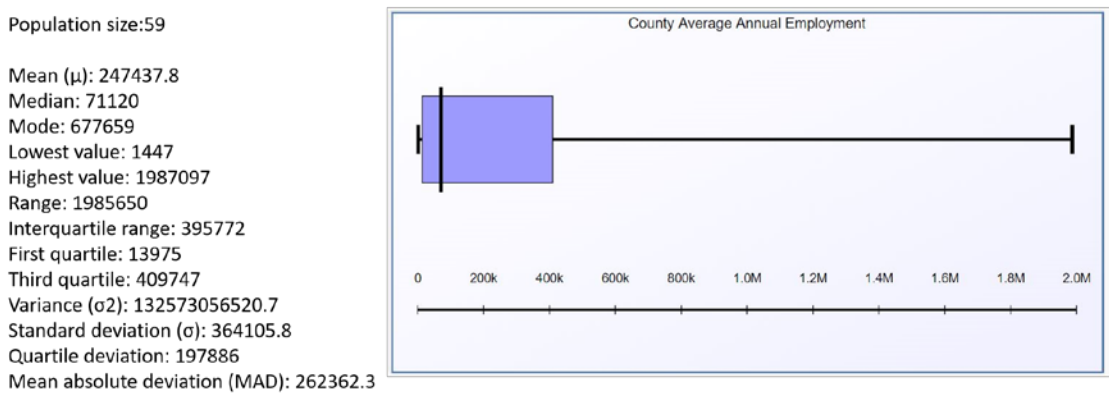

Figure 4.13 EMFD 2010-2018 County-level Average Annual Employment

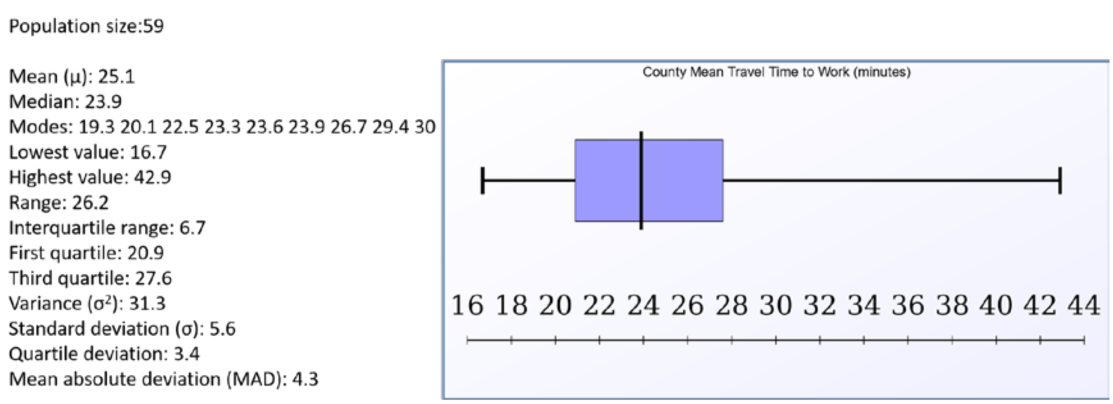

Figure 4.14 EMFD 2010-2018 County-level Mean Travel Time to Work (minutes)

When expounded upon by type of event, Goliad Co., Texas, again, shows up with the lowest average annual employment (1,447) and a larger than average mean travel time to work (30 minutes) for manmade events, while Montgomery Co., Arkansas has the lowest average annual employment (1,651), however with a lower-than-average commute time (20.2 minutes) for natural events. Both of these counties are considered to be completely rural. The counties with the largest average annual employment include Clark Co., Nevada, home of Las Vegas, for manmade events with an average annual employment of 797,062 and a commute time of 23.9 minutes, and Harris Co., Texas, the home of Houston, for natural events, with an average annual employment of 1,987,097 and commute time of 26.9 minutes. Both of these counties are labeled as mostly urban and spread out, suggesting that larger commute times are reflective of traffic, and not people moving out of the county for work.

Similar county-level statistical analyses were performed for both number of hospitals within the county of the event and the number of PSAP/911 centers. Figure 4.15 shows summary statistics and a box and whisker plot for values ranging from a low of no hospitals (Goliad Co, TX), to a high of 58 hospitals (Harris Co., TX) found within the effected counties. Counties with natural events averaged 7 hospitals, while those with manmade events averaged 6, consistent with the overall hospital average of 6.8.

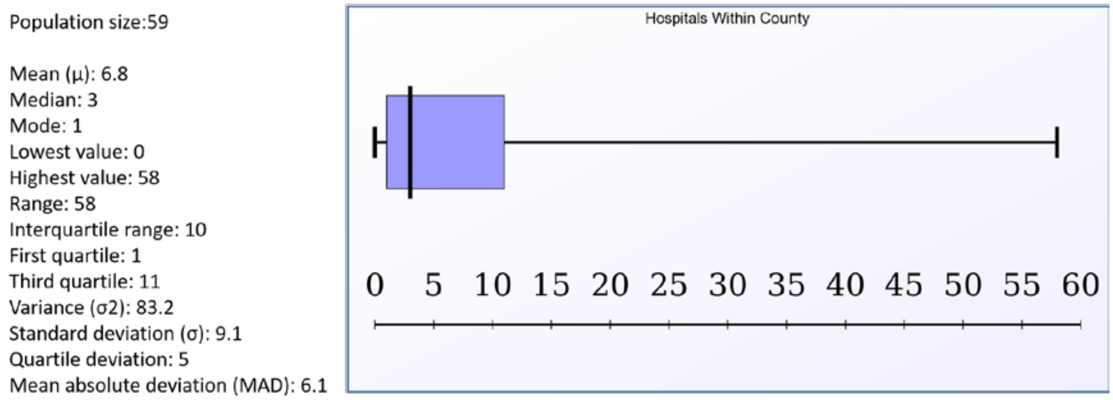

Figure 4.15 EMFD 2010-2018 County-level Number of Hospitals

Public Safety Answering Points (PSAP), managed by the Federal Communication Commission (FCC) are often referred to as 911 centers, as they receive 911 calls and are responsible for distributing those calls to the appropriate responding agency or organization. Data for PSAPs was collected utilizing a county-level PSAP Registry report from the FCC current as of the end of 2019. This is the only variable whose collection data is different than the consistent use of 2010 data, in order to account for the additions or changes to routing in a particular county throughout the period of 2010-2018. Figure 4.16 shows the summary statistics and a box and whisker plot representing the distribution of PSAPs for the 2010-2018 events in the EMFD. A low of one PSAP to a high of 42 PSAPs was found within the effected counties, averaging 7 (6.6) answering centers per county. Both manmade and natural events averaged 7 (6.5) PSAPs within each county, matching the average number of PSAPs for the entire database. It is important to note that all counties labeled as completely or mostly rural had only one or two PSAPs in each county.

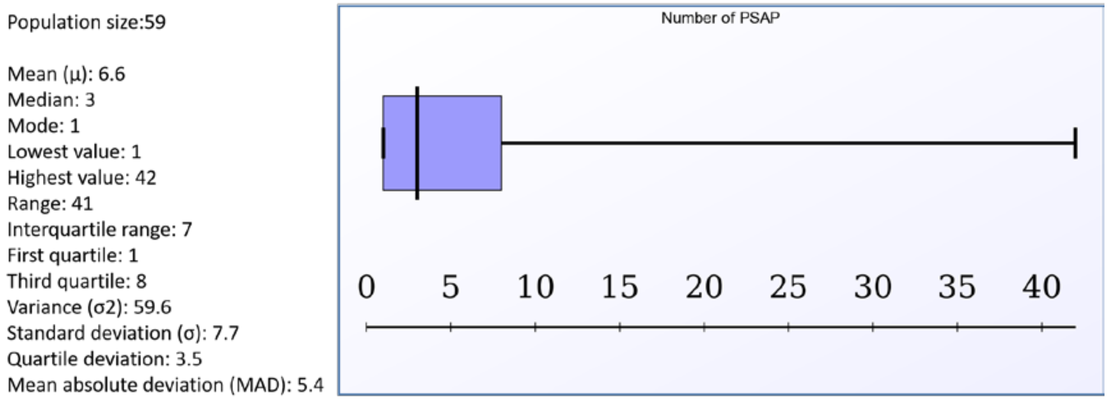

Figure 4.16 EMFD 2010-2018 County-level Number of PSAP/911 Centers

4.3.3 Response: Determining Failure

In order to determine if there was any evidence of communication failure, public reports from each event were examined to see if a consistent definition for communications failure existed. Various terms were found to have been used, and continue to be used, to describe levels or areas of communication failures in ‘disaster’ events, not specific to mass fatality incidents. Reports referencing incidents of 911 calls being dropped, not answered, put on hold, transferred (either successfully or dropped during transfer), damage to cell phone towers or telephone and electric wires that restrict call making or answering abilities, and discussion of issues with radio usage (interoperability between responder agencies, PSAPs, etc.) or personnel issues (not having enough people in the call center) were flagged for further review. After additional examination into the types and intricacies of each failure found, a total of seven categories of failure were created: 1) Evidence of calls being dropped after being answered, 2) Evidence of calls being put on hold, 3) Evidence of calls not being answered (including the 911 system not being available), 4) Evidence of calls being transferred to another PSAP or 911 center, 5) Evidence of not having enough personnel to handle the call volume, 6) Evidence of radio and communication interoperability, and 7) Evidence of damage to cell phone towers and/or electric and telephone lines.

A total of 44.1% of the events (26 out of 59 events) in the Enhanced Mass Fatality Database have public reports documenting at least one category of failure. As seen in Figure 4.1, of those 26 events where any failure occurred, approximately 76.9% (20 events out of 26) of those failures happen in natural events. When examining failure by category of failure type, we see more instances of the 911 system being overwhelmed with calls not being answered (found in 92.3% of failures), damage to the towers and wires supporting the system (found in 80.8% of failures), interoperability and radio issues (found in 65.4% of failures), and calls being transferred to multiple PSAPs occurring most frequently (found 50% of failures) and occurring primarily in natural events. See Figure 4.17. The only categories in which failure occurred more frequently in manmade events as opposed to natural events were when calls were dropped (found in three manmade events versus two natural events) and where personnel issues transpired (documented in four manmade events versus only one natural event). Categories of failure were not independent of each other, as a single event may have shown evidence of multiple types of failure.

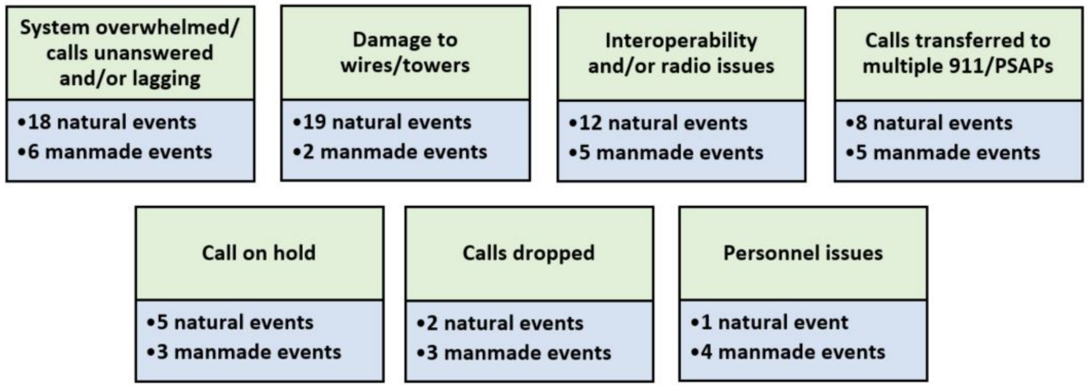

Figure 4.17 EMFD 2010-2018 Events Demonstrating Failure by Failure Category

4.4 Summary EMFD

The diversity of mass fatality events in the United States, in conjunction with the varying types and amount of data collected on each event, make it difficult to determine overarching trends and patterns when looking at these types of events. In order to look at MFIs in a broad framework, all events must be examined using uniform variables, and aggregate data for each event must be the same. This requires the creation of a new Enhanced Mass Fatality Database, which contains event and demographic variables that are consistent both across the events and utilizes single source references for demographic variables. The similar number of natural and manmade events found in the EMFD permit additional analysis to determine what variables affect the chance of telecommunication failures occurring during or after a mass fatality incident. Examination can be done on a macro-scale with the collective of MFIs in the EMFD, or on a micro-scale by exploring the type of event (natural versus manmade) or other MFI specific variable.

Chapter 5

ANALYSIS

5.1 Modeling Communication Failure

The ability to anticipate telecommunication system failures, especially in mass fatality events in which multiple individuals have perished or are injured, is crucial to prevent additional loss of life and property. This knowledge also allows for the creation of appropriate plans and ability to put in place the infrastructure and personnel to prevent additional failures in the future. Previous analytical initiatives using the 911 system focus on predicting geospatial call volume using spatial analyses in order to reduce response time or to map the spatiotemporal extent of large-scale natural, disaster causing, events (Jasso et al., 2007; Cramer et al., 2012). Extremely large-scale MFI events, such as the September 11, 2001 events in New York City and Hurricane Katrina in 2005, highlight the need for more robust 911 infrastructure following broad multisystem failures (Argenti, 2002; Noll, 2003; Comfort & Haase, 2006; Miller, 2006). However, more recent events, with significantly smaller MFI footprints, such as Hurricanes Harvey and Irma (2017) and the California Camp Fire (2018) mimic the need for more robust telecommunication infrastructure following both natural and manmade events in which the infrastructure and systems compromised (Jahanian et al., 2018; Comfort et al., 2019).

Little research has been done to look at multiple MFIs in the same context in order to try to examine what types of events, or if variables associated with those events, directly relate to larger systemic telecommunication failures. The unpredictable nature of mass fatality incidents, in addition to inconsistent data collected and variability in locations in which they occur, demonstrates the difficulty in being able to anticipate not only the event but the possibility for telecommunication failures that follow.

In order to model telecommunication failure in the Enhanced Mass Fatality Database, the seven recognized categories of failure and the aforementioned event and demographic variables were further analyzed using IBM SPSS statistical software to see if there is an association between telecommunication failure and the event and demographic variables collected in the database.

Supported by Figures 4.1 and 4.17, one could make an assumption that the type of event, either manmade or natural, will be one of the biggest predictive factors in whether or not telecommunications failures occur in MFIs, as this is one of the only variables that shows distinct differences between failure occurring. Large scale natural events that cause mass fatality incidents usually occur with environmental damage from winds or flooding, often also effecting critical infrastructure, including electricity and telephone wires, and cell phone towers. These infrastructure damages are not commonly found in manmade events (September 11, 2001 and the California Camp fires of 2018 seem to be the exception), and therefore it could be inferred that telecommunication failures will occur more frequently in natural events. The seven defined categories of failure were each examined independently, and then were grouped together as an ‘any failure’ option (any failure occurs vs. no failure occurs) and as a ‘number of failures’ variable representing the total number of failures for each event.

5.1.1 EMFD Independent Samples T-tests, Correlations, Chi-square Tests of Independence and Cross Tabulations

In order to determine if statistically significant relationships exist between the variables found in the Enhanced Mass Fatality Database and the types of telecommunication failure, the entire database was subject to preliminary exploratory analyses using IBM's SPSS statistics program. Differences between variables are commonly tested using statistical tests such as t-tests, while associations between various types of variables can be determined using correlations, chi-square tests and cross tabulations.

5.1.1.1 Independent Samples T-tests

Two different types of hypotheses were tested using independent samples t-tests:

> Hypothesis 1: Is there a statistically significant difference in the mean value of an event or demographic variable for different types (natural or manmade) of mass fatality incidents?

> Hypothesis 2: Is there a statistically significant difference in the mean value of an event or demographic variable for mass fatality incidents that show evidence of a telecommunication failure and incidents that do not show evidence of a communication failure? This hypothesis was tested for the seven predefined categories of failure.

Independent samples t-tests are commonly used to determine whether there is a significant difference between the means of two groups. Levene's tests for Equality of Variances are used in conjunction with t-tests to see in the groups have homogeneity of variances across the samples. An independent-samples t-test, using Levene's tests for equality of variances, was performed to determine if there were statistically significant differences for the event (number of days, number of dead) and demographic (number of PSAP/911 centers, county population, average annual employment, mean travel time to work and number of hospitals within the county) variables found in the EMFD using the dependent variable of event type (natural or manmade). Additional independent t-tests were performed on those same variables using each of the seven predefined categories of failure. Those statistically significant results of the independent sample t-tests are reported in Table 5.1. For example, the first row of Table 5.1 compares the mean number of dead and the county population for those MFI events with ‘evidence of 911 system being overwhelmed/not answered/lag,’ with the mean number of dead and the county population for those events in which there was no evidence of that specific failure. Overall, there are statistically significant differences in the mean of the number of dead, and in county population, within the groups of: evidence of telecommunication failure in the form of the 911 system being overwhelmed, calls put on hold, transfer to multiple PSAP, damage or not functioning infrastructure and interoperability failures. Levene’s tests show that the variances differ between the groups and that the hypothesis that the means are the same can be rejected. Given these results, further examination into the independent variables will be valuable in determining the strength of the effect of these variables on telecommunication failure. It should be noted that no significant differences were observed for ‘event type’ (Hypothesis 1) and for ‘evidence of call drop’ or ‘evidence of personnel issues’ (two of the seven categories of failure tested using Hypothesis 2).

Table 5.1 EMFD Significant Independent Samples T-tests Results

Group	Variable(s)	Observed t-value (t)	Degrees of freedom (df)	Significance (p) Two-tailed
Evidence of 911 System Overwhelmed/Not Answered/Lag	Dead County Population	-2.67 -1.80	24.95 32.16	.013 .082
Evidence of Call Hold	County Population	-2.29	7.41	.053
Evidence of Transfers to Multiple PSAP	Number PSAP* County Population Avg. Annual Emp. Number Hospitals	-1.84 -2.43 -2.18 -1.90	57 13.60 13.80 13.04	.072 .030 .047 .079
Evidence of Damaged or Not Functioning Wires and Towers	Dead	-2.83	21.22	.010
Evidence of Interoperability Failure/Radio Issues	Dead*	-1.76	57	.083
*Homogeneity of variances as assessed by Levene's test. The assumption of homogeneity of variances for all other independent variables was violated.				

5.1.1.2 Spearman's and Pearson's Correlations

Associations, or correlations, are used to determine if there is a relationship between variables and how the changes of one variable may effect changes in another variable. The following hypothesis was tested using correlations:

> Hypothesis: Is there evidence of statistically significant correlations between the continuous variables collected in the EMFD for mass fatality incidents?

Both Spearman’s and Pearson’s correlations are commonly used statistical tests to examine if any relationship exists between continuous variables and if the manipulation of those variables has a measurable effect on other variables. Pearson’s correlations are commonly used in larger data sets with only linear relationships, while Spearman’s correlations allow for the examination of both linear and monotonic relationships, specifically in smaller samples. Spearman’s correlations were chosen over another commonly used rank correlation test, Kendall’s, based on Spearman’s being more sensitive to error and discrepancies in the data, or the data not having a normal distribution. This was the preferred chosen method, as an examination of histograms of the seven continuous variables in the EMFD (days elapsed, number of dead, county population, number of PSAP/911 centers and hospitals, average annual employment and mean travel time to work), showed skewed distributions, see Figure 5.1. For example, the top row of histograms shows days elapsed, number of dead and county population all positively skewed to the right.

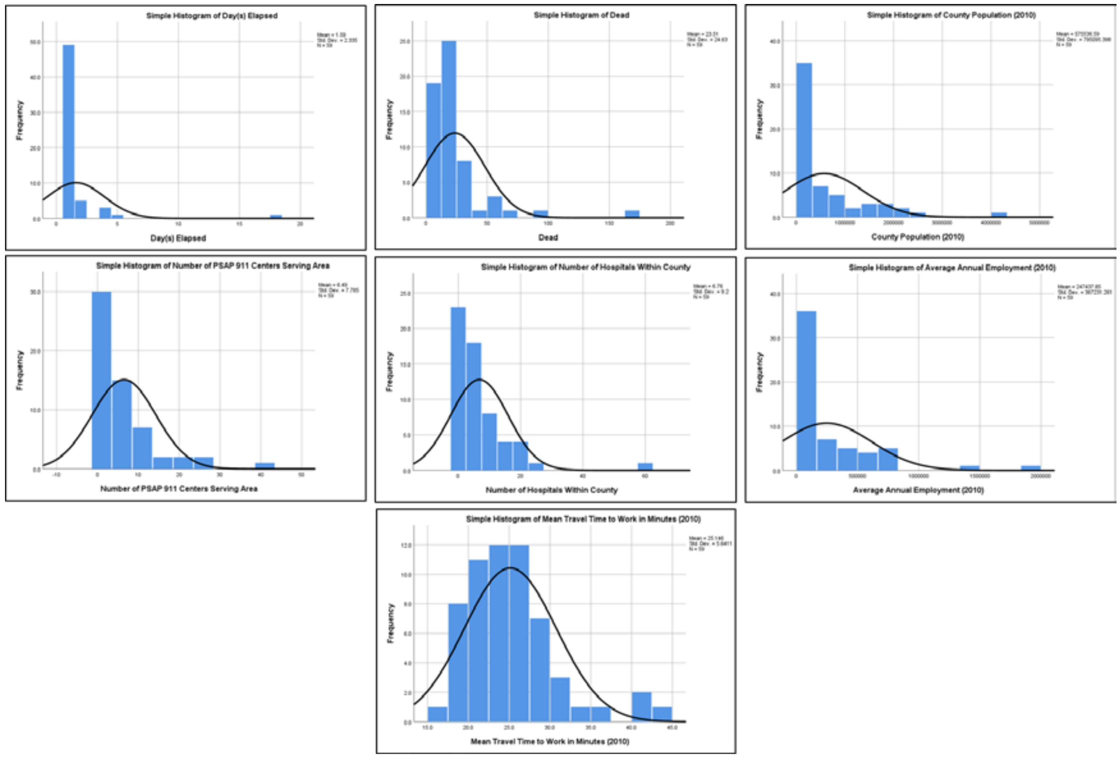

Figure 5.1 Histograms of the Continuous Variables in the EMFD

In order to continue examination of the variables collected in the EMFD, scatterplots and both Spearman's and Pearson's correlations were run on the six independent continuous variables (number of dead, PSAP/911 centers, and hospitals, as well as the county population, average annual employment and mean travel time to work) to determine the strength and direction of any relationship between these variables. As 'days elapsed' showed little variation from the mean of 1, and minimal distribution, with the exception of the 18 days for the 2018 California Camp Fire, it was excluded from the rest of the correlation analysis. Figure 5.2 shows the linear relationship between the variable of 'county population' with the following continuous variables: number of PSAP/911 centers, average annual employment, number of hospitals and mean travel time to work. This suggests that as there is an increase in county population, there should also be an increase any and all of these variables.

Those statistically significant results of the Spearman's and Pearson's correlations, with calculated square of the correlation coefficient (r^2) for Pearson's, are reported in Table 5.2. Both tests showed no significant association between number of dead and any of the other five variables examined. Table 5.2 shows strong positive correlations utilizing both tests between the County population and the number of PSAP/911 centers, and very strong positive correlations between County population and the average annual employment and number of hospitals. County population and mean travel time to work showed a weak positive correlation using the Pearson test but no correlation using the Spearman's test, as evidenced in the last row of Table 5.2. Based on visual evidence of association from scatterplots of the County Population versus the four associated, continuous variables (see Figure 5.2), all showing positive linear correlations, as well as the evidence from the Spearman's and Pearson's Correlation tests, the null hypothesis that there is no association between the continuous variables in the EMFD can be rejected.

Table 5.2 EMFD Significant Results of Pearson's and Spearman's Correlations

Variable 1	**Significant Variable**	**Pearson Corr. Value (r)**	**Square of the Corr. Coeff (r^2)**	**Pearson's Sig (p_r)**	**Spearman's Corr. Value (r_s)**	**Spearman's Rho Sig (p_{rs})**
County Pop	PSAP/911	.726	.527	.000	.671	.000
	Avg. Ann. Emp.	.937	.878	.000	.969	.000
	Time to Work	.334	.116	.010	--	--
	Hospitals	.931	.867	.000	.899	.000
Number of PSAP /911 Centers	Avg. Ann. Emp	.784	.615	.000	.700	.000
	Hospitals.	.774	.599	.000	.671	.000
Average Annual Emp.	Hospitals	.958	.918	.000	.917	.000

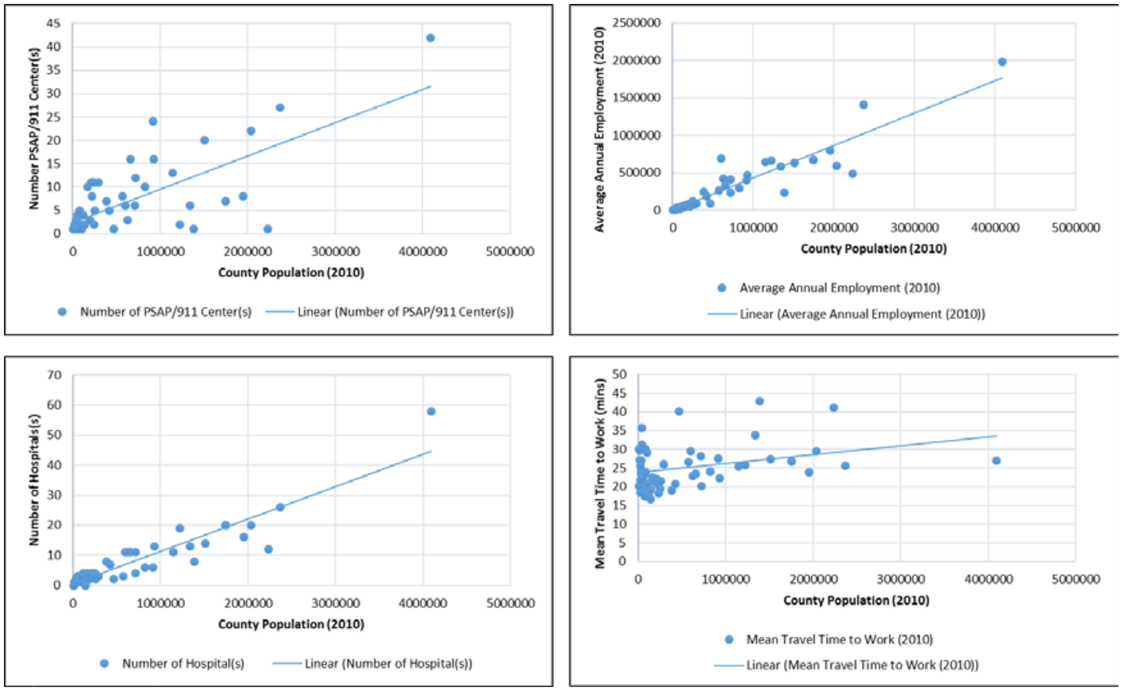

Figure 5.2 Correlation Scatterplots of County Population in Relation to Other Continuous Variables in the EMFD

5.1.1.3 Chi-square Tests of Independence with Cross-tabulations

To continue the examination of the relationship between the variables in the EMFD relate to one another and to the categories of telecommunication failure, chi-square tests of independence were performed. The following hypothesis was tested using chi-square tests of independence with cross-tabulations:

> Hypothesis: Does the type of mass fatality incident, and the categorical demographic variables of the location in which the event occurs in, have an association with a type of telecommunication failure occurring?

Chi-square tests are common statistical analyses used to determine the significance of the observations of data and reflect how they differ from the expected outcomes in a random sample, primarily when there is a small sample size. Chi-square analyzes whether two variables measured at the nominal level are independent or if there is an association between the two variables. In SPSS the chi-square test of independence utilizes the Pearson chi-square statistic and an alpha level of significance of 95% (<.05) and is run when requesting a cross-tabulation in the program. A confidence level of 95% or higher is considered standard, while a 90-94.99% confidence level can be noted for supporting evidence. Cross-tabulations were performed to determine if the type of event and the categorical demographic variables found in the EMFD show any significant relationship to the type and occurrence of one of the categories of failure. A 2x2 table cross-tabulation, with chi-square test of independence, was performed for each of the seven predefined categories of failure and the categorical demographic variables and event typology documented in the EMFD. Several of the categorical variables have multiple categories within them, resulting in larger than 2x2 cross-tabulations tables: state is 2x27, FEMA region is 2x9, population density is 2x3, event subtype is 2x3, and event sub-subtype is 2x10.

Those statistically significant results of the cross-tabulations, with Pearson chi-square value (x^2), degrees of freedom (df) and significance (p), are reported in Table 5.3. There is no evidence of association between evidence of call drop and any of the categorical independent variables, however there is significant associations between the event demographics (event type, subtype and sub-subtype) and several of the categories of failure (911 system overwhelmed, evidence of multiple transfers, evidence of damage/not functioning wires and towers, and interoperability). For example, the first row of Table 5.3 shows that when looking at 'evidence of 911 system overwhelmed/not answered/lagged,' this variable is related to 'event type,' 'event subtype,' 'event sub-subtype,' 'federal disaster declaration,' 'DMORT response,' and '>1/3 child victims.' However, those variables marked by an asterisk represent cells in which there were less than 5 observations in that specific category, so for the variables of 'event sub-subtype,' 'DMORT response,' and '>1/3 child victims,' this demonstrates an unbalanced design and would not be considered statistically sound in order to use those variables to generalize the results to a larger population. Due to the small size of the sample, these variables have been included in the results for supporting evidence only.

There are a total of four telecommunication failure categories (evidence of 911 system overwhelmed, evidence of transfers to multiple PSAPs, evidence of damage/not functioning towers and wires, and evidence of interoperability) that show statistically significant associations with three independent variables in which there are sound cell counts. Those variables include event type, event subtype and federal disaster declaration. General assumptions can be made on the remaining variables found in Table 5.3 that support the variables showing significance, with accepted cell counts: Federal disaster declarations are almost exclusively used in natural event responses, which would allow for the use of DMORT in events where there are a large number of dead, including the possibility of child deaths (as in a plane crash or tornado response). Natural events, based on their unpredictability, have the capacity to create larger scale mass fatality incidents, and may also incapacitate the infrastructure in place leading to telecommunication failures. The evidence of statistically significant associations for these additional variables, allows for the rejection of the null hypothesis, that there is no association, and suggests further examination of the relationship between failure and the variables found in the EMFD.

Table 5.3 EMFD Crosstabs of Failure and the Associated Significant Variables with Pearson Chi-square Value and Significance Level

Dependent Variable	**Independent Variable(s)**	**Pearson chi-square (x^2)**	**Degrees of freedom (df)**	**Significance (p) Two-tailed**
Evidence of 911 System Overwhelmed/Not Answered/Lag	Event Type	10.815	1	.001
	Event Subtype	12.527	2	.002
	Event Sub-subtype*	26.824	9	.001
	Federal Disaster	16.313	1	.000
	DMORT Response*	10.229	1	.001
	>1/3 Child Victims*	3.011	1	.083
Evidence of Call Hold	Event Sub-subtype*	16.219	9	.062
	Federal Disaster*	2.816	1	.093
Evidence of Transfers to Multiple PSAP	Event Sub-subtype*	33.969	9	.000
	Population Density*	5.684	2	.058
	Federal Disaster	3.170	1	.075
Evidence of Damaged or Not Functioning Wires and Towers	Event Type	22.278	1	.000
	Event Subtype*	20.494	2	.000
	Event Sub-subtype*	35.413	9	.000
	Federal Disaster	24.198	1	.000
	DMORT Response*	13.159	1	.001
Evidence of Interoperability Failure/Radio Issues	DMORT Response*	12.413	1	.000
	State*	38.524	23	.022
	Federal Disaster	5.124	1	.024
	Event Type	4.390	1	.036
	FEMA Region*	15.618	8	.048
	Event Subtype*	5.826	2	.054
Evidence of Personnel Issues	Population Density*	5.672	2	.059
	Event Subtype*	4.698	2	.095
*At least 1 cell in the table has an expected cell count less than five. A count of 5 or more is considered statistically sound, providing a balanced design, a greater ability to generalize to a larger population. Cell counts of less than give allow for a greater negative effect a violation of an assumption has on the validity of the test.				

5.1.2 EMFD Regression Models

In order to explore the relationships between independent variables and evidence of telecommunication failure various regression models were created and their performance assessed as predictors of telecommunication failures. These models included using those four categories of failure that demonstrated associations with other EMFD variables, as their own dependent variable, as well as grouping all types of failure into a failure or no failure option, and as a linear regression model in which the number of types of failures that occur was the dependent variable.

5.1.2.1 Logistic Regression: Telecommunication Failure by Category

The statistically significant associations and relationships demonstrated by the t-tests, correlations and chi-square with cross-tabulations, suggest that it may be possible to create predictive regression formula(s) to anticipate telecommunication failure during a mass fatality incident. Binomial logistic regression is a commonly used statistical analysis that attempts to predict the probability that an observation falls into one of two categories of a dichotomous dependent variable based on one or more independent variables that can be either continuous or categorical.

The four categories of failure which showed statistically significant results from the previous statistical analyses, 'evidence of the 911 system being overwhelmed/not answered/lagged,' 'evidence of transfer to multiple PSAP,' 'evidence of damaged or not functioning wires and towers,' and 'evidence of interoperability/radio issues,' were subject to preliminary exploratory analyses using binomial logistic regression in order to test the following hypothesis:

> Hypothesis: Specific types of telecommunication failure can be predicted using event and demographic variables for mass fatality incidents.

Several alternative regressions were executed using all of the originally significant dichotomous independent variables (event and demographic variables) found in the Enhanced Mass Fatality Database in order to determine those variables that were best able to predict the probability that one of the four dichotomous dependent variable categories (telecommunication failure) will occur. The results from the Pearson's and Spearman's Correlation, which showed a significant positive relationship between the variable of 'county population' with 'number of hospitals,' 'number of PSAP/911 centers,' 'average annual employment,' and 'mean travel time to work,' suggest that 'county population' can be representative of these other variables in any regression modelling. There was also evidence of multicollinearity to support this finding in the alternative regression models. Preliminary analysis indicated that the regressions were insensitive to a unit change in population although statistically significant. The regressions were run using the county population in millions. Using event type, the number of dead and county population (in millions) as the independent variables, as these variables showed greater associations and correlations in previous statistical analyses, Table 5.4 shows the final binomial logistic regression formulae with the chi-square (x^2) value and significance (p) for the model, as well as the percent of cases predicted correctly to demonstrate how the model, inclusive of the tested independent variables, performs.

Table 5.4 EMFD Final Binomial Logistic Regression Formulae by Failure Type

Dependent Variable	**Binomial Logistic Regression Formula***	**Model Chi-square (x^2)**	**Model Significance (p)**	**Model Predicted Percent Correct (%)**
Evidence of 911 System Overwhelmed/ Not Answered/ Lag	-3.979 + 1.031 (county pop (m)) + 0.078(dead) + 2.393 (event type)	28.791	<.0005	76.3
Evidence of Transfers to Multiple PSAP	-2.977 + 1.343 (county pop (m)) + 0.016 (dead) + 0.702(event type)	12.187	.007	79.7
Evidence of Interoperability/ Radio Issues	-2.063 + 0.059 (county pop (m)) + 0.019(dead) + 1.196 (event type)	6.688	.083	71.2
Evidence of Damaged or Not Functioning Wires and Towers	-34.010 + 1.325 (county pop (m)) + 0.586(dead) + 24.906 (event type)	59.527	<.0005	94.9

*P(Failure)/(1-P(Failure)) = exp(b_0+b_1(county population (millions)) + b_2(dead)+b_3(event type))

or

$$P(\text{Failure}) = \frac{1}{1+\exp(-(b_0+b_1(county\ population\ (millions))+b_2(dead)+b_3(event\ type)))}$$

Variation in the model is tested using both the Cox & Snell R squared and Nagelkerke R square values, both of which are commonly used statistical methods for calculating the explained variation. The Cox & Snell R^2 value is usually smaller than the Nagelkerke R^2, as it is based on the log likelihood for the model, as compared to the likelihood of the baseline model without the independent variables, and therefore cannot reach a value of 1 to reflect 100% of variation explained. The Nagelkerke R^2 value is a modification of the Cox & Snell value, and therefore will always have a larger value. Both R^2values will be reported to show the range of variation for the binomial logistic regression model. Other reported values include the model sensitivity, specificity, and positive and negative predictive values, as well as the exponential B (Exp(B)), or odds value, for each of the independent variables. The sensitivity refers to the percentage of cases that showed failure and were correctly predicted by the model to show the type of failure, while specificity is the percentage of cases that showed no failure and were also correctly predicted as not having that type of failure. The positive predictive value is the percentage of correctly predicted cases with the observed failure compared to the total number of cases predicted as having the failure, or more simply, the percent correctly predicted of all the cases showing that type of failure. The negative predictive value is the percentage of the correctly predicted cases without the failure, compared to the total number of cases predicted as not having that type of failure. When discussing logistic binomial regressions, odds are used to reference the Exponential B value (Exp(B)), or exponential coefficient, indicating how the change of one unit of the independent variable will then change the odd of the dependent variable by the number shown by the Exp(B) term. Values less than one for the Exp(B) value indicate a decreased odds for an increase in one unit of the independent variable. Table 5.5 shows the independent variables used in each model with variable coefficient (B), Wald test ratio, which is more commonly used than a t-test for smaller sample size such as those found in the EMFD, two-tailed significance level (p) and Exp(B) statistics. Detailed results of the logistic binomial regression analyses for each of the four categories of telecommunication failure are discussed below:

i. A binomial logistic regression was performed to ascertain the effects of event type, number of dead and county population

(2010) on the likelihood of occurrence of telecommunications failure in the form of **911 system overwhelmed/not answered/lag**. The logistic regression model was statistically significant, $\chi^2(3) = 28.791$, $p < .001$. The model explained 38.6-52.1% (Cox & Snell R^2 to Nagelkerke R^2) of the variance in this type of failure and correctly classified 76.3% of cases. Sensitivity was 66.7%, specificity was 82.9%, positive predictive value was 72.7% and negative predictive value was 78.4%. Of the three predictor variables only two were statistically significant at $\alpha=0.05$: number of dead and event type, but all three statistically significant at $\alpha=0.10$. Natural events had 10.943 times higher odds to include this type of failure than manmade events. Increasing number of dead was associated with an increased likelihood of this type of failure. For each additional million in county population the odds of this type of failure are 2.805 times higher.

ii. A binomial logistic regression was performed to ascertain the effects of event type, number of dead and county population (2010) on the likelihood of occurrence of telecommunications failure in the form of **transfers to multiple PSAP/911 centers**. The logistic regression model was statistically significant, $\chi^2(3) = 12.187$, $p = .007$. The model explained 18.7-28.6% (Cox & Snell R^2 to Nagelkerke R^2) of the variance in this type of failure and correctly classified 79.7% of cases. Sensitivity was 30.8%, specificity was 93.5%, positive predictive value was 57.1% and negative predictive value was 82.7%. Of the 3 predictor variables only one was statistically significant: county population, with the odds of failure in a county with an additional million population being 3.832 higher.

iii. A binomial logistic regression was performed to ascertain the effects of event type, number of dead and county population (2010) on the likelihood of occurrence of telecommunications failure in the form of **interoperability failure/radio issues**. The logistic regression model, $\chi^2(3) = 6.688$, $p = .083$, was statistically significant at the 90% level but not at the 95% level. The model explained 10.7-15.3% (Cox & Snell R^2 to Nagelkerke R^2) of the variance in this type of failure and correctly classified 71.2% of cases. Sensitivity was 11.8%, specificity was 95.2%, positive predictive value was 50.0% and negative predictive value was 80.0%. Of the 3 predictor variables, none were considered statistically significant, however event type had a p-value of .057, suggesting that the event type increases the odds of having this type of failure. Natural events have a 3.306 times higher odds to include interoperability issues than manmade events.

iv. A binomial logistic regression was performed to ascertain the effects of event type, number of dead and county population (2010) on the likelihood of occurrence of telecommunications failure in the form of **damaged or not functioning wires and/or towers**. The logistic regression model was statistically significant, $\chi^2(3) = 59.527$, $p<.005$. The model explained 63.5-87.3% (Cox & Snell R^2 to Nagelkerke R^2) of the variance in this type of failure and correctly classified 94.9% of cases. Sensitivity was 90.5%, specificity was 97.4%, positive predictive value was 95.0% and negative predictive value was 94.9%. Of the 3 predictor variables, only two, event type and number of dead, were statistically significant. Natural events and increasing the number of dead increase the odds of having this specific type of failure.

Table 5.5 EMFD Failure Type Binomial Logistic Regression Model Variable Statistics

Dependent Variable	**Independent Variables in Model**	**Coefficient B Value**	**Wald Statistic**	**Sig (p) Two-tailed**	**Exp(B)**
Evidence of 911 System Overwhelmed/ Not Answered/Lag	Event Type	2.393	9.177	.002	10.943
	Dead	.078	6.001	.014	1.081
	County Pop(m)	1.031	3.540	.060	2.805
	Constant	-3.979	14.339	.000	.019
Evidence of Transfers to Multiple PSAP	Event Type	.702	.912	.339	2.018
	Dead	.016	1.664	.197	1.016
	County Pop(m)	1.343	7.397	.007	3.832
	Constant	-2.977	14.295	.000	.051
Evidence of Interoperability	Event Type	1.196	3.612	.057	3.306
	Dead	.019	1.711	.191	1.019
	County Pop(m)	.059	.026	.871	1.060
	Constant	-2.063	10.342	.001	.127
Evidence of Damaged or Not Functioning Wires and Towers	Event Type	24.906	4.708	.030	6.554E10
	Dead	.586	5.189	.023	1.797
	County Pop(m)	1.325	2.672	.102	3.764
	Constant	-34.010	5.060	.024	.000

The results of the binomial logistic regression models for the four categories of telecommunication failure showed evidence that at least three types of failure were found to have statistical significance. The independent variables in the logistic regression formulas, specifically event type and number of dead, showed significant associations to the specific type of failures tested, with county population (in millions) showing some association. Based on this evidence, the null hypothesis, that telecommunication failure is not predicted based on event and demographic variables, can be rejected, however further examination is required to determine if predictability of failure occurring exists given the variables collected in the EMFD.

5.1.2.2 Logistic Regression: Failure or No Failure

Understanding that binomial logistic regression models for the four tested categories of failure demonstrated statistical significance, suggests that a comprehensive "failure" or "no failure" dependent variable should be examined. A "failure" occurred if any of the seven categories of telecommunication failure occurred in order to test the following hypothesis:

> Hypothesis: Telecommunication failure, inclusive of any and all types of failure, can be predicted using event and demographic variables for mass fatality incidents.

Binomial logistic regressions were performed to ascertain the effects of event type, number of dead, and county population (2010) on the likelihood of the **occurrence of any type of telecommunication failure**. Aforementioned binomial logistic regression methodology was employed, and the same statistics and values previously discussed are shown below in Table 5.6 and Table 5.7. These tables show the significance of the models for evidence of any type of telecommunication failure and the data for each of the independent variables, respectively. The binomial logistic regression was performed twice, with and without the independent variable of county population (2010) to ascertain the effects of that variable on the model.

Table 5.6 EMFD Any Failure Binomial Logistic Regression Formula

Dependent Variable	**Binomial Logistic Regression Formula**	**Model Chi-square (x^2)**	**Model Sig (p)**	**Model Predicted Percent Correct (%)**
Evidence of Any Telecommunication Failure (with population)	Failure = -4.078 + 2.747 (event type) + 0.089(dead) + 0.861 (county pop(m))	31.994	<.0005	78.0
Evidence of Any Telecommunication Failure (without population)	Failure = -3.556+ 2.572 (event type) + 0.094(dead)	31.994	<.0005	79.7

Table 5.7 EMFD Any Failure Binomial Logistic Regression Model Variable Statistics

Dependent Variable	**Independent Variables in Model**	**Coeff. B Value**	**Wald Statistic**	**Sig (p) Two-tailed**	**Exp(B)**
Evidence of Any Telecommunication Failure (with county population)	Event Type Dead County Pop (m) Constant	2.747 .089 .861 -4.078	11.623 5.849 2.411 13.684	.000 .016 .120 .000	15.589 1.093 2.365 .017
Evidence of Any Telecommunication Failure (without county population)	Event Type Dead Constant	2.572 .094 -3.556	11.757 7.112 13.330	.001 .008 .000	13.092 1.098 .029

The logistic regression model including county population (2010) was statistically significant, $\chi^2(3) = 31.994$, $p < .0005$. The model explained 41.9-56.1% (Cox & Snell R^2 to Nagelkerke R^2) of the variance in this type of failure and correctly classified 78.0% of cases. Sensitivity was 76.9%, specificity was 78.8%, positive predictive value was 74.1% and negative predictive value was 81.3%. Of the three predictor variables only two were statistically significant: number of dead and event type. Similar to the binomial logistic regression formulae for the four categories of failure tested, the variable of county population showed a coefficient of .000 but suggests a positive association to failure occurring. Natural events had 15.589 times higher odds to have any type of failure occurring as compared to manmade events. Increasing the number of dead and an increase in the county population were also associated with an increased likelihood of any telecommunication failure occurring.

The logistic regression model not inclusive of the variable county population (2010) was statistically significant, $\chi^2(2) = 29.168$, $p < .0005$. The model explained 39.0-52.3% (Cox & Snell R^2 to Nagelkerke R^2) of the variance in this type of failure and correctly classified 79.7% of cases. Sensitivity was 80.8%, specificity was 78.8%, positive predictive value was 75.0% and negative predictive value was 83.9%. Of the two predictor variables both number of dead and event type were statistically significant. When county population was removed from the model, natural events had 13.092 times higher odds of any type of telecommunication failure occurring than manmade events. Increasing the number of dead was again also associated with an increased likelihood of any failure occurring but relatively little influence.

The results of the binomial logistic regression models for any evidence of telecommunication failure (with and without county population) were both shown to have statistical significance. The independent variables in the logistic regression formula, specifically event type and number of dead, showed significant associations to the specific type of failures tested. Based on this evidence, the null hypothesis, that telecommunication failure is not predicted using event and demographic variables, can be rejected, however further examination is required.

5.1.2.3 Linear Regression: Number of Failures

The dependent variable, failure or no failure, from the binomial logistic regression in the previous section, suggested that looking holistically at telecommunication failure provides data that suggests predictive models can be employed to anticipate these types of failures during mass fatality incidents. To further examine this concept, telecommunication failure was transformed into a scaled dependent variable representing the number of types of failure on a scale from 0 (no failure) to a total of 7 (inclusive of all of the predefined categories of telecommunication failure). This new dependent variable can be thought of as an indicator of the complexity of the telecommunications failure in order to test the following hypothesis:

> Hypothesis: The number of types of telecommunication failure(s) that may occur during a mass fatality incident can be predicted using event and demographic variables.

A multiple linear regression analysis is a commonly used statistical method to predict a scale or continuous dependent variable based on multiple independent variables. As this research focuses on the multiple event and demographic variables associated with mass fatality incidents as a means to anticipate telecommunication failure, a multiple linear regression can be applied. Multiple linear regression was completed in order to model the relationship utilizing the scaled dependent variable (number of types of telecommunication failures 0-7) and the scale and dichotomous independent variables (event type, number of dead and county population (2010)), to determine which predictor variables most effected the regression model. Table 5.8 and

Table 5.9 show the overall statistical significance of the model and the statistic details for each coefficient, respectively.

Table 5.8 EMFD Number of Failures Multiple Linear Regression Formula

Dependent Variable	**Linear Regression Formula**	**R^2**	**Adjusted R^2**	**F value**	**Model Sig.(p)**
Number of Types of Failure (0-7)	1.466 + 1.098(event type*) + .031(dead) + 0. 7374(county pop(m))	.349	.314	9.837	<.0005

Table 5.9 EMFD Number of Failures Multiple Linear Regression Model Variable Statistics

Dependent Variable	**Independent Variables in Model**	**Coefficient B Value**	**T value**	**Sig (p) Two-tailed**
Number of Types of Failure (0-7)	Event Type	1.098	11.623	.014
	Dead	.032	5.849	.001
	County Pop (m)	. 7374	2.411	.009
	Constant	-.130	13.684	.736

This linear regression established that event type, number of deaths and county population showed statistical significance in predicting **number of failures** when controlling for all other variables in the model, $F(3, 55) = 9.837$, $p < .0005$ and these those variables accounted for 34.9% of the variability (R^2) in the number of types of failure that can be explained by the independent variable in the data. The adjusted R^2 value, is 31.4%, and provides the explained variability that would be expected in the population. The final multiple linear regression equation, where for event type* 0 =manmade and 1=natural:

Number of types of failures = 1.466 + 1.098(event type*) + .031(dead) + 0.7374(county pop(m))

Similar to the previous logistic regression analyses, the linear regression model shows that natural events, the number of deaths and the county population significantly impact the number of types of telecommunication failures that occur during mass fatality incidents. On average, natural events result in one additional type of failure occurring, while increasing both the number of dead and the county population increase number of types of failures. Approximately 35 additional dead or almost an additional 1.5 million people, in the county of the event, have the same impact on the number of types of failure as a natural event. Based on this evidence, we would reject the null hypothesis that the number of types of telecommunication failures cannot be predicted using event and demographic variables.

5.2 Verifying Communication Failures

The 59 events in the 2010-2018 EMFD were examined using the linear regression formula predicting number of types of failure. When the linear regression, Number of Failures = 1.466 + 1.098(event type*) + .031(number of deaths) + 0. 7374(county population (m)), where for event type 0=manmade, 1=natural, was applied to the database it correctly predicted the occurrence of failure in those events in which failure occurred, *100% of the time* (26 out of the 26 events in the EMFD that had documented failure). When comparing the exact number of documented failures to the correctly predicted number of failures using the linear regression formula, exactly 50% (13 of the 26 events documenting failure) of the number of telecommunication failures were predicted correctly.

Given the constant in the formula of 1.466, failure will always be predicted, including for those events in which there is no evidence of documented failure (33 out of 59 events). These events account for a total of 55.9% of the results of the linear regression being incorrect. This formula correctly predicted some failure occurring in 84.6% (22 out of 26 events) in which failure did occur. It was incorrect in 25.4% of the total events (15 out of 59), but only 15.4% (4 out of 26 events) of events where failure occurred.

Understanding that no model is perfect, the linear regression model was able to correctly predict telecommunication failure occurring in events in which there is documented evidence of some failure happening 100% of the time. More importantly, the data and models provide insights into telecommunication failures during mass fatality incidents, and the attributes of the events and demographics of the counties in which they occur. The model suggests that there will be evidence of, on average, one more type of failure when a natural event takes place. Due to the unpredictable nature of these types of events and not being able to be geographically contained, natural events have a greater opportunity to destroy critical infrastructure and cause an increase in death; all of which is crucial knowledge for those professionals involved in emergency management and telecommunications for planning and preparedness purposes and for the distribution of resources.

5.3 Validation Using 2019 Data

The Enhanced Mass Fatality Database was expanded using the predefined basis of a mass fatality event, for those incidents that took place in 2019, as a means of expounding on the data and using the regression formulas to see if they continued to be able to anticipate telecommunication failure(s), as their profile is consistent with earlier events.

5.3.1 EMFD 2019 Events

A total of seven mass fatality events transpired that had requirements for inclusion into the EMFD. Unlike the 2010-2018 events in which there were practically equal distribution of natural versus manmade events, the 2019 events were skewed in that they were almost exclusively manmade events (85.7% or 6 out of 7 events). The seven events in 2019 consisted of one natural tornado event in Alabama (14.3% of total events), three accidents (42.9% of total events) and three criminal shootings (42.9% of total events), as seen in Figure 5.3.

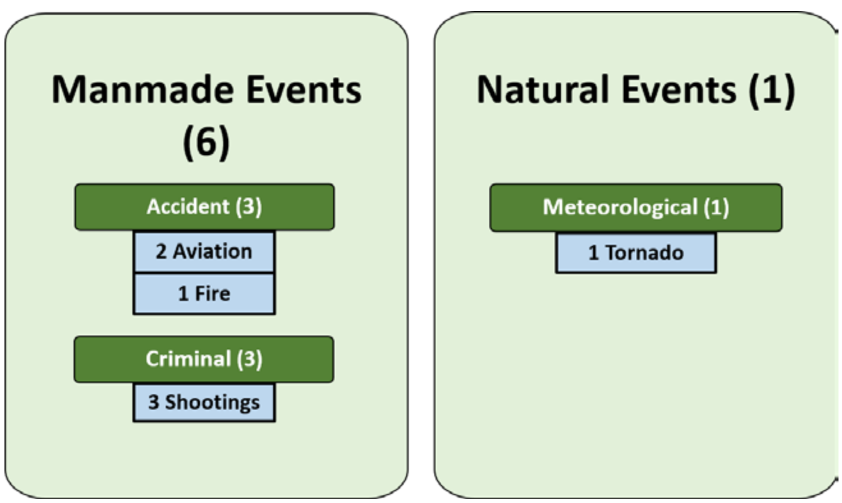

Figure 5.3 EMFD 2019 Events by Type, Subtype and Sub-subtype

Similar to events from 2010-2018, the 2019 events happened across the country, as shown in Figure 5.4, however, each state only had one event (Hawaii, Alabama, Virginia, California and Ohio), with the exception of Texas which had two shootings. Related to the distribution in states, most FEMA regions in which the 2019 MFI events occurred in experienced only one event (Regions 3, 4, 5) with the exception of Region 6 (Texas) and Region 9 (inclusive of California and Hawaii), that each had two MFI events.

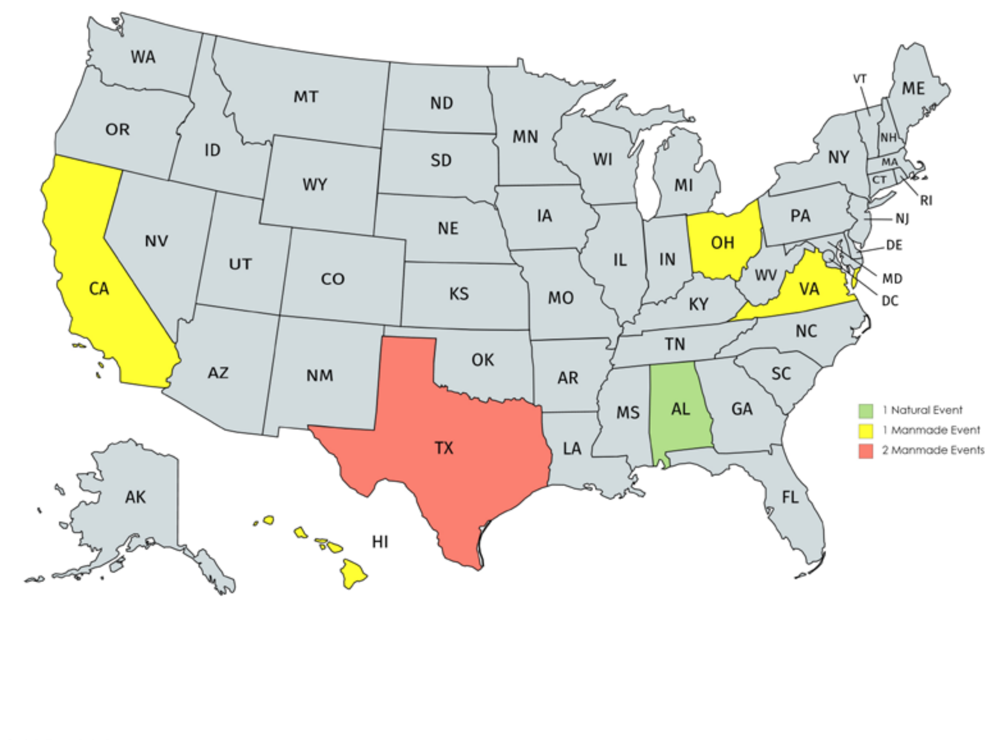

Figure 5.4 EMFD 2019 Events by Location and Type

Event data was again collected on the 2019 MFI events, using public internet and news sources to gain information on the location and number of dead in each incident. All 2019 events lasted only a single day, and occurred in locations that were considered to be ‘mostly urban.’ The average number of dead for the 2019 incidents was approximately 18, with a low of 10 from a plane crash in Addison, TX to a high of 34 in the Conception Boat Fire off the Santa Barbara, CA coast, as seen in Figure 5.5.

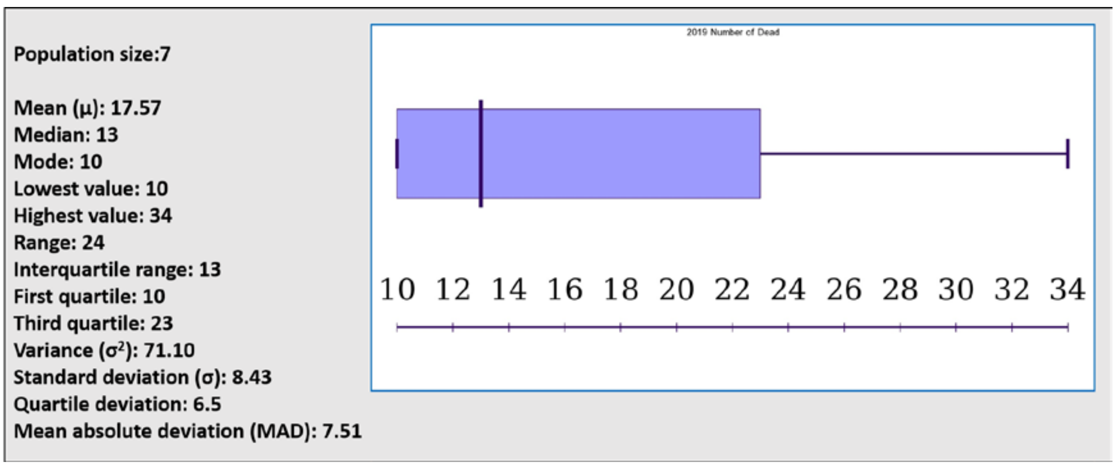

Figure 5.5 EMFD 2019 Events Total Number of Dead

County demographic data was collected on the 2019 events utilizing the most recently published U.S. Census, which was completed in 2010, and the American Community Survey reports, based on the 2010 Census. The average county population for the 2019 events ranged from a low of approximately 140,000 in Lee Co., Alabama (the only natural event) to a high of almost 2.4 million in Dallas Co., Texas, with an average county population of around 800,000. See Figure 5.6. The average county-level annual employment for the 2019 incidents showed a pattern similar to the county population data, as it ranged from a low of approximately 47,000 again in Lee Co., Alabama to a high of approximately 1.4 million, again in Dallas Co., Texas. Figure 5.7 shows the average county annual employment data with an average of approximately 390,000.

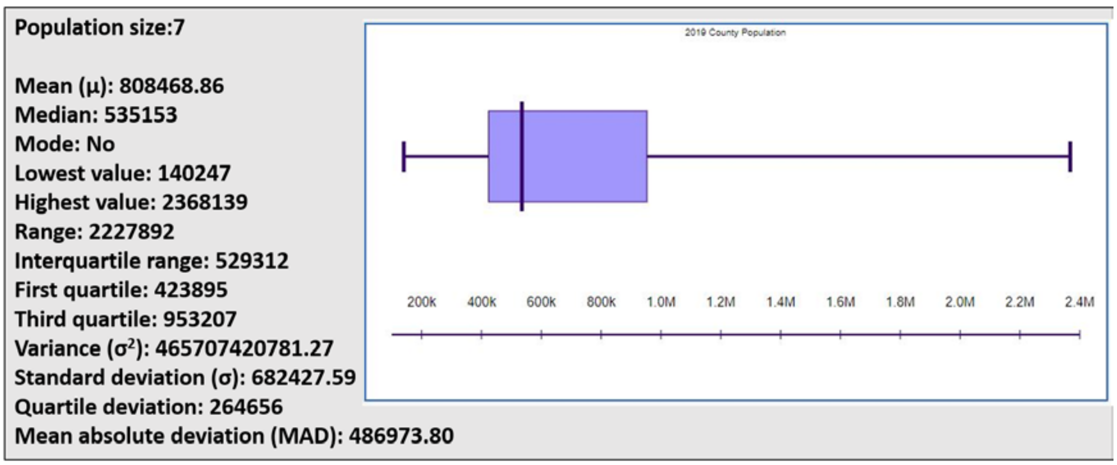

Figure 5.6 EMFD 2019 Events Average County Population

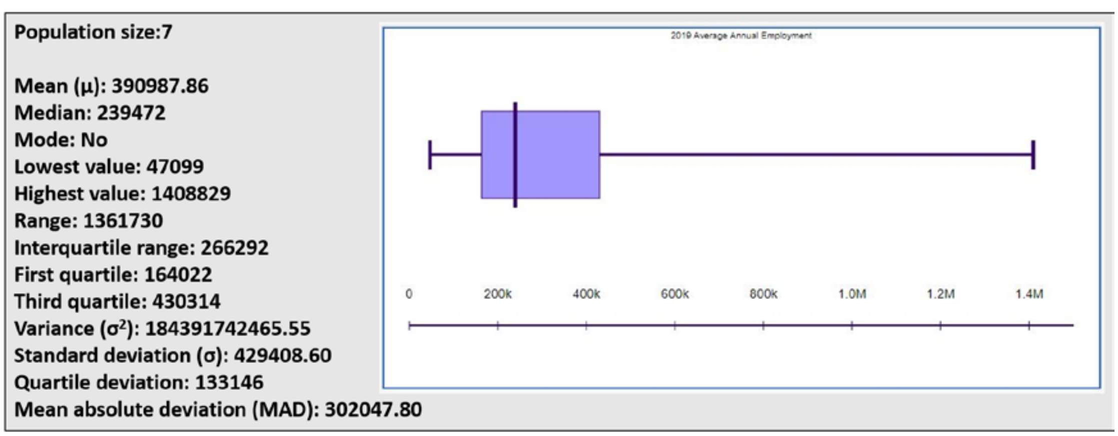

Figure 5.7 EMFD 2019 Events County Average Annual Employment

The average travel time to work for these locations ranged from a low of 20.2 minutes in Santa Barbara Co., CA to a high of 26.5 minutes in Honolulu Co., Hawaii, as depicted in Figure 5.8. There is little data to suggest that these counties have large populations leaving the county each day to find work, so these times are likely due to traffic, indicative of their mostly urban status, with large population and average annual employment ratios.

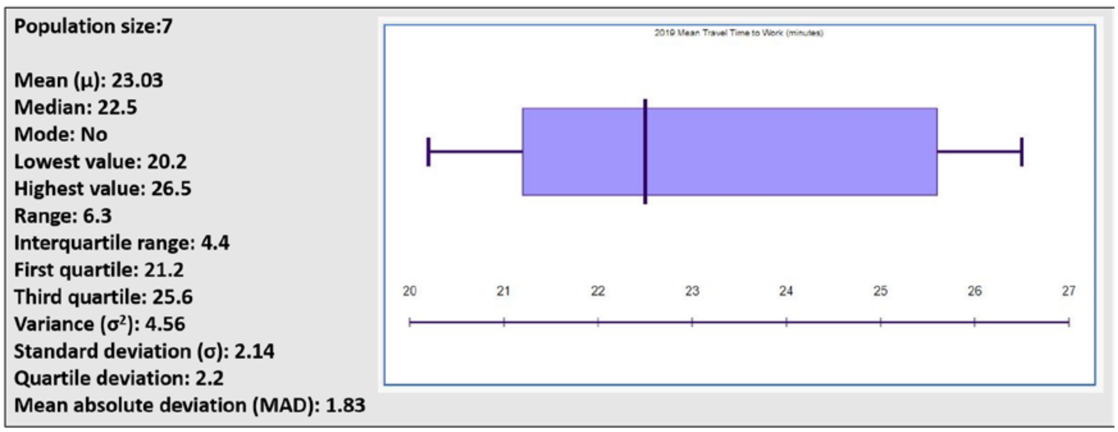

Figure 5.8 EMFD 2019 Events Average Travel Time to Work (minutes)

The total number of hospitals and PSAP/911 call centers for each county were also collected. Figure 5.9 shows the descriptive statistics for the number of hospitals within each county where a 2019 event occurred in. They range from a low of only one hospital (Lee Co., AL) to a high of 26 hospitals (Dallas Co., TX) with an average of 8 hospitals per county. The number of PSAP varied slightly, in that the low was found in Virginia Beach Co., VA with only 2 call centers, and the high once again found in Dallas Co., TX with 27 call centers. Figure 5.10 shows the range of PSAP/911 centers for the seven events with descriptive statistics.

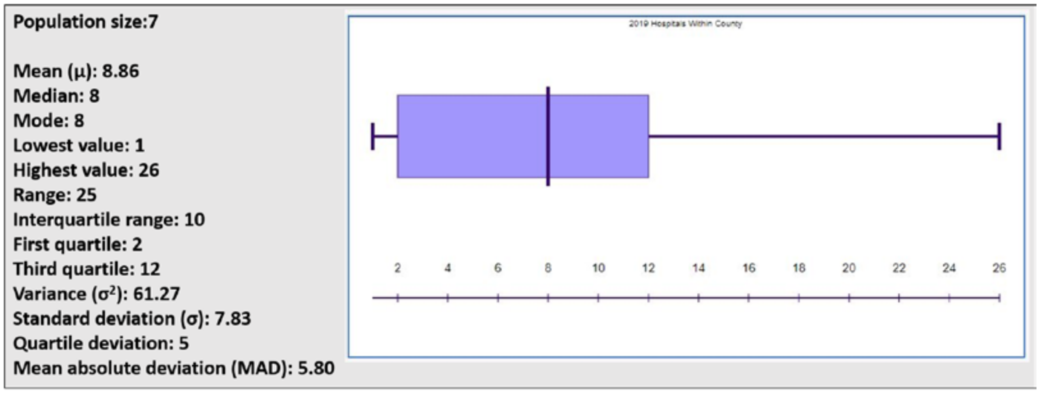

Figure 5.9 EMFD 2019 Events Number of Hospitals

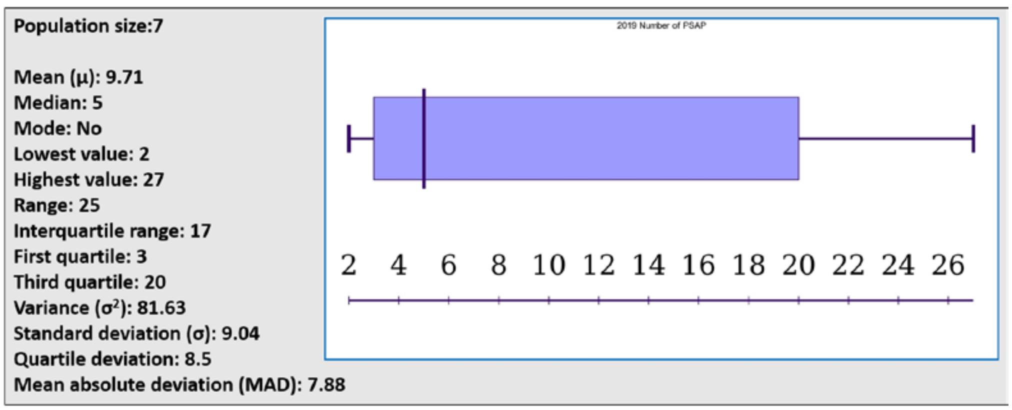

Figure 5.10 EMFD 2019 Events Number of PSAP

Of the seven total MFI events in 2019, only two events (28.6% of total 2019 events), both manmade, as shown in Figure 5.11, discussed evidence of telecommunication failure based on a review of after-action reports and other published event documents. The two events with documented telecommunication failure included the Virginia Beach municipal building shooting in which 13 people died and the El Paso (TX) Walmart shooting where 22 people died. Figure 5.12 further examines the specific types of failure by event type. Both events demonstrated evidence of the 911 system being overwhelmed or not answered/lagged, however in addition to that failure, the Walmart shooting showed calls being transferred to multiple PSAP and personnel issues, while the Virginia Beach shooting had calls being put on hold and interoperability issues for communication between first responders.

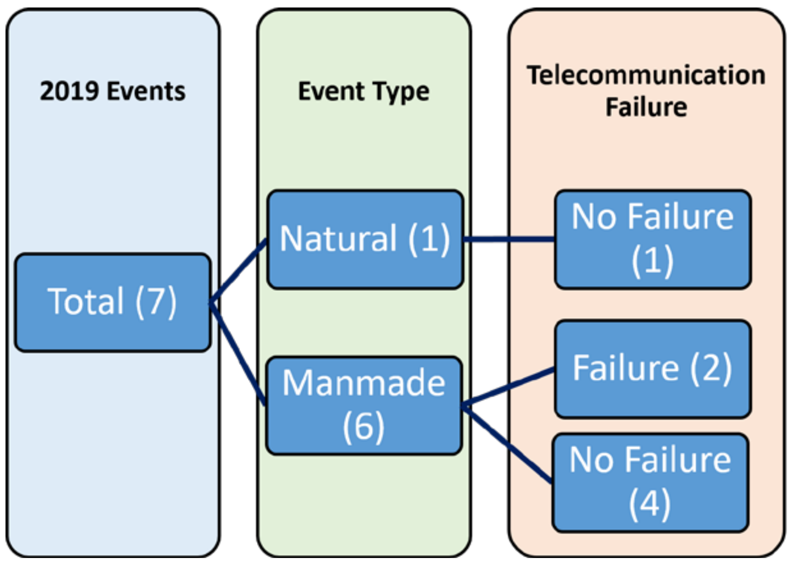

Figure 5.11 EMFD 2019 Events Telecommunication Failure

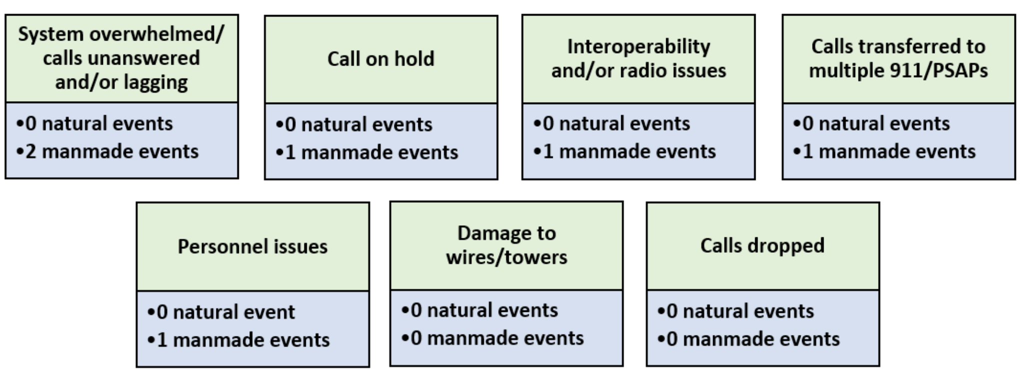

Figure 5.12 EMFD 2019 Events Telecommunication Failure by Category

An overall comparison of the basic central tendencies of the variables found in the EMFD events from 2010-2018 as compared to those from 2019 can be found in Table 5.10. There are similar number of events, seven, occurring in 2019, as compared to the average of 6.5 events per year from 2010-2018. The 2019 events occur in counties with larger populations, as compared to the 2010-2018 group, which may be reflective of the larger means found in the 2019 group for average annual employment, and number of hospitals and PSAP/911 centers, as previously discussed based on their correlation to one another. The variables of days and number of dead differ between the two groups, with 2019 having a smaller mean for both variables as compared to the 2010-2018 group. If the outliers of the 18-day Camp fire and the 166 deaths from the Joplin tornado were excluded from the 2010-2018 group, however, those numbers would be more consistent with one another. It is interesting to note that both groups have more manmade than natural mass fatality events represented.

Table 5.10 Comparison of Summary Statistics of EMFD Samples by Year

		EMFD 2010-2018	**EMFD 2019**
Number of Events		59	7
Number of Days Elapsed	Mean	1.6	1
	Standard Deviation	2.3	0
	Minimum	1	1
	Maximum	18	1
Total Number of Dead	Mean	23.5	17.57
	Standard Deviation	24.4	8.43
	Minimum	10	10
	Maximum	166	34
County Population	Mean	575,536.6	808,468.86
	Standard Deviation	788,328.5	682,427.59
	Minimum	7,210	140,247
	Maximum	4,092,459	2,368,139
Manmade/Natural (%)		50.8/49.2	85.7/14.3
County Average Annual Employment	Mean	247,437.8	390,987.86
	Standard Deviation	364,105.8	429,408.60
	Minimum	1,447	47,099
	Maximum	1,987,097	1,408,829
Mean Travel Time to Work (mins)	Mean	25.1	23.03
	Standard Deviation	5.6	2.14
	Minimum	16.7	20.2
	Maximum	42.9	26.5
Number of Hospitals	Mean	6.8	8.86
	Standard Deviation	9.1	7.83
	Minimum	0	1
	Maximum	58	26
Number of PSAP/911 Centers	Mean	6.6	9.71
	Standard Deviation	7.7	9.04
	Minimum	1	2
	Maximum	42	27
Documented Telecommunication Failure/No Failure (% of events)		44.1/55.9	28.6/71.4

5.3.2 Regression Analysis of the 2019 Events

The linear regression formula developed using the 2010-2018 events in the Enhanced Mass Fatality Database was also used to examine telecommunication failures for the seven 2019 events to see if it could accurately predict telecommunication failure within these new MFI events. The regression formula, Number of Types of Failures = 1.466 + 1.098(event type*) + .031(number of deaths) + 0. 7374(county population (m)), where for event type 0=manmade, 1=natural, was applied to the 2019 EMFD group. Keeping in mind that the constant in the formula is positive and will always predict at least 1.466 failures occurring in an event, the linear regression was able to correctly anticipate some failure occurring in the two events where failure was documented, again 100% of the time. This of course leads to the linear regression formula incorrectly predicting failure where none occurred in five of the seven events (or in a total of 71.4% of the events). When examining the exact number of failures, the linear regression model predicted two failures occurring for each of the events that had documented failure, however, both of those events showed three types of documented failure. It should be noted that as many of the events that occurred in 2019 are of criminal nature, therefore the finalized reports and more internal or graphic details of each event may have not yet been made public and might further improve the data and regression models at a later date.

5.3.3 EMFD Data: Is it Accurate?

In order to demonstrate if the data assembled in the EMFD accurately portray the situation perceived by the personnel involved, an online survey was sent to professionals involved in the response of those incidents occurring from 2016 to 2019. A total of 27 events occurred from January 2, 2016 to December 31, 2019, inclusive of the last full year of data from the original HCIFS database. It is assumed that personnel involved in those more recent events will be able to more accurately remember the events and response associated with the event and may likely still be employed in those agencies. Internet searches were performed to find any people and/or email addresses associated with 911/PSAP centers, emergency management offices and first responder agencies within the county of record for each of the 27 events occurring within the 2016-2019 timeframe.

The online survey was sent to each individual/email address from the educational institute email address of the author, requesting their participation in this dissertation research. A total of 320 email addresses were contacted to request participation in the survey, with a minimum of 5 contacts per event. The introduction email (See Appendix G) requested that the survey be forwarded to any person(s) that the intended felt would have knowledge of the event in order to be able to adequately participate in the survey. All participation was strictly anonymous and could be terminated in the survey at any time. Questions in the survey (See Appendix G) asked participants about their role and agency, and then focused on their perception of any of the predefined categories of telecommunication failures occurring, and if perceived, allowed them to formulate a way to alleviate or reduce the failure. Participants were also asked if they were aware of the staffing levels of the 911/PSAP and details on 911 call transfers (do they occur, how often, where to?). Finally, participants were asked what they felt their agency's preparedness level to respond if a similar MFI event occurred today and what explanation they had for their preparedness level response.

The 27 events included in the survey sample were comprised of twenty manmade events (74% of the sample) and seven natural events (26% of the sample), with the majority of events occurring almost evenly throughout the years of 2017-2019 as shown in Figure 5.13. With the exception of 2016, in which only four MFI events took place, the remaining years had a similar number of events taking place (2017 and 2018 each having eight events, and 2019 having seven events).

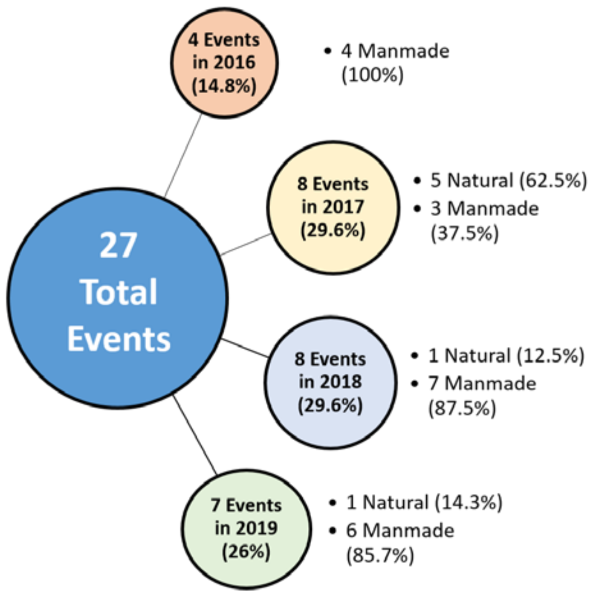

Figure 5.13 EMFD 2016-2019 Survey Event Distribution by Year and Type

A total of 28 surveys were attempted or completed, representing 14 (52%) of the original 27 MFI events in the survey sample. Figure 5.14 shows that survey respondents reported themselves as PSAP/911 center personnel (50%), emergency management (16%), first responders (22%), and other/anonymous (12%), with four respondents marking themselves in multiple categories. Several of the original recipients of the emailed surveyed responded that they could not lawfully respond because the event may still have on-going legal activity pending.

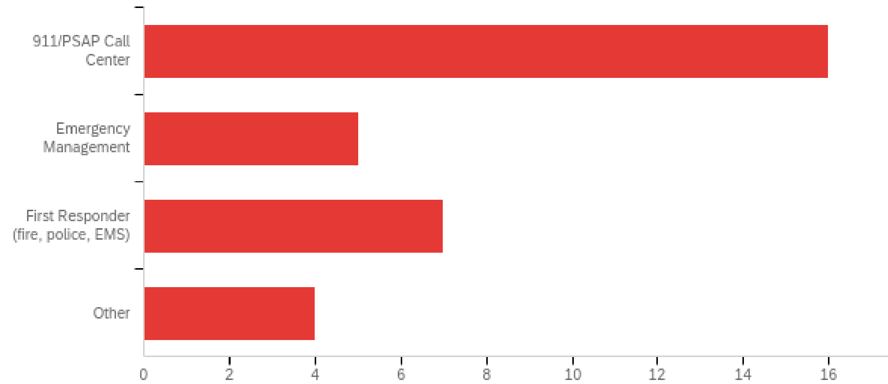

Figure 5.14 EMFD 2016-2019 Survey Self-Identification of Survey Respondents

Table 5.11 shows a comparison of the summary statistics for the original EMFD 2010-2018 database, the EMFD 2019 events, the EMFD 2016-2019 survey sample and the responses to the survey. The results received from the survey have summary statistics that are almost identical to the 2016-2019 sample of events, the documented evidence of failure, which more closely resembles the percentage of documented failure or no failure for the original 2010-2018 group. The statistics for the majority of the county-level demographics variables (mean travel time to work, number of hospitals and number of PSAP/911 centers) from the survey sample look similar to those in the 2019 group, not surprising, as those events make up approximately a quarter of the total survey sample (7 out of the 27 events). The event variables (days elapsed and number of dead) for the survey sample are more similar to those of the 2010-2018 EMFD group than the 2019 group, along with the means and distributions for both county population and average annual employment. The biggest difference between the various groups is the percentage of manmade versus natural events: there are significantly more manmade events in the survey sample (74.1%) and represented in the survey results (78.6%) as compared to the original 2010-2018 EMFD (38.5%) and the 2019 EMFD (50.8%) groups.

Table 5.11 Comparison of Summary Statistics of EMFD Groups, Survey Sample and Survey Response

		EMFD 2010-2018	**EMFD 2019**	**EMFD Survey 2016-2019**	**Survey Responses**
Number of Observations		59	7	27	14
Number of Days Elapsed	Mean	1.6	1	1.9	2.64
	Standard Deviation	2.3	0	3.26	4.39
	Minimum	1	1	1	1
	Maximum	18	1	18	18
Total Number of Dead	Mean	23.5	17.57	25.04	24.62
	Standard Deviation	24.4	8.43	20.01	21.75
	Minimum	10	10	10	10
	Maximum	166	34	88	88
County Population	Mean	575,536.6	808,468.86	811,488.04	899,024.5
	Standard Deviation	788,328.5	682,427.59	933,652.81	1,060,606.90
	Minimum	7,210	140,247	26,405	38,066
	Maximum	4,092,459	2,368,139	4,092,459	4,092,459
Manmade/Natural (%)		50.8/49.2	85.7/14.3	74.1/25.9	78.6/21.4
Average Annual Employment	Mean	247,437.8	390,987.86	368,390.48	384,277.93
	Standard Deviation	364,105.8	429,408.60	462,896.76	506,073.58
	Minimum	1,447	47,099	6,490	6,929
	Maximum	1,987,097	1,408,829	1,987,097	1,987,097
Mean Travel Time to Work (mins)	Mean	25.1	23.03	24.37	24.49
	Standard Deviation	5.6	2.14	3.95	2.63
	Minimum	16.7	20.2	17.5	20.6
	Maximum	42.9	26.5	35.8	31.3

Table 5.11 Comparison of Summary Statistics of EMFD Groups, Survey Sample and Survey Response (cont.)

		EMFD 2010-2018	**EMFD 2019**	**EMFD Survey 2016-2019**	**Survey Responses**
Number of Hospitals	Mean	6.8	8.86	9.7	10.64
	Standard Deviation	9.1	7.83	11.87	14.38
	Minimum	0	1	1	1
	Maximum	58	26	58	58
Number of PSAP/911 Centers	Mean	6.6	9.71	9	9.5
	Standard Deviation	7.7	9.04	9.14	9.77
	Minimum	1	2	1	2
	Maximum	42	27	42	42
Documented Telecommunication Failure/No Failure (%)		44.1/55.9	28.6/71.4	37/63	57.1/42.9

Similar to the breakdown of total events in the survey sample, only three natural events (21.4% of the responses) were represented in the completed surveys and more survey responses were received for those years in which more events occurred (2017 and 2018). The specific events and response types found in the survey responses are expounded upon in Table 5.12.

Table 5.12 EMFD 2016-2019 Survey Response Breakdown

Year	Event	Type	Self-Identified Respondent Agency	Number of Survey Responses
2016	Lockhart (TX) Hot Air Balloon Crash	Manmade	County level law enforcement County level emer. manage. PSAP/911 Center	1 1 2
2016	Memphis (TN) House Fire	Manmade	Regional medical examiner	1
2017	Hurricane Harvey (Harris Co. TX)	Natural	PSAP/911 Center	2
2017	Hurricane Harvey (Orange Co. TX)	Natural	Emergency management	1
2017	Route 91 Shooting (Las Vegas, NV)	Manmade	County level emer. manage. PSAP/911 Center	1 1
2018	Hurricane Michael (Bay Co. FL)	Natural	Local PSAP/911 Center County PSAP/911	2 1
2018	Camp Fire (Butte Co. CA)	Manmade	Other – County IT/Data Manager	1
2018	Santa Fe (TX) HS Shooting	Manmade	Local fire department	1
2018	Stoneman Douglas (FL) HS Shooting	Manmade	Local law enforcement Local fire department Local PSAP/911 Center Anonymous	1 1 1 1
2018	Duck Boat Accident (Taney Co., MO)	Manmade	County level emer. manage. Local PSAP/911 Center	1 1
2018	Thousand Oaks (CA) Shooting	Manmade	County level PSAP/911	1
2019	El Paso (TX) Walmart Shooting	Manmade	Local level PSAP/911 Center	3
2019	Oahu (HI) Sky Diving Plane Accident	Manmade	Local level PSAP/911 Center	1*
2019	Virginia Beach (VA) Shooting	Manmade	Regional PSAP/911 Center Local Emer. Manage.	1* 1*
**Survey looks to be terminated before completion*				

Respondents were asked if they perceived any of the pre-defined categories of failure during the MFI event that they responded to, or if no failure was perceived. Figure 5.15 shows the distribution of failures perceived, with a total of 14% stating that no telecommunication failure was perceived. The respondents that stated they were unaware of any failures included only two events (out of the seven events from the 27 events in the survey where failure was not found in public documents) in which there was no published documented failure. The remaining four events in which respondents said that there were no failures perceived each had other respondents who claimed there were failures occurring in those particular events or did not complete that specific question. It can be assumed that those who responded but did not perceive failures may not have directly observed the pre-defined categories of telecommunication failures.

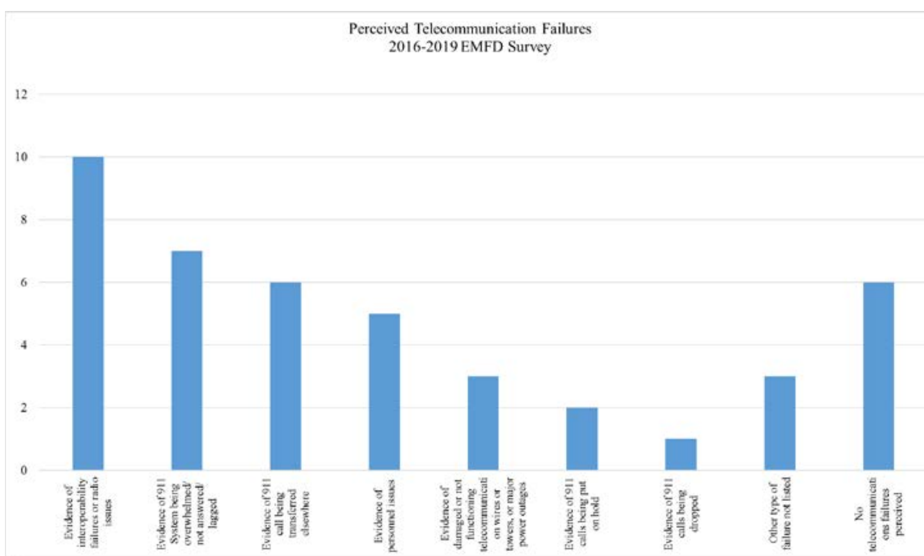

Figure 5.15 EMFD 2016-2019 Survey of Perceived Telecommunication Failure by Type

Perception of failure from the surveys were comparable to the failure discussed in the published documents for the events in which there was evidence of telecommunication failure. Of the 27 events in the survey sample, a total of 37% had documented evidence of any type of failure, with the majority being ‘evidence of the 911 system overwhelmed/not answered/lagged’ (23%) and ‘evidence of transfers to multiple PSAPs’ (20%), followed closely by interoperability and damaged wires (both 14%) and 911 calls being put on hold (13%). Figures 5.16 and 5.17 depict the telecommunication failure breakdown of the survey sample of events as well as the survey respondents’ perception of telecommunication failure.

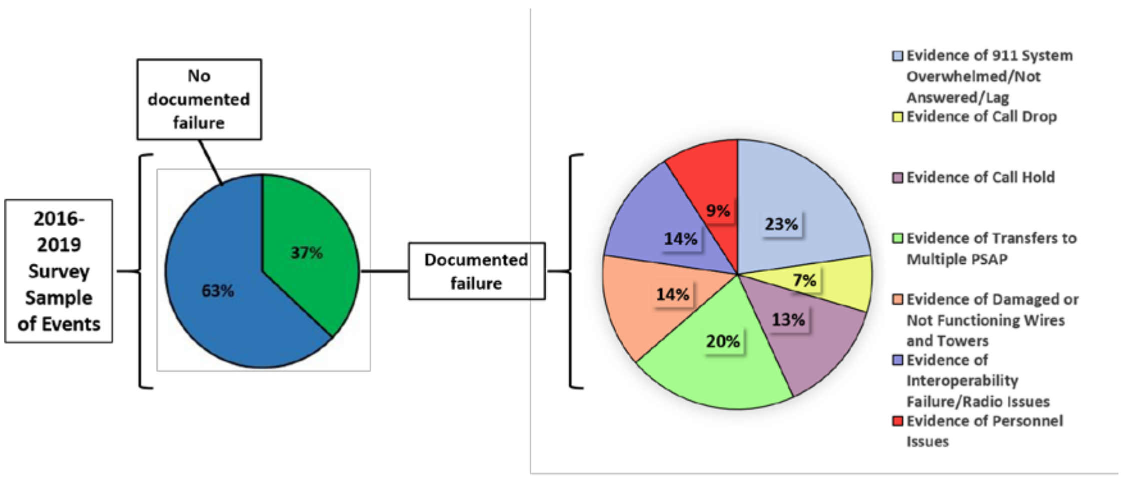

Figure 5.16 EMFD 2016-2019 Survey Sample of Publicly Documented Telecommunication Failure by Type

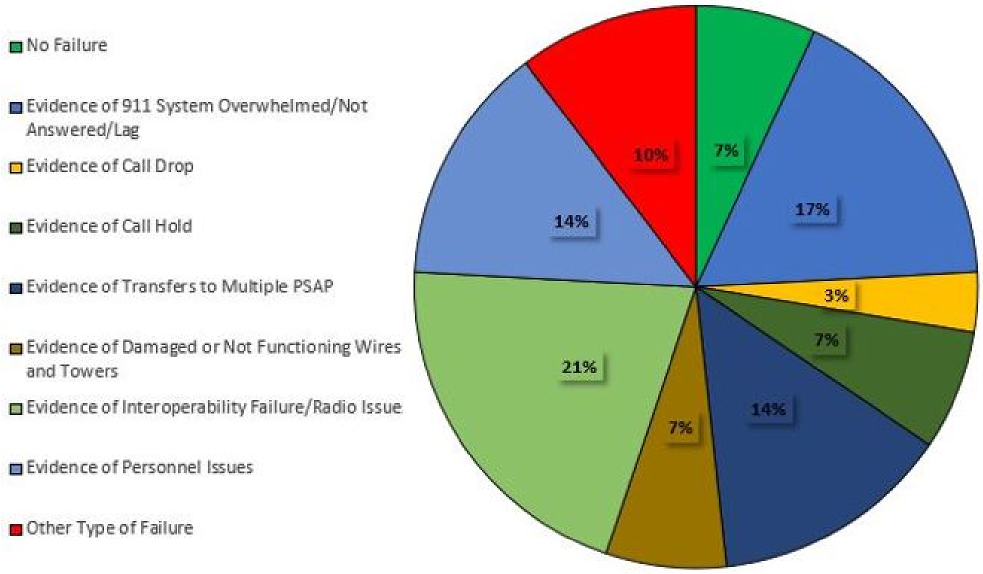

Figure 5.17 EMFD 2016-2019 Survey Respondents Perception of Failure by Type

Figure 5.18 provides a comparison of the documented evidence of failure with the perceived evidence of failure from the survey respondents, and shows that most categories of telecommunication failure that were documented in the reports were also perceived or did occur based on firsthand experience of the events. Perceived failure from the surveys were suggestive of the failure discussed in the published documents for the events in which there was evidence of telecommunication failure. The same top three failures occurred in both the published documents and in the survey results: the 911 system being overwhelmed, interoperability and having multiple transfers occurring. The discrepancies that are found between the documented and perceived failures include the categories of 'no failure,' in which there is significantly more documented evidence (28% documented versus 7% perceived) of failure having not occurred, as well as the categories of 'evidence of interoperability' (10% documented versus 21% perceived) and 'personnel issues' (6% documented versus 14%

perceived). It is interesting to note that the survey responses showed a larger number of these types of failure as compared to the published documents, however, as these individuals worked in and with the PSAP/911 centers it is reasonable to assume that they would have a heightened awareness of the personnel issues and the conversations happening in and between responding agencies.

Survey responses also allowed for an ‘other type of failure’ where respondents were allowed to discuss what types of failure they perceived that were not categorized; these responses consist of: ‘calls were repetitive, overwhelming in the beginning,’ ‘first responder agencies were overwhelmed and could not respond to the calls,’ and that ‘non-emergency lines and published phone numbers of elected and appointed officials were all inundated with calls.’

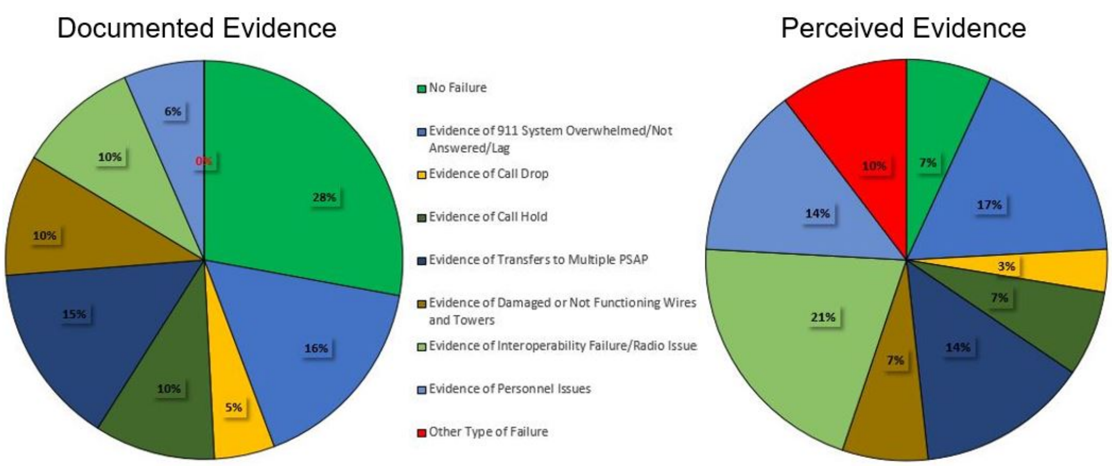

Figure 5.18 EMFD 2016-2019 Breakdown of Documented vs. Perceived Evidence of Telecommunication Failure

Table 5.13 shows a cross-tabulation of the survey sample respondents' perception of failure versus the publicly documented types of failure for the fourteen events that were represented in the survey responses. An entry in the table represents the number of events for the documented and perceived failure(s) responses that were recorded. For example, there were 6 events where survey respondents perceived 'evidence of the 911 system being overwhelmed/not answered/lagged' along with there being documented 'evidence of transfers to multiple PSAP/911 centers.' While the shaded responses provide some sense of the consistency, there is significant double counting. This includes events for which either type of evidence was consistently recorded based on documentation and the survey results. The shaded cells on the diagonal are the most consistent representation of consistency between perceived and documented evidence of no failure or each of the telecommunication failure categories. Table 5.14 shows a cross-tabulation of the total number of events comparing the perceived and documented failures. The maximum number of perceived failures for any event was only five, however, there were at least two events in which all seven predefined categories of failure were documented in the published AARs.

Table 5.13 Cross-tabulation of Perceived Failure and Documented Failure

		Documented Evidence of Failure (Published Reports)								
		No Failure	Evidence of 911 System Overwhelmed/ Not	Evidence of Call Drop	Evidence of Call Hold	Evidence of Transfers to Multiple PSAP	Evidence of Damaged or Not Functioning Wires and Towers	Evidence of Interoperability Failure/ Radio Issues	Evidence of Personnel	Other Type of Failure
Perceived Evidence of Failure (Survey Results)	No Failure	3	0	0	0	0	0	0	0	0
	Evidence of 911 System Overwhelmed /Not Answered/ Lag	1	7	2	5	6	3	3	3	0
	Evidence of Call Drop	0	1	0	0	1	0	0	1	0
	Evidence of Call Hold	1	2	0	1	1	0	1	1	0
	Evidence of Transfers to Multiple PSAP	0	4	2	3	4	3	2	2	0
	Evidence of Damaged or Not Functioning Wires and Towers	0	2	1	1	2	2	1	1	0
	Evidence of Interoperability Failure/ Radio Issues	2	4	2	2	4	2	2	3	0
	Evidence of Personnel Issues	2	3	1	2	3	1	1	2	0
	Other Type of Failure	1	2	0	2	1	0	1	0	0

Table 5.14 Number of Events with Perceived and Documented Failures

		Documented Number of Types of Failures							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Perceived Number of Types of Failures	**0**	3							
	1	1							
	2	1				1			1
	3	1			2			1	1
	4				1				
	5				1				

Survey respondents were ultimately asked if they felt that their agency was similarly, less or more prepared to respond to another MFI, with approximately 2/3 of the respondents (64%) saying that they felt their agency was better prepared to respond to a MFI and the other 1/3 (36%) stating that they were similarly prepared; none felt that they were less prepared. When asked to address why their agency was better prepared, open-ended responses captured the themes: increasing capabilities in the call centers, better interoperability, more personnel and increased trainings, as well as the mentality of ‘having been through it’ so they are more confident in their abilities. Those responses that felt that their agency was similarly prepared cited being short-staffed, high personnel turnover rates and a lack of additional training, utilizing the same equipment, and not having an adequate training that ‘even prepares for this type of incident.’

5.4 Summary and Research Questions Revisited

Exploratory statistical analysis, using a variety of commonly used statistical tests, has shown that the data presented in the EMFD does in fact suggest that telecommunication failure occurs during mass fatality incidents. Natural events, due to their dynamic nature and force, increase the likelihood that telecommunication failure will occur. Those events that occur in areas with higher populations and that cause an increase in the number of deaths also contribute to their being a greater probability that these types of failures will occur.

In summation, the research presented in this dissertation successfully addressed the originally proposed research questions:

1) When a larger scale mass fatality event occurs, is there evidence of the 911 system being overwhelmed? Is there evidence of failures in the telecommunication infrastructure?

After compiling all of the event and demographic data for each of the defined mass fatality incidents into the newly created Enhanced Mass Fatality Database, there is evidence of telecommunication failures demonstrated in both natural and manmade MFIs. Telecommunication failure is evident in a variety of mean, including the 911 system being overwhelmed, showing lag in answering and/or not being answered when there is a call coming into the PSAP or 911 center. This information was corroborated with surveys from the first responders and those who worked in the PSAP/911 center and were directly involved in the response of events occurring from 2016-2019 where they discussed their perception of telecommunication failure.

2) What data do public archives, such as After-Action Reports (AARs), provide regarding the various types of infrastructure failures to the 911 system during and after a mass fatality incident? What types of variables effect these issues? Is it dependent on the categorical type of incident or some other qualitative or quantitative factor(s)?

After-action reports and other publicly documented reports do provide evidence of telecommunication failure occurring during mass fatality incidents, as these were the primary source of factual evidence for failures documented in the EMFD. Through preliminary and final statistical analyses of the event and demographic data compiled in the EMFD, it has been shown that the event type, number of dead and county population all show statistical significance in predicting the possibility of telecommunication failure occurring during and after a mass fatality event. When natural events occur, the odds of certain types of telecommunication failure occurring increase over 10 times compared to manmade events. A natural event, as well as an increase in the number of dead and the county population also show a positive correlation to telecommunication failure occurring.

3) Can 911 infrastructure failure surrounding a mass fatality incident be anticipated?

Utilizing the results of the statistical analyses of the EMFD, and specifically the binomial logistic regressions and the linear regression, there is evidence of a correlation of natural events having a greater likelihood of telecommunication failure occurring. Increasing the number of dead and the county population also suggests an increase in the odds of failure occurring. Anticipatory models constructed using logistic and linear regressions suggest that failure will occur, and will likely increase, during a natural MFI in a county where there is a higher population, and when more death occurs.

5.5 Recommendations

On a more proximate level, the regression models formulated from the data in this research suggest that natural mass fatality events are more prone to cause failures of the telecommunication system. This is not surprising, given that these types of events – primarily tropical storms, tornados, wildfires and floods – often destroy large portions of the electrical and communication infrastructure. The locations around the country that are more likely to be effected by these types of events, such as the Gulf coast states subjected to tropical weather events, western states effected by wildfire, and those in the Midwestern states/tornado alley need to invest in telecommunication infrastructure to prevent failure from occurring due to large-scale outages.

At an overarching, more ultimate level, this research fills a significant void in understanding a sliver of the intricacies in mass fatality incidents and how these events may incapacitate or weaken the telecommunication system that is vital in the response to those events. It highlights the need for enhanced infrastructure and an increase in personnel to work the 911/PSAP center(s), which is echoed in the results of the survey of those who worked through these events.

Suggestions for decision-makers and stakeholders at the local, county and state-level, based on the results of this research include:

1. Investment in enhanced telecommunication infrastructure and personnel. Locations that are especially susceptible to natural events need an understanding of how those events incapacitate the telecommunication infrastructure and determine ways to prevent that from happening. Similarly, a greater emphasis needs to be placed on the employees who are responsible for responding at these PSAP/911 centers. This may include higher pay and better benefits for telecommunicators, as well as MOUs or agreements between agencies or organizations for the ability to pull adequately trained/cross-trained staff for use as additional call-takers/dispatchers if needed.

2. Regional PSAP/911 centers that are automated to accept calls when a local PSAP/911 center is overwhelmed or not working correctly. Interagency cooperation and having a trigger point, for instance calls taking longer than 5 seconds to answer are automatically routed to another PSAP/911 center, provides an additional level of support for

smaller centers who may not have the capabilities needed to respond to a MFI or other large-scale incident, as well as those centers who may become incapacitated during an event due to infrastructure failures.

3. Training in mass casualty and mass fatality incidents, highlighting the high-intensity of the situation and the need for interoperability between agencies. These trainings should allow the many organizations that could respond to any type of MFI to discuss the best ways to communicate between them, with an understanding of the current capabilities of each agency and what would be needed to communicate between them successfully. Takeaways from these trainings should include standard operating procedures (SOPs) that discuss the technical capabilities of the agencies, with specific directions for responders on how to communicate effectively, including which channel(s) are to be used in interagency response situations.

Chapter 6

CONCLUSION, CONTRIBUTIONS AND FUTURE RESEARCH

6.1 Outcomes and Contributions

This research fills a significant research gap for both academics and practitioners in the various fields that deal with mass fatality incidents, including those in emergency response and emergency management, as well as those involved in the planning and financial aspects of response and preparedness as it relates to infrastructure and personnel, just for MFIs. It fulfills a portion of the original ask by the NIST OSAC DVI subcommittee for a comprehensive examination of the type and amount of data produced during a MFI, more specifically by looking at telecommunication failures resulting from these types of events. By approaching these types of events that occur in the United States using a general, systematic scope, rather than anecdotally at single events with random variables, overarching patterns of telecommunications surge and failure are discovered.

The tangible contribution of this research is the creation of a new mass fatality database, the Enhanced Mass Fatality Database, which defines and expounds upon the various intricacies that surround mass fatality events in the United States. It is the first comprehensive database of mass fatality incidents of this level and provides a singular definition with which to define a MFI: a minimum of 10 decedents in one event, in a county in the United States. The EMFD compiles detailed event and demographic data on the county that the MFI occurred in, in order to have a proportionate means of exploring mass fatality events. The creation of the EMFD subsequently resulted in the seven defined categories of telecommunication failure. While important for this exploratory research to move forward, the failure categories also quantify and highlight specific areas where telecommunications improvement can occur before a MFI or other devastating event can occur. This information is especially important for those who study the effects of ‘disaster’ events on the telecommunication systems and networks associated with them, as that research primarily focuses on the results of the disruption or failure, and does not quantify the demand or cause, which this research does (Bertelli et al., 2018; Gomes et al., 2016; Konsgen et al., 2012).

Additionally, exploratory analyses of the data in the EMFD shows a strong correlation between the type of event occurring, number of deaths and telecommunication failure. Understanding that those areas of the country that may be more prone to natural, unplanned events, have a higher chance of finding themselves in a scenario where a mass fatality incident, coupled with telecommunication failure is likely. This research demonstrates that telecommunication failures do occur during MFIs through documented evidence, and corroborated through first-hand knowledge from those actors who participated in the response to these events.

The statistical analysis of the data in the EMFD provides solid associations between variables, such as the county population which is highly correlated with a number of other variables crucial to preparedness and response for MFIs, such as number of hospitals and number of PSAP/911 centers within the county. The creation of the anticipatory models, through a variety of regression analyses, provides jurisdictions with a baseline with which to determine their own level of susceptibility and preparedness in various types of events. The data and survey results both suggest a need for more robust infrastructure, larger numbers of personnel and greater interoperability between responding agencies.

6.2 Broader Impacts

Addressing the nuances and complexities surrounding mass fatality incidents in the United States, represents an interdisciplinary crossroads. This research and its findings have implications and impacts that support many stakeholders, including but not limited to, the fields of emergency managements, various first responder groups, governance and policy, technology, sociology, and economy and budgeting, as well as the people living in communities that may be effected by a MFI throughout the country.

It is important to address how these research questions can successfully add something to each field and yet be accessible to additional fields that may benefit from an understanding of these types of events. It is the hope that this research creates tangible data to use as a baseline for local systems to determine their level of preparedness in the face of various mass fatality incidents *before* those types of events occur. This data can be used to support or highlight strengths of current systems, address potential forthcoming technological and personnel needs, and create and implement infrastructure, policies or MOUs to allow for a more efficient response and recovery when a MFI occurs. On a global scale, the anticipatory models suggesting evidence of telecommunication failure during a mass fatality incident could be adjusted using comparable international data for worldwide use.

6.3 Limitations

It should be noted that there are several limitations with this study largely related to uncertainties associated with the lack of consistent information and data collection and then whether or not those details are publicly documented. First, this research is strictly focused on events in the United States, so the use and implication for international users is unknown.

Limitations can also be found within the data and beginning data set. The original Harris County (TX) Institute of Forensic Science's Mass Fatality Database was admittedly incomplete for the years of 2017 and 2018, and due to the variety of sources used for that database, likely missed mass fatality incidents based on their original parameters. A lack of consistent data was also evidenced in the 911 data and little published quantifiable data on call volume on a 'blue sky day,' let alone during a mass fatality incident. By increasing the minimum number of decedents to 10, it was more likely that a mass fatality incident of that size in the United States was publicized in the media and able to be included in the Enhanced Mass Fatality Database. This also resulted in fewer overall events meeting the minimum requirements to be included in the EMFD and having a significantly smaller data set to work with. Unfortunately, having media coverage of an event does not equate to official public documents, from reputable sources, verifying details of the mass fatality event that were needed for this research. For instance, official documents from the event (AARs, contractor reports, etc.) might not have complete information on all calls and potential failures, but there might be a news article interviewing actors in the events who said a call dropped or they couldn't get through to the 911 center. This discrepancy was quite common (examples include the Sutherland shooting and the Santa Fe High School shooting), but not verified by a reputable source, such as in the AARs, and therefore those “failures” were not documented in the EMFD. Variables such as who/what agency wrote the report, how much time and effort they were allotted to write the report and their primary foci, how detailed it was, the type of event that occurred, whether the telecommunication system was an area of focus, all contributed to areas of limitations. This lack of consistent, verifiable data, or any reporting requirements at all, for mass fatality incidents leads to a general lack of overall understanding of these types of events. It can also be suggested, that the use of any report, including after-action reports, have an inherent bias built into them, as it is impossible to discuss all aspects and details of an event and the response to that event, and the agency writing the document determines what to include and not include.

Another limitation to the study is the small size of the dataset and the statistics associated with that data. Depending on the school of thought, there are different minimum requirements for sample sizes, as well as minimum observations needed per variable used in regression analyses, in order to be considered statistically sound. These minimum event numbers range from 30 to 100 or more, therefore having a sample size of only 59 events for the 2010-2018 EMFD immediately questions whether it meets overall soundness guidance in the statistics world. The small sample size also effects the reliability of the regression models. Larger sample sets would provide a more robust level of statistical significance, and increase the ability to anticipate these types of telecommunication failures.

Similarly, the survey sample of events and the survey response size were quite small, again questionable as to whether or not they meet the minimum number for statistical soundness. Without having firsthand knowledge of the individuals who worked at the various responding agencies, and means to engage them, the resulting contacts were subject to online searches. Many of the people who would have the knowledge of these events, may no longer work at these agencies, and even if they did, may not have published, official email addresses. Therefore, the distribution of the online survey was dependent on those actors who 1) actually received the email, 2) were someone who responded to the event or knew another individual who responded to the event, and 3) were able to forward the survey to those actors. This entire series of events provides many avenues for limitations, and does not consider the fact that many of these events might be subject to legal and litigious action(s) and therefore those actors are not legally permitted to participate in the survey. The online nature of the survey provides its own areas of limitation in the sheer nature that it was an online survey, so participants may not have all had access to take it online, and even if they did have access to it, they might not have understood the questions or had the time to adequately address each one. The length of time from some of the events (beginning in 2016) to the time of the survey (Summer of 2020) could also be considered a limitation. The survey was disseminated when most of the same agencies who were involved in the questioned MFI were now in the thick of responding to the first COVID-19 pandemic wave, which may have reduced the accurate memories of the MFI and potential for remembering any details of possible telecommunication failure.

Other sources of limitations may include changes in emergency management processes and procedures (How are PSAP/911 centers operated? Is the role of the telecommunicator more valued in the future so that these call centers are less likely to be understaffed?) or the change in the government's role in 'disasters' (Changes to the legislature governing the requirements for PSAPs or what denotes a 'disaster event' allowing for Federal funding to be utilized for preparedness initiatives; Could

DMORT respond without a disaster declaration?). There must also be transparency in potential anthropogenic limitations; for instance, if there are cultural changes in which the identification of the dead is no longer revered, or if culturally, we as Americans become ‘numb’ to mass fatality incidents. Meteorological changes due to the human causes of, and the effects from, climate change and if these continue to result in an increase in the nature and severity of natural hazards, which could in turn, create more MFIs, and changes in development and resource allocation patterns may also create limitations. Finally, the author’s level of statistical knowledge, coding and implementation of the analysis of the data can be considered a limitation. Additional training in the field of statistics could strengthen the ability for analysis and the argument of the results. Addressing any number of these potential constraints may provide future avenues for research.

6.4 Opportunities for Future Research

There are numerous opportunities for additional avenues of research based off of this exploratory research. The simplest opportunity is to continue this research, adding the 2019 events to the overall 2010-2018 EMFD, as well as any additional mass fatality incidents, that occur that meet the minimum requirements from 2020 and moving forward. Similarly, the original parameters for inclusion into the database can be altered. In order to combat the question of sample size and statistical soundness, the scope of the Enhanced Mass Fatality Database can be changed to include either a larger timeframe or reducing the minimum number of dead to 5. Either of these changes could exponentially increase the size of the database, allowing for more refined regression analyses. The original justification for the minimum decedent count of ten allowed for the EMFD to be easily used on an international status, where the accepted definition of a mass fatality incident is one that causes at least ten deaths. As countries around the world do not use counties as geographic outlines, a different, consistent, source would need to be utilized to determine the demographic variables found in the EMFD.

Expounding on the results from the survey and applying the regression formulae to counties around the United States is another avenue for future research. This research can include additional discussions with emergency management, PSAP/911 center stakeholders and infrastructure and planning staff to determine if the anticipatory models are helpful and/or informative to their respective disciplines. How this information is beneficial to them and what additional information can the EMFD provide to address their needs. Are those stakeholders aware of event and demographic variables that might contribute to telecommunication failures that are not currently included in the EMFD? When these agencies are creating AARs or employing private entities to write them after mass fatality incidents, are there any specific telecommunication requirements that should be included? Should any standards exist for mass fatality incidents and reporting, what would that reporting consist of and how would that occur?

Examining the original questions and needs posed by the MFI OSAC – what types of data surround mass fatality incidents, what are the volume and type of those data and is there a surge of it that occurs when there is a MFI? - suggests that other types of data could be examined, but again requires that that evidence is documented consistently. Instead of looking for failures, additional research could examine the amount and type of social media posts based on the MFI, or if there was an increase in text-to-911 or access and functional needs related to 911 calls (use of non-English languages, or teletype calls for the deaf and hard-of-hearing communities).

The original parameters of this research purposely excluded mass fatality incidents that fell under the pandemic and epidemic heading, because it was difficult to determine a specific start and end date in which to constrain the MFI, and there were very few instances of these events killing more than 10 people in a single county. This was the case of course, prior to February of 2020, when the COVID-19 pandemic first came to the United States, and as of publication, caused more than 200,000 deaths on American soil. The counties that make up the Greater New York City metropolitan area (Kings, Queens, Bronx, New York, and Nassau), have experienced over 2,000 deaths *each*, since COVID-19 hit the east coast of the United States. One has to wonder, especially given the climate that we now find ourselves in, how pandemic deaths and what exceptionally large numbers of deaths would do to the analyses of the data in the EMFD. Future research could include an entire subset of the EMFD dedicated strictly to COVID-19 deaths.

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Appendix A

EXPLORATORY PILOT STUDY: RHODE ISLAND NIGHTCLUB FIRE

This appendix documents an exploration pilot study of the Rhode Island nightclub fire in 2003. The study aimed to explore the potential sources of data related to information surge.

The state of Rhode Island was chosen as an exploratory pilot to determine if larger scale mass fatality incidents would indeed provide the greatest amount of information regarding an increase in contacts. Utilizing the MFI database created by the HCIFS, Rhode Island had a single entry per their MFI requirements over the 17-year period of 2000-2017: the 2003 Station Nightclub fire in Providence, RI in which 100 individuals lost their lives. To begin to test this theory, email and phone contact was made to Dr. Alexander Chirkov, the current chief medical examiner of RI, to Dr. Elizabeth Laposata, the chief medical examiner at the time of the incident, and to the local emergency management 911-system to garner a sense of the amount and type of data that may have been collected or received at and around the time of the fire. No response was received from either the current chief medical examiner or the EMS/911 system. Several emails and phone calls were exchanged with Dr. Laposata, in which it was determined that the lack of records and data collection systems in place in 2003 resulted in practically no data being recorded beyond direct involvement with a decedent. Given the recent emphasis on data collection in disaster events and emergency management in general, this finding was not completely unexpected; it does however, provide additional avenues of scoping Phase II of the dissertation for those incidents that may have sufficient documented data resources.

Appendix B

IDENTIFICATION PRACTICES IN MFIS

B.1 Historical Identification Practices in MFIs

Medicolegal personnel in North America have been documenting their experiences recovering and identifying the dead for just over a century. The history and interdisciplinary nature of disaster victim identification in mass fatality incidents has existed for half of that time in some form or capacity. Before mass travel, the military encompassed the only major incidents of mass fatalities in the United States, with the exception of the occasional train derailment or 'large' accident. During those events the military would bring in their own experts in various fields for identification purposes and in smaller localities, the jurisdictional authorities would identify whom they could, and store or bury remains of those they could not. As more and more people began to travel, especially in airplanes, situations where mass casualties occurred became more frequent. In the United States, the formal concept of mass fatality and mass casualty management was first credited to the National Funeral Directors Association (NFDA) (ASPR, 2017). In the early 1980s, committee members of the NFDA voiced their concern over a lack of standards regarding the handling of the deceased in mass casualty events after attending to the dead in numerous airplane crashes throughout the 1970s and early 1980s. Funeral directors around the country agreed that outside professionals who focused on aspects of forensic science, such as odontology and anthropology, would need to assist in the disaster victim identification

(DVI) in order to supplement services in cases of mass fatality incidents (MFIs) or mass casualty events. This led to the NFDA's purchase of the components for, and the creation of, the first disaster portable morgue unit (DPMU). The NFDA committee also suggested the creation of a "multi-faceted nonprofit organization open to all forensic professionals to support the idea of a national level response protocol for all related professions." This nonprofit group would be the basis for the Disaster Mortuary Operational Response Team (DMORT), which was formally created in 1992 (Winskog and Byard, 2016; US DOJ OJP, 2005). The DMORT is composed of a network of 10 regional teams across the country, currently organized via the Department of Health and Human Services' Office of Emergency Preparedness. Team members come from a wide variety of forensic backgrounds, as it was realized that recovery and identification of decedents required experts in various fields such as pathology, anthropology, biology, odontology and radiology.

In any given mass fatality incident, it is the role of the local medical examiner or coroner, depending on the geographic location of the incident and that area's specific laws governing death investigations, who has the ultimate responsibility for determining cause and manner of death of decedents. Most medical examiners are medical doctors who often have had some focus of education in forensic pathology and can perform autopsies, or postmortem (PM) examinations, on a dead body; unlike a coroner, who is an elected official and who may have no previous medical training and therefore cannot perform an autopsy. In cases where a mass fatality incident occurs, and a coroner system is used, the coroner must rely on a pathologist to perform the autopsy of the victim, as well as to take fingerprints and perform any other radiographic/imaging evidence. Pathologists can further examine the external and internal condition of the body including documentation of any identifying scars, tattoos, prosthetics or implants with serial numbers, and will often take samples of body fluids to send for testing by other forensic experts, such as DNA samples for testing by forensic biologists, or request that an anthropologist or odontologist come in to examine the skeletal remains or the jaws and teeth of the decedent, respectively (Simpson et al., 2007). In a mass fatality situation, the roles of the medical examiner or pathologist are different in that more often than not, the cause and manner of death is already known from the event, but the main goal is the collection and identification of the decedent and any other data collection. Medicolegal professionals likely only get a few minutes to examine the body, take samples and record their portion of evidentiary material into the disaster software system before the body needs to move to the next professional in a, sometimes mobile and rudimentary, disaster morgue. If local medicolegal jurisdictions realize that they do not have the resources available to address the mass fatality incident, they can request additional assistance via ESF-8 of the National Response Framework provided by FEMA and the Department of Health and Human Services. When ESF-8 is requested, the first step is to mobilize the regional DMORT team to the affected area to provide much needed manpower and testing resources.

When DMORT teams are assembled, they move into the event location and set up portable morgue units, with all required technology and experts who are trained on how to use the machines, in order to provide aide and assistance to the medical examiner or coroner’s department in their recovery and identification efforts. Teams often consist of forensic experts from different disciplines such as pathology, anthropology, odontology, as well as fingerprint technologists and radiologists, depending on the needs of the event and the condition of the bodies. They come equipped with computers, additional equipment, tests and machines in order to aid the local government and pathologists in the response of the mass fatality incident.

The various medicolegal disciplines associated with identification during a mass fatality incident, along with the types of data and how they are utilized is found in Table B.1. A detailed discussion of these professionals and examples of their application in MFIs can be found in Appendix C.

Table B.1 Medicolegal professionals utilized, and data collected during MFIs

Field	**Type of Data**	**Result**	**Software Utilized**	**References**
Pathology	Autopsy; external and internal physical examination of the body	Cause and Manner of death; medical implant serial numbers. Produces tentative ID	VIP, UVIS	Birngruber et al., 2011; Matoso et al., 2013;
Biology	DNA sample from blood, tissue, hair, bone or dentin	Nuclear DNA and/or Mitochondrial DNA profile. Produces definitive ID	LIMS, CODIS and/or MDKAP	LeClare et al., 2007; ICRC, 2009; Hartman et al., 2011; Montelius and Lindblom, 2012; Zietkiewicz et al., 2012; Butcher et al., 2014
Anthropology	Bone measurements, tool mark examinations	Biological profile (sex, height, race, age and any AM or PM skeletal abnormalities). Produces tentative ID	ForDisc	Jantz and Ousley, 2005; Langley and Jantz, 2016; Langley et al., 2016
Odontology	Dental examinations	AM and PM dental comparisons, dental implant identification. Produces definitive ID.	WinID (US), Interpol Odontograms (International)	Fischman, 1985; Pittayapat et al., 2012; Adams and Aschheim, 2016

Table B.1 Medicolegal professionals utilized, and data collected during MFIs (cont.)

Field	Type of Data	Result	Software Utilized	References
Camera/ Imaging	Photography and Radiography (X-rays, CT scans)	Visual representation of the body both internally and externally. Produces tentative ID	Synapse3D, VirtualGrid,	Kahana and Hiss, 1997; Porter and Doran, 2000; Koot et al., 2005; Sidler et al., 2007). Blau et al., 2008; Robinson et al., 2008; Ross et al., 2015
Printing	Fingerprints (may also include foot, palm and lip prints)	10-print fingerprint card. Produces definitive ID.	IAFIS	deCosmo, S. and J. Barbera, 2012; Johnson and Rieman, 2018

B.2 State of the Practice in Disaster Victim Identification

As there is no set standard state or federal policy or system with which to use in the case of a mass fatality incident, jurisdictions are left to apply their own local procedures and use of resources immediately available to them when dealing with any number of casualties; this usually begins with the local medical examiner or coroner initially handling any bodies, before ESF-8 assistance arrives, if requested. Several larger cities and counties, such as Los Angeles (CA) and New York (NY) have created their own mass fatality management plans that include specific procedures for how to recover and identify decedents, and New York City has created their own system with which to input ante- and postmortem data, and then utilizes this information to match identifications with bodies, however, these plans and systems are very rare in the national context (Forrester et al., 2008). In fact, there are currently only 10 states in the country that have a statewide mass fatality plan in place (CA, CT, FL, GA, MA, MD, MI, NJ, TN and TX), although none discuss options beyond the DMORT software to input and view decedent records with (NAME, 2012; NFDA, 2015).

After the creation of DMORT, the National Transportation Safety Board (NTSB) was tasked by the Aviation Disaster Family Assistance Act to coordinate assistance to families involved in major aviation accidents in 1996. This act also required the NTSB to identify a human services organization to assist them in the coordination of the provisions of mental health and spiritual care services for victims' families (LaDue and Herrmann, 2010). The American Red Cross (ARC) has a long-standing history of assisting in disaster events and the NTSB have worked collaboratively since 1996 on many types of MFI resulting from transportation events, however, operationally, many local chapters of the ARC are unaware of the actual provisions in the Act that they should be providing in the immediate aftermath of a disaster event. In 2000 a congressional appropriation, administered by the CDC, created the beginnings of the National Mass Fatalities Institute (NMFI) and the Hazardous Materials Training and Research Institute to provide technical guidance and training at the local and state levels as a resource pertaining to the field of mass fatalities management (Hanzlick et al., 2006). Unfortunately, federal funding for these programs ended in 2007, causing the creator of the programs, Peter Teahen, to take the company private and rebrand it as the International Mass Fatalities Center. In June of 2005, the National Institute of Justice Working Group produced 'MFI: A Guide for Human Forensic Identification,' in which they addressed several elements of preparedness for the management of mass deaths and acknowledged significant gaps regarding the extent to which a medical examiner or coroner can operate between the “normal fatality management” operations and those involving mass fatalities (US DOJ OJP, 2005). Also, in 2005 was the release of The Capstone Document: Mass Fatalities Management for Incidents Involving Weapons of Mass Destruction, providing specific areas of concern and basic procedures for potential contamination of bodies and protection for the fatality investigators (USARDEC, 2005). A work group sponsored by the U.S. Northern Command in cooperation with the Department of Health and Human Services convened in 2006 to discuss MFI in relation to influenza pandemics. This ultimately led to Concept of Operations (CONOPS) for Fatality Management published in 2007 in the hopes of identifying federal fatality management resources and outline basic procedures for their engagement during a mass fatality event when ESF-8 assistance is requested (US DHS, 2007). Most recently in 2014, a high-level Mass Fatality Management Executive Steering Committee was formed by FEMA to help provide effective guidance on MFI preparedness and management. As evidenced throughout the past two decades, several government offices and private organizations have raised concerns about a lack of national consistency with mass fatality incident management, unfortunately there continues to be minimal correlation from the various committee findings into current policy and practice, leaving jurisdictions and forensic experts to continue to operate as they have in the past: using the resources and programs that they have direct access to and familiarity with. This has also resulted in a variety of data software programs and statistical algorithms being used in the field, with little comingling of pertinent data for all investigators in a MFI to have access to.

When multifaceted DMORT teams are dispatched they are tasked with the creation of freestanding morgue operations that encompass all of these forensic disciplines and more. This requires different stations to record and provide any information about the deceased for comparison to known antemortem records, usually in order of least invasive to most invasive. Bodies are escorted through each of the stations via an attendant in order to ensure that the remains are handled correctly and that documentation at each station is complete. Identification stations are commonly initiated in the following order: in-processing station where an ID number is created and any decontamination occurs, photography and full-body radiology station (x-ray), personal effects station (clothing, jewelry), fingerprint station, medical radiology station (CT/MSCT), pathology station, dental station, anthropology station and mortuary science station where the remains are prepared for preservation or interment (TWG MFFI, 2005; NVSS, 2017). Data from every DMORT morgue station is uploaded into a real-time computer database called the Victim Identification Profile (VIP) program. The VIP was created by DMORT members in the mid 1990s to allow for the various examiners at an incident to keep track of, and have access to, information regarding a specific decedent. It currently has the capability of assimilating over 800 different item categories, including photographs and radiological scans, with specific screens dedicated to the ante- and postmortem examination in radiology, pathology, personal effects, clothing, jewelry, fingerprints, odontology, anthropology, and DNA (Klimetz, 2017). Additional information on the VIP program used by DMORT in mass fatality incidents can be found in Appendix D.

After the 9/11 attacks on the World Trade Center site in New York, New York, city officials with the New York City Office of Chief Medical Examiner, along with the NYPD, Department of Information Technology and Telecommunications and the Office of Emergency Management recognized the potential of the VIP program and they organized the creation of their own identification software known as the Unified

Victim Identification System (UVIS) (Sell, 2009). The UVIS online database has been designed to assist in the handling of mass fatalities, as long as all forensic team members have a secure internet access, via a computer terminal, laptop or phone. It is directly connected to the city's 311 phone service, a hotline manned 24 hours a day to provide callers with 'quick, easy access to all NYC government services and information,' during emergency incidents in and around New York City. Investigators can upload information and pictures from the scene in real time to UVIS and attach or match it to missing person reports simultaneously coming into the 311-call center and being entered into the UVIS system. Similar to the VIP program, UVIS is consistently updated as new connections and availabilities are being made, with one of the most recent additions requiring that all health care facilities in the NYC area being added to UVIS, allowing real time data on residents in case of a pandemic influenza or other public health MFI. At its capacity, UVIS has been tested to handle 156 incidents at one time, with 750 users providing input and accessing data at the same time, though this has never needed to occur in real time, as of Fall of 2017 (Sell, 2009). New York City has graciously provided access to the basic UVIS program to other municipalities, counties, states and other governmental agencies free of charge. Most recently, the Regional Catastrophic Planning Team for Connecticut, New York, New Jersey and Pennsylvania announced that the state of New Jersey has formally adopted the UVIS system, modeled directly after the one utilized in NYC.

Appendix C

MEDICOLEGAL EXPERTS IN MASS FATALITY INCIDENTS

This appendix provides a summary of the roles of various medicolegal experts in mass fatality incidents. Examples of the roles of pathologists, forensic anthropologists, forensic odontologists, radiographers or imaging experts, and forensic biologist or DNA analysts are presented.

Pathologists may come across potentially identifying markers, like specific tattoos, which were used as tentative identifications for approximately 1% of the 230,000 badly decomposed bodies in the December 2004 Indian Ocean tsunami disaster (Birngruber et al., 2011). Ante-mortem photographs of the tattoos were superimposed upon the decedents' bodies with matches leading to further corroborative testing. Similarly, both tattoos and orthopedic implants can lead to identification, as was the case of a severely burned body in Brazil, where a partial tattoo was visible for tentative identification, and the placement and serial number off of the victims' metal plate attached to the ulna (forearm), provided absolute identification (Matoso et al., 2013).

While pathologists are able to examine the external and internal portion of the body, in many cases of mass fatality incidents, decedents may be left unrecognizable, due to any number of situations, such as exposure to fire, long term water exposure, and even dismemberment or partial or complete skeletonization. In these cases, a **forensic anthropologist** will be utilized to examine the bones of the individual. Physical anthropologists, are trained as forensic anthropologists via postmortem examinations, and have an intimate knowledge of the skeletal remains of human beings and have been involved in disaster victim identification since before the actual term was used. Early involvement in DVI included search and recovery assistance as every forensic anthropologist is trained in basic archaeological extraction, and the development and calculation of biological profiles of the decedents (Langely and Jantz, 2016). These biological profiles can provide information on the decedent based on measurements and identifiable areas on certain bones, which allows them to determine the sex, height, race, age and any skeletal abnormalities that may be have occurred from disease, injury or genetics. In cases where tissue left on the body may hinder the anthropologist's ability to visualize and precisely measure certain areas of the skeleton, it can be removed in a process known as maceration in which the body or body parts are placed in water with an enzymatic additive that cleans the bones, which can take several days to complete. Once the bones are clean, the anthropologist can take measurements of the long bones of the arms and legs of the decedent using specific natural markers in the bone as guidelines.

These measurements can then be put into a program used by forensic anthropologists across the world known as ForDisc, which uses over 80 years of proven statistical methods and discriminant functions to generate estimates of sex, ancestry, age and height (Jantz and Ousley, 2005; Langley and Jantz, 2016; Langley et al., 2016). ForDisc was created by the University of Tennessee's Forensic Anthropology Center, based on a grant from the National Institute of Justice in the 1980s. ForDisc 3.0 is the current version of the program and is based on repeatedly measured bones in a collection of approximately 3,400 modern human skeletons, from various ethnic populations, allowing it to be used in forensic criminal cases as well as

MFIs (Kahana and Hiss, 1997; Langley et al., 2016). Due to an inability by anthropologists to assess a quantifiable age in “sub-adults,” or those under the age of 18, ForDisc proves unreliable for creating accurate biological profiles for children.

The New York City Office of Chief Medical Examiner utilized their anthropologists during the 9/11 recovery and identification of decedents for almost 8 years after the event. These anthropologists identified tiny pieces of bones and extracted DNA samples which were then provided to the forensic biology department for DNA testing. Unfortunately, biological profiles cannot be utilized as the sole means of identification, but rather are used as a way to reduce a potentially large population for definitive identification methods by another discipline, such as odontology (dentition matching), or forensic biology (DNA testing).

Forensic odontologists are specialists who focus on the teeth, bite pattern, jaws, changes in dentition, as well as any and all dental devices or modifications that may occur over a decedent’s lifetime. Odontologists are also specialists when it comes to comparing x-rays and other radiological evidence, both ante- and postmortem, to definitively identify a decedent via comparison to their known dental records. Similar to anthropologists, an odontologist often needs access to a decedent’s jaw and teeth without additional tissue present, which may require the removal of the jaws and subsequent maceration previously described (Fischman, 1985; Pittayapat et al., 2012). They also have their own nationally recognized software system, WINID, for the event specific notation of known antemortem records, which can then be compared to decedent dental characteristics from bodies recovered due to the MFI. WINID allows odontograms, or dental diagrams, to be automatically created via the data entered for both ante- and postmortem records and allows discriminant “best matches” to be immediately available for further confirmation before a definitive identification is agreed on. Studies on the reliability of WINID have included over 50,000 reference samples, including missing and incomplete data samples to simulate a mass fatality incident, with an almost 80% success rate in identifying individuals based on their dentition. The American Board of Forensic Odontology (ABFO) uses and promotes the use of the WINID program. WINID is a paperless dental identification system that contains digitized ante- and postmortem options for dental charting, radiographs and photographs and enables specific comparisons to be made on a tooth-by-tooth basis. This is especially useful in instances of extreme heat, fire or impact damage to bodies, which may result in only portions of the jaw or single teeth available for examination. Unfortunately, many of these samples take between 3-5 days to go through testing, which can increase the identification period by some time (Adams and Aschheim, 2016). In the 2004 Indian Tsunami event, over 73% of the nearly 230,000 victims were identified using their dentition, using the international standard software, INTERPOL odontograms, with basic extraction and visual matching of ante-mortem and post-mortem x-rays (Pittayapat et al., 2012).

The use of WINID becomes difficult when dentists and odontologists in offices around the country utilize different dental coding symbols that they may have originally been taught in. Decoding of antemortem records can become especially challenging and time consuming, in an already time-sensitive setting such as those of a MFI. It would benefit forensic experts if a universal coding system was created and taught to established and new dentists, so that going forward, dental terminology and coding symbols would be consistent regardless of the state or part of the country records were being received from.

As we can see from the previous disciplinary evidence, the need for photographic and radiological evidence dominates all aspects of the disaster victim identification process in a mass fatality incident. **Photographers** with forensic training are one of the first professionals to encounter the deceased at a mass fatality incident. They document every step of the recovery and identification process, from location of the body at the incident to its transportation throughout the morgue stations, using digital cameras and are often also trained in advanced radiographic imaging techniques such as x-rays, or plain film radiographs, and computed tomography (CT) scans.

Examination of these radiographs can produce ‘tentative matches,’ although no set number of areas matching is considered standard, its use can significantly reduce an open population of decedents to a smaller number for additional means of definitive testing (Blau et al., 2008). Plain film radiographs allow examiners to see bones, teeth, calcifications, fractures and healing of bones, some tumors and other dense matter in the body, like surgical implants; CT scans combine x-rays with computer technology to produce cross-sectional images of the body (Porter and Doran, 2000; Ross et al., 2015). A multi-slice CT scan, or MSCT, allows an examiner to view the size, shape and position of organs, tissues, tumors, as well as those structures visible by traditional x-rays, and can compile them into a 3-D model of the decedent using various computer programs (Robinson et al., 2008). These images can be stored in an electronic database and also in hard copy format, allowing any of the forensic examiners involved in the recovery and identification of decedents at a MFI to then access these images for ante- and postmortem comparison and superimposition (Kahana and Hiss, 1997; Koot et al., 2005; Sidler et al., 2007). Matching ante- and postmortem images allows the team to compile a disaster victim identification list. The Department of Justice's Technical Working Report on the use of radiological evidence in identification, utilizing teams from three major universities in the United States, proved this. They found that when examining bodies, comparisons from a minimum of at least two locations, usually lateral cranial, chest, or proximal femur x-rays, resulted in a 97% probability of identification (Pittayapat et al., 2012). These x-rays are also the most common, as the cranial x-rays are usually available through a dentist.

A definitive identification can also be achieved using DNA testing, though this process requires significantly more time, technology and manpower, and costs significantly more money than traditional methods of identification such as radiological or fingerprint methods. As DNA is specific to only one person, meaning even identical twins have different DNA, the use of DNA testing can definitively match a MFI decedent to a missing persons record for that incident. In order to do DNA testing, a **forensic biologist** or **DNA analyst** must have access to the decedent's body to take a sample from the soft tissues (skeletal muscle, organ tissue and skin), or blood.

In cases where a body is decomposed due to exposure or a byproduct of the mass fatality incident, contaminated, or fragmented, DNA samples can also be extracted from bones and teeth (ICRC, 2009). As dental enamel is one of the hardest materials in the human body and can withstand extreme heat and pressure conditions, it is often used as a source of DNA extraction and testing for definitive identification purposes. A reference sample is also required to compare, and hopefully match and identify, to the decedent. This can be provided via a known antemortem sample (personal effects such as a toothbrush, razor or hairbrush, or biological specimens from previous medical procedures) or through a DNA sample from a direct relative of the decedent. A variety of DNA tests can be completed depending on the size and scope of the samples involved and the degradation of the sample, but the most common DNA tests are STR (short tandem repeats), mtDNA (mitochondrial DNA which requires female direct family members to compare to), and Y-chromosome testing (requires male direct family members to compare to), with most requiring a minimum of 13-20 loci, or areas, of matching to corroborate a definitive DNA match (Montelius and Lindblom, 2012; Zietkiewicz et al., 2012). The DNA samples can then be compared in a local software system, LIMS (laboratory information management system), or in the federal software system commonly used in the United States, CODIS, or the Combined DNA Identification System, that is also used by local, state and federal governments to address DNA samples in criminal and civilian settings.

Forensic biologists run DNA testing on a variety of machines depending on the test being utilized, the amount of DNA sample originally received and the level of degradation. There are currently only 6 nationally accepted “Expert System” software systems that can interpret the data generated from a DNA analysis instrument in accordance with laboratory-defined quality assurance rules and the FBI Director’s Quality Assurance Standards. The current standard for DNA matching requires a minimum of 20 different locations (loci) from the known antemortem sample to the unknown victim sample; the previous number was only 13 loci (Hartman et al., 2011). All DNA results are uploaded into the FBI’s National DNA Index System (NDIS) database using the Combined DNA Index System (CODIS), a software program that registers all DNA testing records from crime scenes, missing persons sample, relatives of missing persons, unidentified bodies, criminals convicted of a felony and any other

DNA samples contributed by federal, state and local labs. According to the FBI website, as of September 2017, CODIS contains over 16 million DNA profiles, assisting in almost 400,000 cases.

During the September 11, 2001 recovery and identification process, over 21,741 body parts were recovered, and of those, only 996 were identified using only DNA testing by December of 2008 (Montelius and Lindblom, 2012). Unfortunately, regardless of the DNA testing chosen, the materials and equipment required to perform the test are often too expensive to have in a local medical examiner's office, costing upwards of $50,000 per machine and a minimum of $400 per test, with each test taking at least 5 days to receive results (Hartman et al., 2011; Butcher et al., 2014).

Similar to the federal DNA database, there is also a federal database for fingerprints, the Integrated Automated Fingerprint Identification System (IAFIS), also operated by the FBI. IAFIS is considered the repository for criminal fingerprints from criminal offenders and unknown prints from crime scenes, all military and civilian federal employees and any other individuals as authorized by Congress, such as anyone who works with minors. With the passing of the Homeland Security Information Act in 2002, fingerprints of suspected and known terrorists are also in IAFIS. The system processes approximately 63,000 fingerprint samples each day, with each criminal submission taking approximately 2 hours to run through the entire database.

Appendix D

DMORT AND THE VIP PROGRAM

This appendix describes DMORT and the VIP program. Disaster Mortuary Operational Response Teams (DMORT) is a network of 10 regional teams across the country, currently organized via the Department of Health and Human Services' Office of Emergency Preparedness. The Victim Identification Profile (VIP) is the computer repository utilized by DMORT teams, which is accessible online, and is used to assemble ante-mortem (AM) and post-mortem (PM) information on victims.

The VIP system used by DMORT members during a mass fatality incident is built on a FileMaker Pro platform and is available for download on any computer with any operating system, as long as it has internet access. Users are given their own specific username and password and are able to access any screen and can create specific searches, as well as output reports that can be easily read in Microsoft Excel. The specific screens allow for investigators to utilize their forensic discipline accepted formulae and input that information into their notes on the VIP screens. Unfortunately, the VIP screens cannot "talk" to outside programs and users are required to describe where and how they came up with the data they are entering into the VIP. When presumptive matches are established in VIP, the results are then presented to an assembled Identification Team, chaired by a pathologist, consisting of representatives from all of the stationed departments, as well as the local coroner or medical examiner's office, for final confirmation before a death certificate is created and remains are released to family members for interment. The VIP program was most notably utilized in the response during 9/11 and Hurricane Katrina in 2005, and has subsequently been used in all national mass fatality incidents, since its inception, where DMORT has responded. It can handle over 1 million records for any one incident (Klimetz, 2017). Many state emergency management documents now list the VIP program as part of their procedures for victim identification; however, according to DMORT, very few coroners and medical examiners have actually received any formal training on the program.

In a 2017 discussion with Gregory Klimetz, one of the original members of DMORT and the creator and current database administrator for the VIP program, he echoed the concerns expressed in the general state of preparedness among coroners and medical examiners in the United States: there is a lack of overall consistency and quantitative data is hard to come by due to not being expected or having been asked for it in the past. According to Klimetz, "it is possible to integrate a lot of separate systems, but that requires three things: the federal government has to give permission and access these other programs, potentially providing access over the internet and that alone is highly unlikely to occur, money to either purchase the programs outright in order to add and build the integration from one program to another, and finally, the developers who can do the technological integration, which brings us back to the second requirement, money (Klimetz, 2017)." DMORT members have made suggestions and tried to introduce concepts into the VIP that make it as user friendly as possible and simple enough to work anywhere, at any time and on any computer with internet access. If there was to be an integration of programs into a unified system, it could potentially cost multimillions of dollars and not necessarily work as well, while being too expensive for local jurisdictions to access and operate. Klimetz continues to meet with federal and forensic personnel on a regular basis to keep abreast and address these issues, while constantly adding operations in the VIP software that he can account for. Subjective fields, such as fingernail length (originally listed as short, medium, long, very long) are being altered to have specific, more objective outcomes, in hopes that a faster, concrete identification can be obtained. Previous VIP input screens on surgical devices are being updated to allow investigators to add serial numbers and manufacturer names, as these items are known to provide relatively immediate identification to the individual that they were implanted in (Matoso et al., 2013). As tattoos and piercings have become more culturally acceptable, additional fields have also been added to the VIP program for examiners to describe and take photographs of them. Tattoos have been shown to withstand trauma, including fire, as the ink from a tattoo penetrates several layers of the skin, and can often be used to reduce a large population of decedents to a smaller, manageable group (Birngruber et al., 2011).

Appendix E

EMFD DOCUMENTATION OF FAILURE

The following resources were analyzed and referenced the aforementioned telecommunication failure(s) discussed within the Enhanced Mass Fatality Database:

Table E.1 Documents Referencing Evidence of Telecommunication Failure

Year	Event	Telecommunication Failure Evidence Documentation
2010	Albert Pike Campground Floods	USGS "Flood of June 11, 2010 in the Upper Little Missouri River Watershed, Arkansas" https://pubs.usgs.gov/sir/2011/5194/pdf/sir2011-5194.pdf USDA Review Team Report "Inquiry Regarding June 11, 2010 Flash Flood Incident Albert Pike Recreation Area Ouachita National Forest" https://wehco.media.clients.ellingtoncms.com/news/documents/2010/10/22/albertpikereviewteamreport0924.pdf USDA "Recreation Visitor Safety Report" https://wehco.media.clients.ellingtoncms.com/news/documents/2010/10/22/recreationsafetyreport1018.pdf
2011	April Super Tornado : Dekalb Co, AL	Tornado Recovery Action Council of Alabama 'Cultivating a State of Readiness: Our Response to April 27, 2011' https://alabamaema.files.wordpress.com/2017/01/trac_report.pdf D. Rhoades. Alabama Power Company. "AMI Extends Alabama Power's Outage System Effectiveness in Historic Storm" https://electricenergyonline.com/energy/magazine/615/article/AMI-Extends-Alabama-Power-s-Outage-System-Effectiveness-in-Historic-Storm.htm

2011	April Super Tornado : Franklin Co, AL	Tornado Recovery Action Council of Alabama 'Cultivating a State of Readiness: Our Response to April 27, 2011' https://alabamaema.files.wordpress.com/2017/01/trac_report.pdf D. Rhoades. Alabama Power Company. "AMI Extends Alabama Power's Outage System Effectiveness in Historic Storm" https://electricenergyonline.com/energy/magazine/615/article/AMI-Extends-Alabama-Power-s-Outage-System-Effectiveness-in-Historic-Storm.htm
2011	April Super Tornado : Jefferson Co, AL	Tornado Recovery Action Council of Alabama 'Cultivating a State of Readiness: Our Response to April 27, 2011' https://alabamaema.files.wordpress.com/2017/01/trac_report.pdf D. Rhoades. Alabama Power Company. "AMI Extends Alabama Power's Outage System Effectiveness in Historic Storm" https://electricenergyonline.com/energy/magazine/615/article/AMI-Extends-Alabama-Power-s-Outage-System-Effectiveness-in-Historic-Storm.htm
2011	April Super Tornado : Lawrence Co, AL	Tornado Recovery Action Council of Alabama 'Cultivating a State of Readiness: Our Response to April 27, 2011' https://alabamaema.files.wordpress.com/2017/01/trac_report.pdf D. Rhoades. Alabama Power Company. "AMI Extends Alabama Power's Outage System Effectiveness in Historic Storm" https://electricenergyonline.com/energy/magazine/615/article/AMI-Extends-Alabama-Power-s-Outage-System-Effectiveness-in-Historic-Storm.htm
2011	April Super Tornado : Marion, AL	Tornado Recovery Action Council of Alabama 'Cultivating a State of Readiness: Our Response to April 27, 2011' https://alabamaema.files.wordpress.com/2017/01/trac_report.pdf D. Rhoades. Alabama Power Company. "AMI Extends Alabama Power's Outage System Effectiveness in Historic Storm" https://electricenergyonline.com/energy/magazine/615/article/AMI-Extends-Alabama-Power-s-Outage-System-Effectiveness-in-Historic-Storm.htm

2011	April Super Tornado : St. Clair, AL	Tornado Recovery Action Council of Alabama 'Cultivating a State of Readiness: Our Response to April 27, 2011' https://alabamaema.files.wordpress.com/2017/01/trac_report.pdf D. Rhoades. Alabama Power Company. "AMI Extends Alabama Power's Outage System Effectiveness in Historic Storm" https://electricenergyonline.com/energy/magazine/615/article/AMI-Extends-Alabama-Power-s-Outage-System-Effectiveness-in-Historic-Storm.htm
2011	April Super Tornado : Tuscaloosa, AL	Tornado Recovery Action Council of Alabama 'Cultivating a State of Readiness: Our Response to April 27, 2011' https://alabamaema.files.wordpress.com/2017/01/trac_report.pdf D. Rhoades. Alabama Power Company. "AMI Extends Alabama Power's Outage System Effectiveness in Historic Storm" https://electricenergyonline.com/energy/magazine/615/article/AMI-Extends-Alabama-Power-s-Outage-System-Effectiveness-in-Historic-Storm.htm
2011	April Super Tornado : Monroe, MS	FEMA Mitigation Assessment Team Report "Tornado Outbreak of 2011 in Alabama, Georgia, Mississippi, Tennessee, and Missouri: Observations on Critical Facility Performance." https://www.fema.gov/media-library-data/20130726-1827-25045-9365/tornado_mat_chapter7_508.pdf
2011	Joplin Tornado	FEMA "The Response to the 2011 Joplin, Missouri Tornado Lessons Learned Study" https://kyem.ky.gov/Who%20We%20Are/Documents/Joplin%20Tornado%20Response,%20Lessons%20Learned%20Report,%20FEMA,%20December%2020,%202011.pdf NIST NCSTAR 3 "Technical Investigation of the May 22, 2011 Tornado in Joplin, Missoui" https://www.govinfo.gov/content/pkg/GOVPUB-C13-a0ac8adb5269166f1b1e230423cf79ec/pdf/GOVPUB-C13-a0ac8adb5269166f1b1e230423cf79ec.pdf

2012	Hurricane Sandy: NYC	NYC Hurricane Sandy After Action Report and Recommendations https://www1.nyc.gov/assets/housingrecovery/downloads/pdf/2017/sandy_aar_5-2-13.pdf CDC Morbidity and Mortality Weekly Report "Deaths Associated with Hurricane Sandy – October-November 2012" https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6220a1.htm
2012	Hurricane Sandy: NYC/Staten Island	NYC Hurricane Sandy After Action Report and Recommendations https://www1.nyc.gov/assets/housingrecovery/downloads/pdf/2017/sandy_aar_5-2-13.pdf CDC Morbidity and Mortality Weekly Report "Deaths Associated with Hurricane Sandy – October-November 2012" https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6220a1.htm
2012	Hurricane Sandy: Long Island Nassau County	NYC Hurricane Sandy After Action Report and Recommendations https://www1.nyc.gov/assets/housingrecovery/downloads/pdf/2017/sandy_aar_5-2-13.pdf CDC Morbidity and Mortality Weekly Report "Deaths Associated with Hurricane Sandy – October-November 2012" https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6220a1.htm
2012	Sandy Hook Elementary School Shooting	State of Connecticut Division of Criminal Justice "Report of the State's Attorney for the Judicial District of Danbury on the Shootings at Sandy Hook Elementary School" https://www.documentcloud.org/documents/841589-sandy-hook-final-report.html#document/p1 State of Connecticut Division of Criminal Justice "Appendix to Report on the Shootings at Sandy Hook Elementary School"

		https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=12&cad=rja&uact=8&ved=2ahUKEwjw1v363N3mAhVPnFkKHXUPARUQFjALegQIARAC&url=https%3A%2F%2Fschoolshooters.info%2Fsites%2Fdefault%2Ffiles%2FAppendix_to_Sandy_Hook_Official_Report.pdf&usg=AOvVaw21xOySmGBFa_brVaK6lLoe
2013	Oklahoma Tornado	NIST "Preliminary Reconnaissance of the May 20, 2013, Newcastle-Moore Tornado in Oklahoma" https://www.nist.gov/publications/preliminary-reconnaissance-may-20-2013-newcastle-moore-tornado-oklahoma FEMA "Formal Observation Report: Tornado: Moore, Oklahoma, May 20, 2013" https://www.fema.gov/sites/default/files/2020-07/tornado-report_moore-oklahoma_2013.pdf Oklahoma Dept. of Emergency Management "Severe Weather Impacts State" https://www.ok.gov/OEM/Emergencies_&_Disasters/2013/20130518_Severe_Weather_Event/20130524_Situation_Update_7.html
2013	Washington Navy Yard shooting	Metropolitan Police Department "AAR Washington Navy Yard" https://www.policefoundation.org/wp-content/uploads/2015/05/Washington-Navy-Yard-After-Action-Report.pdf
2014	Oso Mudslide	Center for Homeland Defense and Security "Massive Oso Landslide Response" https://www.chds.us/c/chds-alumni-in-action/fullstory-oso
2015	Inland Regional Center holiday shooting	Braziel et al. "Bringing Calm to Chaos: A critical incident review of the San Bernardino public safety response to the December 2, 2015, terrorist shooting incident at the Inland Regional Center" https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=14&cad=rja&uact=8&ved=2ahUKEwiut9KJ79DlAhUNrVkKHYfiBs8QFjANegQIBhAC&url=https%3A%2F%2Fwww.justice.gov%2Fusao-cdca%2Ffile%2F891996%2Fdownload&usg=AOvVaw2w5I4SKoOeFc8U5r3Zda9m

2016	Pulse Nightclub shooting	National Police Foundation “Rescue, Response, and Resilience: A Critical Incident Review of the Orlando Public Safety Response to the Attack on the Pulse Nightclub” https://www.policefoundation.org/publication/rescue-response-and-resilience-a-critical-incident-review-of-the-orlando-public-safety-response-to-the-attack-on-the-pulse-nightclub/
2017	Harris Tropical Strom (Hurricane Harvey)	HCIFS Storm-Related Deaths of Hurricane Harvey https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=13&cad=rja&uact=8&ved=2ahUKEwiQ3oXMi9HlAhXnnuAKHSzNCW04ChAWMAJ6BAgFEAI&url=https%3A%2F%2Fifs.harriscountytx.gov%2FDocuments%2FHarrisCountyHarvey-RelatedDeaths.pdf&usg=AOvVaw38K3cUD-KoMbymCeA_i5au Blake and Zelinsky National Hurricane Center Tropical Cyclone Report “Hurricane Harvey 17 Aug-1 Sept. 2017” https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=15&ved=2ahUKEwjgte__i9HlAhWriOAKHSa7CHcQFjAOegQIBxAC&url=https%3A%2F%2Fwww.nhc.noaa.gov%2Fdata%2Ftcr%2FAL092017_Harvey.pdf&usg=AOvVaw1CUKSwEp5U8N4eRl2VO6dD
2017	Bridge City Flash Flood (Hurricane Harvey)	Blake and Zelinsky National Hurricane Center Tropical Cyclone Report “Hurricane Harvey 17 Aug-1 Sept. 2017” https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=15&ved=2ahUKEwjgte__i9HlAhWriOAKHSa7CHcQFjAOegQIBxAC&url=https%3A%2F%2Fwww.nhc.noaa.gov%2Fdata%2Ftcr%2FAL092017_Harvey.pdf&usg=AOvVaw1CUKSwEp5U8N4eRl2VO6dD
2017	Hurricane Irma	FCC “2017 Atlantic Hurricane Season Impact on Communications: Report and Recommendations” https://docs.fcc.gov/public/attachments/DOC-353805A1.pdf MB Public Affairs Inc. “Communications, 911 Call Center, and Electrical Service Outages Caused by Hurricane Harvey & Hurricane Irma” https://mbpublicaffairs.com/wp-content/uploads/2017/09/Hurricane-Cellular-Outage-Data-Memo-September-15-2017.pdf

		Witt O'Briens "City of Pompano Beach Hurricane Irma After Action Report" http://pompanobeachfl.gov/assets/docs/pages/fire/1-Pompano%20Beach%20IRMA%20AAR%20Final%20Report.pdf
2017	Hurricane Irma	FCC "2017 Atlantic Hurricane Season Impact on Communications: Report and Recommendations" https://docs.fcc.gov/public/attachments/DOC-353805A1.pdf Miami Dade Commissioner Levine Cava "HURRICANE IRMA REPORT & RECOMMENDATIONS" https://www.miamidade.gov/district08/library/irma-after-report.pdf MB Public Affairs Inc. "Communications, 911 Call Center, and Electrical Service Outages Caused by Hurricane Harvey & Hurricane Irma" https://mbpublicaffairs.com/wp-content/uploads/2017/09/Hurricane-Cellular-Outage-Data-Memo-September-15-2017.pdf
2017	Route 91 Vegas Harvest Festival	FEMA "1 October AAR" https://www.hsdl.org/?abstract&did=814668
2017	First Baptist Church Sutherland TX shooting	Scherer, J. "Seven minutes of terror: survivor recalls church massacre. " https://www.expressnews.com/news/local/article/Seven-minutes-of-terror-Survivor-recalls-church-12346347.php
2018	Stoneman-Douglas HS shooting	Florida Commission Report "MSD Public Safety Commission Initial Report" http://www.fdle.state.fl.us/msdhs/commissionreport.pdf Revised Commission Report http://www.fdle.state.fl.us/MSDHS/MSD-Report-2-Public-Version.pdf National Police Foundation "Regional Public Safety Communications in Broward County" http://www.policefoundation.org/wp-content/uploads/2020/03/Broward-County-Regional-Public-Safety-Communications-Interim-Report.pdf

2018	Santa Fe TX HS Shooting	Blad, S. “Substitute Teacher Shot in Santa Fe High School Attack Says Subs Need Safety Training” https://www.edweek.org/ew/articles/2019/05/15/substitute-teacher-shot-in-santa-fe-high.html Texas Dept. of Public Safety “Assessing the Threat of Mass Attacks in Texas” https://www.dps.texas.gov/director_staff/media_and_communications/2020/txMassAttackAssessment.pdf Timeline of Santa Fe HS Shooting Phone Calls https://www.wfaa.com/video/news/local/timeline-of-santa-fe-high-school-shooting-phone-calls/285-8133213
2018	Hurricane Michael	FCC “October 2018 Hurricane Michael’s Impact on Communications: Preparation, Effect, and Recovery” https://docs.fcc.gov/public/attachments/DOC-357387A1.pdf Bay County FL “Hurricane Michael: Response, Recovery and Lessons Learned” https://www.fl-counties.com/sites/default/files/2019-10/Policy%20Conference%20PPT%20-%20ALL%20-%20Compressed.pdf
2018	California Camp wildfires	Frazier, A. “Not Their Place to Run” https://iaedjournal.org/not-their-place-to-run/ Comfort et al. “Collective Action in Communities Exposed to Recurring Hazards: The Camp Fire, Butte County, California, Nov. 8, 2018” https://hazards.colorado.edu/quick-response-report/collective-action-in-communities-exposed-to-recurring-hazards State of California, Public Utilities Commission https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/News_Room/NewsUpdates/2019/11.13.19%20Letter%20to%20Telecos%20for%20Information%20and%20Hearing.pdf

2019	Virginia Beach Shooting	Hillard Heintze "The City of Virginia Beach: An Independent Review of the Tragic Events of May 31, 2019" https://www.vbgov.com/government/departments/city-auditors-office/Documents/Hillard%20Heintze%20Final%20Report%20for%20Virginia%20Beach%2011-13-2019.pdf Virginia Beach Police Department "May 31, 2019 Mass Homicide Updated Executive Summary" https://www.vbgov.com/government/departments/communications-office/Documents/04242020_InterimMay31InvestSummary_(002).pdf
2019	El Paso Walmart Shooting	Saenz, M. "Police chief, fire chief give updates to City Council about El Paso shooting" https://kfoxtv.com/news/local/police-chief-fire-chief-give-updates-to-city-council-about-el-paso-shooting Martinez, V. "The First Call: Between the chaos, call takers and dispatchers look back to Aug. 3 shooting" First Person Resources https://www.elpasotimes.com/in-depth/news/2020/07/30/el-paso-walmart-mass-shooting-911-dispatchers-recall-august-3/5480660002/

Appendix F

IRB EXEMPTION LETTER

Institutional Review Board
210H Hullihen Hall
Newark, DE 19716
Phone: 302-831-2137
Fax: 302-831-2828

DATE:	July 7, 2020
TO:	Melissa Brown de Gerena, PhD
FROM:	University of Delaware IRB
STUDY TITLE:	[1613616-1] COMPLEXITIES OF MASS FATALITY INCIDENTS IN THE UNITED STATES: PREDICTING TELECOMMUNICATION SURGE
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
EFFECTIVE DATE:	July 7, 2020
REVIEW CATEGORY:	Exemption category # *(2)*

Thank you for your New Project submission to the University of Delaware Institutional Review Board (UD IRB). According to the pertinent regulations, the UD IRB has determined this project is EXEMPT from most federal policy requirements for the protection of human subjects. The privacy of subjects and the confidentiality of participants must be safeguarded as prescribed in the reviewed protocol form.

In-person research interaction with subjects cannot begin until the UD moratorium in response to the declaration of national emergency related to the COVID-19 pandemic is lifted. Please continue to reference https://research.udel.edu/coronavirus for the most up-to-date recommendations.

This exempt determination is valid for the research study as described by the documents in this submission. Proposed revisions to previously approved procedures and documents that may affect this exempt determination must be reviewed and approved by this office prior to initiation. The UD amendment form must be used to request the review of changes that may substantially change the study design or data collected.

Unanticipated problems and serious adverse events involving risk to participants must be reported to this office in a timely fashion according with the UD requirements for reportable events.

A copy of this correspondence will be kept on file by our office. If you have any questions, please contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu. Please include the study title and reference number in all correspondence with this office.

INSTITUTIONAL REVIEW BOARD

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Appendix G

TELECOMMUNICATION FAILURES IN MASS FATALITY EVENT SURVEY DOCUMENTATION

G.1 Introductory Email

To Whom It May Concern:

My name is Melissa Brown de Gerena and I am a Ph.D.student at the University of Delaware currently conducting dissertation research on large-scale mass fatality events in the United States. In [XXX] your organization was involved in a mass fatality [XXX] and it was publicly documented that there may have been telecommunication failures that occurred during this event. I am hoping that representatives from your 911 center, first responders and/or emergency management division would be able to answer some brief questions around the 911 communication response to that event.

No personal or identifying information is required, and all answers will be kept confidential. Reporting of the survey results will be objective summaries of all responses and will not discuss the specific location, who responded other than to say 911, first responder and emergency management staff, or the specific answers, but rather the overall outcomes from all of the responses. The survey should take no more than 10 minutes

If you were directly involved in the response for this event, I would appreciate you completing this survey. Whether you were directly involved or not, I would appreciate it if you would please forward this email and attached survey link to whomever you think would be best suited. If you are not comfortable sharing this email, please send me the email address(es) of those individuals you think would be able to address communications during the event. Thank you for your consideration in participating in this research. The link and QR code for the survey are below.

Best

Melissa Brown de Gerena

Communications in Mass Fatality Events Survey

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G.2 Survey Questions

1 You are being asked to participate in a research study being done by Melissa Brown de Gerena at the University of Delaware for purposes of understanding the preparedness of the 911 system during mass fatality events. Being in this study is optional and confidential. NO personal information is required.

If you choose to be in the study, you will complete a brief survey regarding the 911 center response to mass fatality event(s) that occurred in your community. The survey will take approximately 5-10 minutes to complete. You can stop the survey at any time. We will keep your answers confidential and will not share your responses with anyone outside the research team.

Any question can be directed to Melissa Brown de Gerena at MLBDG@udel.edu. If you have questions or concerns about your rights as a research participant, you can contact Dr. Sue McNeil at smcneil@udel.edu.

Are you willingly participating in this survey?

- O Yes (1)
- O No (2)

2 Please choose the mass fatality incident(s) from the choices below that you were involved in.

- ▢ 2019 Lee County, AL tornadoes (1)
- ▢ 2019 Conception boat fire (CA) (2)
- ▢ 2019 sky diving crash (HI) (3)
- ▢ 2019 Dayton, OH shooting (4)
- ▢ 2019 Addison, TX plane crash (5)
- ▢ 2019 El Paso, TX Walmart shooting (6)
- ▢ 2019 Virginia Beach, VA municipal building shooting (7)
- ▢ 2018 Camp, CA fires (8)
- ▢ 2018 Thousand Oaks, CA shooting (9)
- ▢ 2018 Pittsburgh, PA Tree of Life shooting (10)
- ▢ 2018 Bay County (FL) Hurricane Michael (11)
- ▢ 2018 Scholarie, NY limo crash (12)
- ▢ 2018 Taney, MO duck boat accident (13)
- ▢ 2018 Santa Fe High School shooting (TX) (14)
- ▢ 2018 Stoneman-Douglas High School shooting (FL) (15)
- ▢ 2017 First Baptist Church shooting (Sutherland, TX) (16)
- ▢ 2017 Route 91 Harvest Festival shooting (Las Vegas, NV) (17)

- 2017 Monroe County (FL) Hurricane Irma (18)
- 2017 Broward County (FL) Hurricane Irma (19)
- 2017 Orange County (TX) Bridge City flash flood/Hurricane Harvey (20)
- 2017 Harris County (TX) Hurricane Harvey (21)
- 2017 Gila County (AZ) Washington Park flash flood (22)
- 2017 Uvalde County (TX) church bus/truck crash (23)
- 2016 Ghost Ship warehouse fire (Alameda, CA) (24)
- 2016 Memphis house fire (Shelby Co., TN) (25)
- 2016 Lockhart (TX) hot air balloon crash (26)
- 2016 Pulse Nightclub shooting (Orlando, FL) (27)
- A 2016-2019 event not listed in which 10 or more people perished (28) ____

3 What organization did you work for during the above chosen mass fatality incident?

____

4 What was your role? Choose all that apply

- ▢ 911/PSAP Call Center (1)
- ▢ Emergency Management (2)
- ▢ First Responder (fire, police, EMS) (3)
- ▢ Other (please explain) (4) ____

5 Did you perceive any telecommunication failures? Please choose any that you are aware of occurring during the above mentioned mass fatality incident.

- ▢ Evidence of the 911 system being overwhelmed or calls not being answered and/or calls lagging (1)
- ▢ Evidence of 911 calls being dropped (2)
- ▢ Evidence of 911 calls being put on hold (3)
- ▢ Evidence of 911 calls being transferred elsewhere (ex. to multiple PSAPs or 911 centers) (4)
- ▢ Evidence of damaged or not functioning telecommunication wires or towers, or major power outages (5)
- ▢ Evidence of interoperability failures or radio issues (ex. first responders not on the same radio channel) (6)
- ▢ Evidence of personnel issues (ex.being understaffed, arguing) (7)
- ▢ Other (please specify) (8) ____

6 If you were aware of any evidence of telecommunication failure listed above (in Q5), what do you think would have alleviated or reduced the failure?

____

7 At the time of the incident, was the 911 center fully staffed?

- Yes (1)
- No (2)
- I don't know (3)
- Other (please explain) (4) ____________________

8 How often are 911 calls transferred?

- All of the time (100%) (1)
- Most of the time (75-99%) (2)
- Often (51-74%) (3)
- About half of the time (50%) (4)
- Some of the time (26-49%) (5)
- Rarely (1-25%) (6)
- Never (0%) (7)
- I don't know (8)

9 Are dropped call transfers common?

- Yes (1)
- No (2)
- I don't know (3)
- Other (please explain) (4) ____________________

10 Where are calls transferred to? (select all that apply)

- Other PSAP or 911 center (1)
- Within the 911 center (ex. to fire or police dispatch, or another call-taker) (2)
- Calls are not transferred (3)
- Other (please explain) (4) ____________________

11 If a similar event occurred today or in the near future how would you rank your organization's preparedness level to handle the telecommunication issues previously discussed?

- Better prepared (1)
- Similarly prepared (2)
- Less prepared (3)

12 Can you explain what prompted you to select your preparedness choice from Q11? (ex. what tools have been implemented, are there more staff, etc.)