



**NAVAL
POSTGRADUATE
SCHOOL**

MONTEREY, CALIFORNIA

THESIS

**UNDERSTANDING CROWD DYNAMICS AND PSYCHOLOGY
FOR BETTER EMERGENCY RESPONSE**

by

Steven L. Bartram

June 2023

Co-Advisors:

Nadav Morag (contractor)
Erik J. Dahl

Approved for public release. Distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC, 20503.			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE June 2023	3. REPORT TYPE AND DATES COVERED Master's thesis	
4. TITLE AND SUBTITLE UNDERSTANDING CROWD DYNAMICS AND PSYCHOLOGY FOR BETTER EMERGENCY RESPONSE		5. FUNDING NUMBERS	
6. AUTHOR(S) Steven L. Bartram			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A		10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.		12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) Large events around the world—including sporting matches, music festivals, religious events, and other outdoor gatherings—continue to result in crowd crush injuries and deaths. Examined closely, crowd crush incidents tend to have the same causal factors that could have been addressed and avoided. When they are not prevented, the cases are often not recognized as a crowd crush, so an effective response is delayed. In crowd crush fatalities, compressive asphyxia is the most common cause of death. The treatment of patients depends on the timely response of emergency medical services to resuscitate patients. Through case studies of the 1989 Hillsborough soccer match, the 2021 Astroworld music festival, and the 2022 Itaewon, South Korea, crowd crush, this thesis reveals deficiencies in responding to these tragedies. Event organizers and first responders share responsibility in handling these events and must coordinate their efforts to prevent injuries caused by dynamic crowds. This thesis recommends that fire departments participate directly in the planning process and management of the event as one of the primary stakeholders. Furthermore, training in crowd dynamics and safety should be a part of the first responder's knowledge base and education.			
14. SUBJECT TERMS crowd dynamics, crowd psychology, crowd modeling		15. NUMBER OF PAGES 75	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release. Distribution is unlimited.

**UNDERSTANDING CROWD DYNAMICS AND PSYCHOLOGY FOR BETTER
EMERGENCY RESPONSE**

Steven L. Bartram
Battalion Chief, Los Angeles County Fire Department
BA, California State University, Bakersfield, 2004

Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL
June 2023**

Approved by: Nadav Morag
Co-Advisor

Erik J. Dahl
Co-Advisor

Erik J. Dahl
Associate Professor, Department of National Security Affairs

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Large events around the world—including sporting matches, music festivals, religious events, and other outdoor gatherings—continue to result in crowd crush injuries and deaths. Examined closely, crowd crush incidents tend to have the same causal factors that could have been addressed and avoided. When they are not prevented, the cases are often not recognized as a crowd crush, so an effective response is delayed. In crowd crush fatalities, compressive asphyxia is the most common cause of death. The treatment of patients depends on the timely response of emergency medical services to resuscitate patients. Through case studies of the 1989 Hillsborough soccer match, the 2021 Astroworld music festival, and the 2022 Itaewon, South Korea, crowd crush, this thesis reveals deficiencies in responding to these tragedies. Event organizers and first responders share responsibility in handling these events and must coordinate their efforts to prevent injuries caused by dynamic crowds. This thesis recommends that fire departments participate directly in the planning process and management of the event as one of the primary stakeholders. Furthermore, training in crowd dynamics and safety should be a part of the first responder’s knowledge base and education.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I.	INTRODUCTION.....	1
A.	RESEARCH QUESTION	2
B.	LITERATURE REVIEW	2
1.	Crowd Dynamics.....	2
2.	Crowd Psychology.....	4
3.	After-Action Reviews and Regulatory Publications	4
4.	Naval Postgraduate School Theses	6
C.	RESEARCH DESIGN	6
D.	CHAPTER OVERVIEW	7
II.	CROWD DYNAMICS AND PSYCHOLOGY.....	9
A.	CROWD DYNAMICS.....	10
1.	Density.....	11
2.	Shockwaves.....	11
3.	Crowd Collapse	12
4.	Compressive Asphyxia.....	13
B.	CROWD PSYCHOLOGY	14
1.	Crowd Craze.....	15
2.	Collective Psychosocial Resilience	16
C.	CONCLUSION	16
III.	CASE STUDIES.....	19
A.	HILLSBOROUGH STADIUM DISASTER.....	19
1.	Sequence of Events.....	20
2.	Identifying and Understanding the Mistakes	24
B.	ASTROWORLD MUSIC FESTIVAL	28
1.	Sequence of Events.....	28
2.	Identifying and Understanding the Mistakes	31
C.	ITAEWON, SEOUL, SOUTH KOREA.....	34
1.	Sequence of Events.....	34
2.	Identifying and Understanding the Mistakes	37
IV.	CONCLUSIONS AND RECOMMENDATIONS.....	41
A.	CONCLUSIONS	41
1.	Planning	42
2.	Command and Control.....	43

3. Training 44

B. RECOMMENDATIONS..... 44

1. Fire Departments Should Take the Lead in Crowd Safety..... 44

2. Provide Awareness-Level Crowd Safety Training for Fire Department and EMS Personnel..... 45

3. Leverage Emerging Technologies..... 45

C. FINAL THOUGHTS 46

LIST OF REFERENCES..... 47

INITIAL DISTRIBUTION LIST 55

LIST OF FIGURES

Figure 1.	Map of Hillsborough Stadium and Surrounding Area.....	21
Figure 2.	Spectators Crushed at Hillsborough Stadium.	23

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

DMAT	disaster medical assistance team
EAP	event action plan
EMS	emergency medical service(s)
EOP	event operations plan
HFD	Houston Fire Department
HPD	Houston Police Department
ICS	Incident Command System
MCI	mass casualty incident
MIP	major incident plan
NMC	National Medical Center
SYMAS	South Yorkshire Metropolitan Ambulance Service
SYP	South Yorkshire Police
TTFCS	Texas Task Force on Concert Safety
UCC	unified command and control

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Crowd crush events continue to happen around the world as large crowds meet at sporting events, entertainment venues, and religious gatherings. The most recent crowd crush in the United States was at the November 5, 2021, Astroworld music festival, which resulted in nine deaths—calling into question safety procedures at major entertainment venues.¹ Internationally, the October 29, 2022, Itaewon disaster in a Seoul, South Korea, entertainment district, killed 158 people, and on April 30, 2021, in Mt. Meron, Israel, 45 perished during the annual pilgrimage to the Tomb of Rabbi Shimon bar Yochai. One report showed that over a decade (1992–2022), 262 people died and 66,787 people were injured in outdoor music festivals worldwide.² The United States continues to be at risk for crowd crush incidents as people attend large events in ever greater numbers. It is estimated that over 30 million people attend music concerts every year.³ In 2019, it was reported that 150 million people attended sporting events in North America.⁴

This thesis asked how patterns of crowd dynamics and behavior might be determined and used in the planning and response to future events by fire departments and emergency responders. Using qualitative research methods, this thesis investigated patterns in crowd dynamics and behavior and their application in emergency response, with case studies of crowd crushes with extensive injuries at large venues, beginning with the 1989 Hillsborough tragedy. A analysis of the tenets of crowd dynamics and behavior was used to establish the basic terminology and accepted concepts in these fields. This analysis

¹ Jack Denton, “Yes, the Dangerous Crowd Crush at Astroworld Was Probably Preventable,” *Vice*, November 9, 2021, <https://www.vice.com/en/article/bvnx7a/the-dangerous-crowd-crush-at-astroworld-was-probably-preventable>.

² Aldo Raineri, “The Causes and Prevention of Serious Crowd Injury and Fatalities at Outdoor Music Festivals,” in *Proceedings of the SIA 12th Annual Occupational Health and Safety VISIONS Conference* (Brisbane: Safety Institute of Australia, 2005), 1–14, <https://doi.org/10.13140/2.1.3036.0005>.

³ Joe Lynch, “Check Out These Surprising Stats about U.S. Music Festivals,” *Billboard*, April 22, 2015, <https://www.billboard.com/culture/events/music-festival-statistics-graphic-6539009/>.

⁴ U.S. Travel Association, “The Impact of Sports on the Travel Industry” (Washington, DC: U.S. Travel Association, 2019), https://www.ustravel.org/system/files/media_root/document/2019_Sports_Travel_07.11.19.pdf.

involved reviewing public reports and after-action reviews of the incidents, which provided valuable insight into both the beneficial and harmful actions of responders.

Understanding crowd behavior and its underlying psychological elements is another important aspect for emergency responders in crowd-related disasters. In crushing incidents, a series of events or crowd behaviors lead up to the accident. Outside influences and group perceptions might spur a group to move en masse, causing possible injuries. The threat of danger or a perceived loss, natural or human-made, can cause a fear reaction in the group, resulting in crowd movement that creates the conditions for crushing injuries. Such aspects of crowd psychology are important to first responders during emergencies.

This thesis offers the following recommendations.

First, fire departments should take the lead in crowd safety. Fire departments and EMS agencies have a primary responsibility in life safety. They provide EMS support in the field and are responsible for transporting the injured to hospitals.

Second, fire department and EMS personnel should receive awareness-level crowd safety training. Specifically, crowd management courses and certifications should be a part of the fire department’s training process, and recruits should encounter this material in their initial training. Members of the fire service should develop simple warning signs to alert personnel to an imminent crowd crush. Such guidance and associated firefighting orders have proven successful in wildland firefighting and can be applied to crowd dynamics, too.⁵

Third, fire departments should leverage emerging technologies. Emerging technologies have shown promise in detecting dangerous crowd dynamics more rapidly and alerting crowd managers and first responders to risks before they turn into tragedy. Developing crowd monitoring systems that can scrutinize real-time crowd conditions to evaluate crowd dynamics—analyzing crowd density, movement, and behavior—will prove

⁵ “18 Watch Out Situations, PMS 118,” National Wildfire Coordinating Group, January 25, 2023, <https://www.nwcg.gov/publications/pms118>.

beneficial in preventing crowd crush in the first place.⁶ Additionally, machine learning and automatic speech recognition software can assist dispatch centers, as keywords and phrases used by callers may indicate a crowd crush is imminent.

⁶ Victoria Hutchison, “Crowd Source,” *NFPA Journal*, August 2020, <https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2020/July-August-2020/Features/Crowd-Control>.

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

First and foremost, to my wife, Judi, thank you for your unwavering support and encouragement during this long process. You were my go-to editor so many times. To my children, Jonathan and Jordan, thank you for your patience when you saw your dad sitting at the computer, again.

To my advisors, Dr. Erik Dahl and Dr. Nadav Morag, thank you for your guidance and patience. To Greta Marlatt, thank you for your reference and citation work. I would also like to thank Dr. Chris Bellavita, who encouraged me to stay in the program when the pressures of work increased exponentially during the COVID pandemic, civil unrest, and an upcoming Super Bowl.

Additionally, I want to thank the Graduate Writing Center and, especially, Chloe Woida, who reviewed most of my thesis and gave me so many great suggestions.

I also extend my gratitude to the County of Los Angeles Fire Department for supporting my going to CHDS and for being such a blessing over the years to my family and me.

Last, I want to thank my classmates from Cohort 2005/2006, who encouraged me to continue, especially the East Coasters, who always answer the phone when I call.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

The crowd crush at the Astroworld music festival in Houston, Texas, on November 5, 2021, resulted in 10 deaths, including a nine-year-old boy. The incident occurred when large crowds pushed toward the stage as the singer Travis Scott was about to perform.¹ The victims, centered near the front, suffered the effects of compressive asphyxia and, in some cases, trampling resulting in their deaths. In the aftermath, more than 300 were reported injured.² The crowd, a mix of adults, teenagers, and some children, attended the festival with the expectation of a safe and enjoyable concert. The crowd crush developed over several hours and was not fully recognized by event staff.³ It was called the worst crush incident in the United States since The Who concert in Cincinnati, Ohio, in 1979.⁴

The NRG arena complex in Houston, Texas, is one of thousands of large-scale venues around the globe that provide a meeting point for mass events.⁵ Crowd crush incidents like many emergencies are low-frequency, high-risk events for which agencies should prepare.⁶ Fire departments find it difficult to plan for the effects of crowd dynamics and should work in conjunction with law enforcement in emergency response applications.⁷ Specific work in crowd dynamics related to large venues is ongoing and can

¹ “Governor Abbott Forms Texas Task Force on Concert Safety following Astroworld Festival Tragedy,” Office of the Texas Governor, November 10, 2021, <https://gov.texas.gov/news/post/governor-abbott-forms-texas-task-force-on-concert-safety-following-astroworld-festival-tragedy>.

² Palmer Haasch, “Crowd Surges like the One at Travis Scott’s Astroworld Concert Have a Long History,” Insider, November 11, 2021, <https://www.insider.com/crowd-astroworld-crush-surge-travis-scott-concert-festival-disaster-history-2021-11>.

³ Ashley Collman, “‘I’m Going to Die Because This Man Is Not Stopping the Concert’: How the Deadly Crowd Surge at Astroworld Unfolded,” Insider, November 13, 2021, <https://www.insider.com/how-travis-scott-astroworld-crowd-surge-unfolded-2021-11>.

⁴ “1979: The Who Concert Tragedy,” Working with Crowds, accessed January 21, 2023, <https://www.workingwithcrowds.com/1979-the-who-concert-tragedy/>.

⁵ “Home Page,” NRG Park, accessed April 10, 2023, <https://www.nrgpark.com/>.

⁶ Gordon Graham, “High-Risk, Low-Frequency Events in Public Safety,” *Lexipol* (blog), July 15, 2020, <https://www.lexipol.com/resources/blog/high-risk-low-frequency-events-in-public-safety/>.

⁷ Rick Griggs, “Fire Department Perspective: Crowd Dynamics and Safety at Outside Events” (master’s thesis, Naval Postgraduate School, 2017), <https://hdl.handle.net/10945/56930>.

be valuable to the planning process. A risk analysis of site construction, entry and exit points, and normal and emergency operations is important in understanding crowd crush.⁸

As the Astroworld festival tragedy demonstrates, the interactions of large crowds exhibit complexity that sometimes leads to crushing accidents. By understanding how crowds act in dynamic situations, first responders can better prepare to handle these situations with the limited resources available to them.

A. RESEARCH QUESTION

How might patterns of crowd dynamics and behavior be determined and used in the planning and response to future events by fire departments and emergency responders?

B. LITERATURE REVIEW

This literature review aims to examine the various aspects of crowd dynamics and group psychology and how they apply to emergency response. The applicable literature falls into four main categories: crowd dynamics, crowd psychology, after-action reviews, regulatory publications, and past Naval Postgraduate School theses.

1. Crowd Dynamics

The primary target of the literature is the study of crowd dynamics and crowd behavior. Since the 1970s, researchers have extensively examined crowd behavior and, more recently, crowd and group psychology, each one playing a role in this body of knowledge. Researchers G. Keith Still, John Fruin, and Andrew Adamatsky have written comprehensively on crowd dynamics. The concept of crowd surge and the associated deleterious effects it has in certain settings represent a key component of crowd dynamics. This phenomenon is well documented in the literature and the results cited in many of the cases.⁹ A significant portion of the literature arises from Europe and the United Kingdom (UK). Regulatory bodies in the UK and the European Union publish regulations and

⁸ G. Keith Still, *Introduction to Crowd Science* (London: CRC Press, 2014), <https://doi.org/10.1201/b17097>.

⁹ Still.

guidelines covering large events. Various sources document the notorious injuries inflicted on soccer fans at venues due to large crowds and the continual need to regulate such events. In the UK, the Sports Ground Safety Authority's *Green Guide* provides detailed guidance on large sports venues.¹⁰ The guide is a general source that helps event planners and venue operators adequately address issues that arise when large crowds are present. The document has been revised several times since its inception in 1975. The current edition shows its evolution and addresses incidents such as the 1996 Hillsborough tragedy, where 96 people lost their lives in a crowd crush situation at a popular soccer match.

Crowd dynamics researchers study crowd modeling, both qualitatively and quantitatively. Still posits that computer simulations of groups in various situations help to explain larger group dynamics. He also proposes that qualitative knowledge is much more insightful and practical, especially in emergency situations that cause injuries.¹¹ Still's work provides a valuable foundation for crowd science and dynamics. At its core, his book helps the reader understand the basics of crowd density and its effect on static and dynamic situations. In this context, crowd density is a measure of how many individuals occupy a given area. He details the shock wave and crowd surge concepts and explains how the phenomena result in injuries to individuals and sometimes large groups.¹² Furthermore, the work contains practical applications to event planning and emergency response that are well worth examining.

Like Still, John Fruin has extensively researched the crowd dynamics of large events. He highlights that injuries due to crowd dynamics arise in myriad situations, from large events to more isolated and unique events like funerals.¹³ Fruin argues that in crowd dynamics, unique qualities in combination contribute to the magnitude and severity of

¹⁰ "Guide to Safety at Sports Grounds: 'Green Guide,'" Sports Grounds Safety Authority, accessed March 29, 2021, <https://sgsa.org.uk/greenguide/>.

¹¹ Still, *Introduction to Crowd Science*.

¹² Still, 44.

¹³ John J. Fruin, "The Causes and Prevention of Crowd Disasters" (paper presented at the First International Conference on Engineering for Crowd Safety, London, England, March 1993), 10.

accidents.¹⁴ As part of the research into crowd dynamics for emergency response, Fruin's concepts apply to the planning process for large crowd events.

2. Crowd Psychology

Significant research has explored crowd behavior and psychology and how the group reacts to chaotic events. Some researchers initially assumed that people subject to traumatic events simply panic and act irrationally and that the acts of a few carry over to the group as a whole. The thought was that panic would set in, causing the fight-or-flight response that would lead the crowd to stampede like cattle. Anthony R. Mawson, in his research on mass panic, counters the commonly held belief that groups exposed to trauma tend toward panic. His research cites many cases in which the group acts collectively to aid each other.¹⁵

Crowd psychology is as important as the physical dimensions of the crowd. Numerous studies of crowd psychology warrant further investigation as it relates to this thesis. A University of Sussex study by Cocking, Drury, and Reicher applies modern psychological theories to crowd dynamics in emergencies.¹⁶ The study posits that crowd panic does not exist; the scholars, challenging the idea that people simply run for their lives in utter panic, counter that people for the most part act in controlled ways. Cocking, Drury, and Reicher address the fire service in particular with this observation and recommend additional studies that should be investigated.

3. After-Action Reviews and Regulatory Publications

The range of literature includes after-action reviews and regulatory agency publications from various countries. These reports serve as case studies that examine

¹⁴ Fruin, 5.

¹⁵ Anthony R. Mawson, "Understanding Mass Panic and Other Collective Responses to Threat and Disaster," *Psychiatry: Interpersonal and Biological Processes* 68, no. 2 (Summer 2005): 95, <https://doi.org/10.1521/psyc.2005.68.2.95>.

¹⁶ Chris Cocking, John Drury, and Steve Reicher, "The Psychology of Crowd Behaviour in Emergency Evacuations: Results from Two Interview Studies and Implications for the Fire and Rescue Services," *Irish Journal of Psychology* 30, no. 1–2 (2009): 59–73, <https://doi.org/10.1080/03033910.2009.10446298>.

dynamic crowd events resulting in injuries. In many instances, what or who is at fault is the central aim. Findings and recommendations for improvement close out the reports and provide valuable insight for further study. For example, the report on the 2010 Love Parade in Duisburg, Germany, reviews a case in which 21 people were killed and 500 injured.¹⁷ The review exhaustively analyzes the venue, staff, and emergency and police personnel. Its multiple findings merit further investigation. For example, the evidence for crowd turbulence shows its role was a factor in injuries and deaths.¹⁸ Thus, this literature provides a rich source of recommendations for improvement.

The UK's *Green Book* represents the regulatory agencies' contribution to crowd dynamics whereas the European Union's LETSCROWD tools provide extensive guidance for handling crowds at large events. In North America, the Event Safety Alliance publishes a guide similar to the European publications.¹⁹ Though these guiding documents are for event planners, they do provide valuable insight into various aspects of large events not easily explained otherwise. The *Green Book* and the Event Safety Alliance guides go into detail about crowd management and crowd capacity, detailing ingress and egress requirements relating to normal event operations and emergency evacuation. LETSCROWD resources look at law enforcement and detection capabilities at large events. These resources are valuable in that they lean heavily on optical system use in determining issues in crowds. The use of optical systems is an area worth investigating further; the potential for providing situational awareness about crowd conditions to responders may become a valuable tool.

¹⁷ Dirk Helbing and Pratik Mukerji, "Crowd Disasters as Systemic Failures: Analysis of the Love Parade Disaster," *EPJ Data Science* 1 (2012): 40, <https://doi.org/10.1140/epjds7>.

¹⁸ Helbing and Mukerji.

¹⁹ Sports Grounds Safety Authority, "Guide to Safety at Sports Grounds"; Matteo Mauri, "LETSCROWD Server—LETSCROWD Tool Presentation Cards #7," LETSCROWD, November 8, 2019, <https://letscrowd.eu/server-toolcard/>; Donald C. Cooper, ed., *The Event Safety Guide: A Guide to Health, Safety and Welfare at Live Entertainment Events in the United States* (Scottsdale, AZ: Event Safety Alliance, 2013).

4. Naval Postgraduate School Theses

Several theses authored by students at the Center for Homeland Defense and Security provide valuable insight into the research question of this thesis. Two theses that shed light on crowd dynamics and emergency response are Rick Griggs’s “Fire Department Perspective: Crowd Dynamics and Safety at Outside Events” and Robert Leverone’s “Crowds as Complex Adaptive Systems: Strategic Implications for Law Enforcement.”²⁰ They examine two perspectives on crowd dynamics, one concerning the fire department response to emergencies in large outside venues, the other the law enforcement response to a crowd’s changing dynamics.

The available literature and research are substantial for the topic of crowd dynamics and emergency response. Emergency response is not necessarily the main issue addressed, but the safety of the public is the overarching aim in most cases. Every year, significant incidents challenge first responders at large events and drive the need to better understand the dynamics of crowds. A detailed investigation of the available information will reveal insights that can be applied to emergency response.

C. RESEARCH DESIGN

The aim of this thesis was to use qualitative research methods to investigate patterns in crowd dynamics and behavior and their applications to emergency response. It investigated the characteristics of crowd crush incidents such as the 1998 Hillsborough soccer match tragedy. A large-scale crowd-related event may be the single most difficult incident for emergency responders, and the first few minutes of a major incident are the most challenging, especially when the scene is a large venue like a sports arena.

First, I investigated the complex field of crowd dynamics and crowd behavior. These two interconnected phenomena necessitated an understanding of the multilayered complexity wherein individuals and groups move and act in large crowds. An analysis of the tenets of crowd dynamics and behavior was used to establish the basic terminology and

²⁰ Griggs, “Crowd Dynamics and Safety at Outside Events”; Robert H. Leverone, “Crowds as Complex Adaptive Systems: Strategic Implications for Law Enforcement” (master’s thesis, Naval Postgraduate School, 2016), 126, <https://hdl.handle.net/10945/48549>.

accepted concepts in these fields. Outlining terminology and principles enabled my case study analysis.

In the second part of my research, I assembled case studies on incidents in which multiple fatalities occurred. These situations involved crowded venues, multiple injuries, and violent incidents. In cases that involved significant loss of life, inquiries were conducted and official public reports and after-action reviews issued, providing valuable insight into both the beneficial and harmful actions of responders.

In undertaking the two parts of my research, I synthesized current concepts in crowd dynamics and psychology, such as crowd surge and panic. This synthesis allowed for a deeper analysis of incident reviews and recommended best practices. The goal was to provide key principles and guidelines that would help emergency responders in future dynamic crowd events involving injuries. Currently, responders approach a crowded venue with little to no preparation for entering, navigating, and interacting with the crowd. By using key concepts in crowd dynamics, responders could assess the crowd and make better decisions when entering the gathering. In addition, acts of violence complicate the situation. Indeed, emergency response has room for improvement in response times, travel tactics, treatment strategies, and general situational awareness of crowd behavior.

D. CHAPTER OVERVIEW

This thesis starts by looking at the basic elements of crowd dynamics and crowd psychology in Chapter II. These key concepts, terminology, and definitions form the lexicon of dynamic crowd events. Publications from the UK, such as the *Green Guide*, and the United States, such as the *Event Safety Guide*, that provide standards for large events use this common terminology.²¹ The focus of Chapter III is three case studies: the 1989 Hillsborough soccer match, the 2021 Astroworld music festival, and the 2022 Itaewon crowd crush in Seoul, South Korea. In each of these cases, significant injuries and deaths resulted from the crowd crush phenomenon. Similar factors across the three case studies speak to how fire departments and emergency medical services (EMS) should respond.

²¹ Sports Grounds Safety Authority, “Guide to Safety at Sports Grounds”; Cooper, *The Event Safety Guide*.

Chapter IV presents the findings from the case studies, draws conclusions, and makes recommendations for better fire department response.

II. CROWD DYNAMICS AND PSYCHOLOGY

Crowd crush events continue to happen around the world, as large crowds meet at sporting events, entertainment venues, and religious gatherings. The most recent crowd crush in the United States was the November 5, 2021, Astroworld music festival, which resulted in nine deaths, thus calling into question safety procedures at major entertainment venues.²² Internationally, the October 29, 2022, Itaewon disaster, in a Seoul, South Korea, entertainment district, killed 158 people, and in April 30, 2021, in Mt. Meron, Israel, 45 perished during the annual pilgrimage to the Tomb of Rabbi Shimon bar Yochai. One report showed that over a decade (1992–2022), 262 people died and 66,787 people were injured in outdoor music festivals worldwide.²³ The United States continues to be at risk for crowd crush incidents as people attend large events in ever greater numbers. It is estimated that over 30 million people attend music concerts ever year.²⁴ Moreover, in 2019, 150 million people attended sporting events in North America.²⁵

This chapter presents background information and examines elements of crowd dynamics and crowd psychology that are relevant for understanding what happens in a crowd crush situation. When crowd crushes occur, they are devastating—the result of the physical dynamics of people massed together and the group behavior of the crowd. The first responder’s job is thus to control the situation, help the injured, and eventually treat everyone and transport them to the hospital. It is important to differentiate between crowd dynamics and crowd psychology in relation to this study. The physical size and distribution of the crowd constitute crowd dynamics whereas the thought processes and actions of the

²² Jack Denton, “Yes, the Dangerous Crowd Crush at Astroworld Was Probably Preventable,” *Vice*, November 9, 2021, <https://www.vice.com/en/article/bvnx7a/the-dangerous-crowd-crush-at-astroworld-was-probably-preventable>.

²³ Aldo Raineri, “The Causes and Prevention of Serious Crowd Injury and Fatalities at Outdoor Music Festivals,” in *Proceedings of the SIA 12th Annual Occupational Health and Safety VISIONS Conference* (Brisbane: Safety Institute of Australia, 2005), 1–14, <https://doi.org/10.13140/2.1.3036.0005>.

²⁴ Joe Lynch, “Check Out These Surprising Stats about U.S. Music Festivals,” *Billboard*, April 22, 2015, <https://www.billboard.com/culture/events/music-festival-statistics-graphic-6539009/>.

²⁵ U.S. Travel Association, “The Impact of Sports on the Travel Industry” (Washington, DC: U.S. Travel Association, 2019), https://www.ustravel.org/system/files/media_root/document/2019_Sports_Travel_07.11.19.pdf.

group make up crowd psychology. Likewise, crowd dynamics involve the study of how crowds form and reach a critical density that creates vulnerability and catastrophic injuries.²⁶ Crowd psychology, in contrast, involves individuals' actions in a group setting and the group's reactions to outside stimuli. The key components of crowd dynamics and psychology inform an emergency responder's ability to deal with crowd dynamics and behavior in large-scale events.

A. CROWD DYNAMICS

The work of G. Keith Still and John Fruin has contributed extensively to the understanding of crowd dynamics. Still's work in crowd dynamics has investigated "how and where crowds form and move above the critical density of more than 7 persons per square meter."²⁷ The concept of crowd surge and its associated deleterious effects in certain settings represent a key component of crowd dynamics. As documented in the literature and the results cited in many of the cases, key aspects of it have been identified and explained in sufficient detail to allow these key terms to become standardized in the crowd dynamics field.²⁸ This standardization is crucial in maintaining clear communications in an emergency response between agencies and different professions involved in large venues.

Key concepts of crowd dynamics are relevant to this study for emergency responders. These areas provide definition and clarity for how and why emergency events happen in dynamic crowd situations. Crowd density, shockwaves, and collapse are some of the many important aspects of crowd dynamics. Compression asphyxia, the mechanism by which most people die in crush incidents, also must be understood. Emergency responders should grasp each of these concepts as they enter a chaotic situation involving large crowds.

²⁶ G. Keith Still, "Crowd Dynamics" (PhD diss., University of Warwick, 2000), https://www.gkstill.com/Support/Links/Documents/2000_still.pdf.

²⁷ Still, 44.

²⁸ Still, *Introduction to Crowd Science*.

1. Density

The number of people who occupy a given area is critical to the study of crowd dynamics. Whether people are static or moving comes into play as movement requires more area for safe travel.²⁹ For Still, critical values emerge in static crowds as densities reach five people per square meter. At seven people per square meter, people are in close contact, and their multiplication of force can result in shockwaves and crowd crush.³⁰ In U.S. measurements, the values change only slightly when yards are used. Below this threshold, pedestrians can travel freely, and the risk of injury decreases. At seven persons, travel is restricted or diminished, and the risk of injury from crowd dynamics intensifies.

Pedestrians at this density can no longer control their movement and are subject to multiplied forces against their bodies. These forces induce lateral movements and crushing forces unimaginable in normal circumstances. The crowd crush phenomenon is a direct result of overcrowding and exceeding the threshold of seven persons per square meter. Thus, high crowd density is the principal factor in injuries at large events and has a long-documented history in the UK and Europe.

One of the most well-documented events demonstrating this phenomenon was the tragic Hillsborough soccer match on April 15, 1989. During this incident, several thousand fans rushed to get into the stadium for the start of the soccer match. When the unregulated crowd surged through a single tunnel into a standing-room-only area called the “pens,” fans at the front of the area were forced violently against the security fence. The crowd grew to double the capacity of the pens, exceeding the critical density of seven people per meter and resulting in the deaths of 97 people and injuries to 776.

2. Shockwaves

Shockwaves are a series of phase transitions within a moving body of individuals that develop over some time and are dependent on the density of the crowd.³¹ In studying

²⁹ Still.

³⁰ Fruin, “The Causes and Prevention of Crowd Disasters.”

³¹ Hamish Johnston, “‘Crowd Turbulence’ Has Deadly Consequences,” *Physics World*, January 25, 2007, <https://physicsworld.com/a/crowd-turbulence-has-deadly-consequences/>.

video footage of the tragedy that developed in 2006 at the hajj pilgrimage site in Mecca, Helbing and Anders Johansson recognized three distinct phases in the dense crowds: a buildup to high density, a transition to stop-and-go movement, and finally, a transition movement in all directions, called turbulence.³² At turbulence, the randomness of crowd motions causes pressure waves that propagate through the crowd at significant levels, causing people to stumble, fall, and be thrown off balance.³³ The crowd crush phenomenon occurs at high-density levels that allow the propagation of force from one body to the next. The resulting force is magnified by individuals coalescing into a group and compounding exertion. In many cases, hundreds of pounds of force can be exerted on individuals and structures that contain the crowds.³⁴ The multiplied force can reach hundreds of pounds of pressure that can even bend heavy metal railing. Thus, people can be forced against each other and structures, causing asphyxia due to the individuals' inability to breathe.³⁵

3. Crowd Collapse

Collapse is an involuntary movement of people in the crowd that results in their being thrown off balance, off their feet, and clumped in masses. In many instances, bodies become stacked on one another, causing injury and asphyxia due to the weight of adjacent bodies pressed together. The gravity of the situation is exacerbated by the size of the crowd as the victims in the collapse often go unnoticed and unheard by the throngs.³⁶ Crowd collapse has resulted in victims piled sometimes 10 feet high.³⁷

A crowd crush and collapse occurred before The Who concert on December 3, 1979. A crowd of 8,000 lined up before the concert in anticipation of the gates opening. When fans mistakenly thought the concert had started after hearing a band member conduct a sound check, the crowd surged forward toward the gates. One fan caught in the crowd

³² "Timeline of Tragedies during Hajj Pilgrimage in Mecca," *Guardian*, September 24, 2015, <https://www.theguardian.com/world/2015/sep/24/timeline-of-tragedies-in-mecca-during-hajj>.

³³ Johnston, "'Crowd Turbulence' Has Deadly Consequences."

³⁴ Fruin, "The Causes and Prevention of Crowd Disasters."

³⁵ Fruin.

³⁶ Fruin.

³⁷ Fruin.

described what happened: “A wave swept me to the left and when I regained a stance, I felt I was standing on someone. The helplessness and frustration sent a wave of panic through me. I screamed with all my strength that I was standing on someone. I couldn’t move. I could only scream.”³⁸ Eleven people died in the aftermath of the incident.³⁹

4. Compressive Asphyxia

In crowd crush incidents, a significant number of deaths are due to compression asphyxia whereby pressure is exerted against other people or fixed objects.⁴⁰ Many of these events have been at major sporting venues, including Hillsborough in 1989, Ibrox in 1971, and Astroworld in 2021. Findings from the Hillsborough disaster showed that compression asphyxia was the cause of death for all 96 victims.⁴¹ Injuries due to crush forces occurred at Hillsborough as continuous pressure was exerted by spectators flooding into the stands. The situation was exacerbated by the collapse of the horizontal crush barrier inside the viewing area, causing spectators to be thrown forward.⁴²

Crush asphyxia and traumatic asphyxia are terms used interchangeably and are a form of mechanical asphyxia.⁴³ Pressure applied to the front and rear of the chest restricts the ability of the lungs to expand, thus impairing the breathing function and lowering the blood oxygen level, referred to as hypoxemia. Compression asphyxia—the term used in the Hillsborough inquests—is less common than traumatic or crush asphyxia but is similar in mechanism. Unconsciousness occurs when oxygen concentration reaches approximately 56 percent, a value well below normal oxygen levels of 96 to 99 percent. This can happen within one to two minutes if breathing is completely obstructed. Oxygen values continue

³⁸ John Seabrook, “Crush Point,” *New Yorker*, January 30, 2011, <http://www.newyorker.com/magazine/2011/02/07/crush-point>.

³⁹ Working with Crowds, “The Who Concert Tragedy.”

⁴⁰ “Compression Asphyxia,” Working with Crowds, accessed January 8, 2023, <https://www.workingwithcrowds.com/compression-asphyxia/>.

⁴¹ Jerry P. Nolan et al., “Compression Asphyxia and Other Clinicopathological Findings from the Hillsborough Stadium Disaster,” *Emergency Medicine Journal* 38, no. 10 (October 2021): 798, <https://doi.org/10.1136/emmermed-2020-209627>.

⁴² Nolan et al., 798.

⁴³ Nolan et al., 798.

to decrease until cardiac arrest occurs. A significant component of compression deaths is caused by a flail chest, whereby five to eight broken ribs impede breathing.⁴⁴ A severe crush also reduces venous flow to the heart, reducing cardiac output.

Once a person goes unconscious, the head tends to slump forward, occluding the airway. In some cases, victims who receive variable crushing forces may die from occluded airways in the crowd or after being rescued. Another form of mechanical asphyxia is smothering where the nose and mouth are obstructed. This kind of asphyxia is more common in smaller adults and children pinned between larger adults. Other injuries include head trauma, injuries to internal organs and arteries, and lacerations to the lungs due to broken ribs. Besides the obstruction of breathing, pressure applied to the chest on the right side of the heart can impair venous return and lead to congestion, cyanosis, and petechial formation.⁴⁵

Victims at Hillsborough received differing levels of pressure and duration in the crowd crush, which made it impossible to determine when people lost consciousness and went into cardiac arrest. Resuscitation efforts were started by fellow spectators, some off-duty doctors, and EMS personnel.⁴⁶ In the Hillsborough incident, no patient who was in cardiac arrest when admitted to the hospital survived. A total of 30 patients reported losing consciousness, and 16 reported having seizures, an indication of prolonged hypoxemia. There are insufficient data regarding resuscitations of victims from crowd crush incidents, but historical cases suggest poor outcomes when victims experience cardiac arrest.⁴⁷

B. CROWD PSYCHOLOGY

Understanding crowd behavior and its underlying psychological elements is another important aspect for emergency responders in crowd-related disasters. In crowd situations that create crush injuries, there is a behavioral element to the series of events leading to the accident. Outside influences and group perceptions cause a group to move

⁴⁴ Working with Crowds, “Compression Asphyxia.”

⁴⁵ Nolan et al., “Compression Asphyxia and Other Clinicopathological Findings,” 801.

⁴⁶ Nolan et al., 801.

⁴⁷ Nolan et al., 801.

en masse, causing possible injuries. The threat of danger or a perceived loss, natural or human-made, can cause a fear reaction in the group. The result is the movement of a crowd, causing the conditions for crowd crush and resulting injuries. First responders can identify elements of crowd psychology and use that knowledge in emergencies. Clarity of thought and a basic understanding of key crowd psychology concepts will help in this research as it relates to fire department response.

1. Crowd Craze

Crowd craze is a term used to describe a crowd's reaction to an outside influence that creates a sudden urgency to move to a different area. This stimulus may even lead the crowd to perceive it is missing some part of the event. The perception of gaining an advantage or better position can also have an undue influence on the behavior of a crowd. The sudden movement of the crowd can cause an increase in crowd density and a resultant crowd collapse, crush, or trampling of people within the group. One of the earliest examples of crowd craze was the June 16, 1883, Victoria Hall disaster in Sunderland, England. The result was the death of 183 children from a crush situation at the bottom of a staircase. Poor messaging by performers on the stage caused children to think they were missing out on free toys. The resulting mad rush from children on the upper balcony to get to the lower level caused a crush as they converged on the stairwell.⁴⁸ Crowd craze can arise from a particular area due to outside influences ranging from acts of nature, to violence, to other stimuli that cause urgency in the crowd. Notably, the perceptions of individuals in the crowd cause a sudden perpetual motion or forward movement in the individuals and the whole.

⁴⁸ "The Victoria Hall Disaster 1883," Working with Crowds, accessed January 1, 2023, <https://www.workingwithcrowds.com/1883-the-victoria-hall-disaster-sunderland/>.

2. Collective Psychosocial Resilience

Collective psychosocial resilience is a trait of some crowds that is vital to emergency responders.⁴⁹ Emergency personnel and organizations preplan for a multitude of situations, but they rarely consider what crowds will do after a catastrophic event, such as a crowd crush or other crowd-related behaviors that arise. Cases in which citizens step forward to help victims in extreme situations, referred to as “emergence,” are well documented and should be considered a vital part of the response process.⁵⁰ Simply put, with collective psychosocial resilience, the crowd acts as first responders to assist fellow eventgoers. In his work, Quarantelli describes the conditions that cause emergence: the “perceived need to act on urgent matters.”⁵¹ This behavior often manifests as the result of a significant event. As indicated by the Federal Emergency Management Agency in its *1 October After-Action Report* following the Las Vegas tower shooting, the crowd turned into “immediate responders,” giving unforeseen assistance to the injured and creating a positive influence in the aftermath of the event.⁵²

C. CONCLUSION

This chapter examined the elements of crowd dynamics and crowd psychology that are relevant to the study of crowd crush incidents. There is every indication that communities will continue to have crowd-related fatalities where large gatherings form for public events. The critical element of crowd density is integral to recognizing the potential for injuries. Compression asphyxia as the predominate mechanism for injury and death in crowd crushes should drive first responders, in particular fire departments, to improve

⁴⁹ John Drury et al., “Facilitating Collective Psychosocial Resilience in the Public in Emergencies: Twelve Recommendations Based on the Social Identity Approach,” *Frontiers in Public Health* 7, no. 141 (2019): 1–21, <https://doi.org/10.3389/fpubh.2019.00141>.

⁵⁰ Craig M. Cooper, “The Crowd Machine: Leveraging Emergent Crowd Behavior in Policy and Response” (master’s thesis, Naval Postgraduate School, 2021), <https://hdl.handle.net/10945/67119>.

⁵¹ E. L. Quarantelli, *Emergent Behaviors and Groups in the Crisis Time Periods of Disasters* (Newark: University of Delaware, Disaster Research Center, 1994), 14, <http://udspace.udel.edu/handle/19716/591>.

⁵² Clark County Fire Department, Las Vegas Metropolitan Police Department, and Federal Emergency Management Agency, *1 October After-Action Report* (Washington, DC: Federal Emergency Management Agency, 2018), 12, 18–19.

timely responses. The next chapter looks at several case studies where crowd crushes caused significant loss of life. The concepts of crowd dynamics and crowd psychology are crucial in these case studies and will help develop an understanding of how fire departments can provide better service to victims of crowd crushes.

THIS PAGE INTENTIONALLY LEFT BLANK

III. CASE STUDIES

Ample crowd crush incidents have been well documented and undergone extensive investigations and review. This study looks at three incidents that happened in large municipal settings: the 1989 Hillsborough Stadium tragedy; the 2021 Astroworld music festival in Houston, Texas; and the 2022 Itaewon crowd crush in South Korea that killed 159 people. These incidents reflect the issues that many fire agencies encounter when their jurisdictions host sports and performance entertainment at large venues. Such agencies tend to have greater daily EMS needs and must often support large public gatherings. Each case examines the organizational structure, emergency plans, the fire and EMS response, and key findings from the investigations and literature that followed these events. The goal is to highlight what responders did, what went wrong, and what was effective and to improve what fire and EMS will do to promote life safety services if they encounter similar events in the future.

A. HILLSBOROUGH STADIUM DISASTER

The crowd crush incident in Sheffield, England, on April 15, 1989, at the Hillsborough Stadium is perhaps one of the most defining moments in the study of crowd dynamics. It has many of the classic components of a dynamic crowd event that, combined, resulted in the deaths of significant numbers of people. The inquiries and investigations have a checkered past: a combination of falsified reports, a lack of accountability, and finger pointing created turmoil for three decades after the incident.⁵³ The events of that day were heavily scrutinized over that time. Ultimately, the organizers, law enforcement, and EMS providers shared responsibility in the operation and safety of the event.

⁵³ David Conn, "Hillsborough Disaster: Deadly Mistakes and Lies That Lasted Decades," *Guardian*, April 26, 2016, <https://www.theguardian.com/football/2016/apr/26/hillsborough-disaster-deadly-mistakes-and-lies-that-last-edecades>.

1. Sequence of Events

Fears of fan soccer violence led to an arrangement for separating fans and was a contributing factor in the crowd crush injuries and fatalities that occurred later that day.⁵⁴ A sold-out crowd of 54,056 was in attendance that April afternoon in Sheffield. Semi-final matches such as this one had a history of violence between rival fan groups, or soccer hooliganism, a prime concern for venue management and law enforcement.⁵⁵ The event was managed and staffed by members of the South Yorkshire Police (SYP), Sheffield Wednesday staff, and South Yorkshire Metropolitan Ambulance Service (SYMAS). To keep rival fans apart, seating for Liverpool fans was reserved in the North and West Stands, with 24,256 total seats, while seating for Nottingham Forrest fans was reserved in the East and South Stands, with 29,800 total seats. The fans were also assigned separate entrances, with Liverpool fans entering through the west Leppings Lane entrance turnstiles and Nottingham Forrest fans entering through the east side gates.⁵⁶ This entrance arrangement created a disparity in the number of turnstiles that could handle each fan base as they entered the stadium. The Nottingham Forrest fans had a total of 60 turnstiles when they entered from the east side while the Liverpool fans entering from Leppings Lane had 23. The Leppings Lane entrance was narrow and described as a “bottleneck” by the police and stadium staff.⁵⁷ Notably, fans were not local to the area, and most had traveled by train or car to the stadium.⁵⁸

Crowd issues were present before the game started outside the stadium, foreshadowing what lay ahead. The match was scheduled to start at 3:00 p.m. Reports from SYP at the Leppings Lane entrance indicated that fans started building up at the entrance well before start time, and a bottleneck had formed by 2:30 p.m. Reports from police and

⁵⁴ Hillsborough Independent Panel, *Hillsborough: The Report of the Hillsborough Independent Panel* (London: Stationery Office, 2012), 133.

⁵⁵ “Football Hooliganism—All You Need to Know,” Politics.co.uk, accessed January 30, 2023, <https://www.politics.co.uk/reference/football-hooliganism/>.

⁵⁶ Hillsborough Independent Panel, *Hillsborough*, 9.

⁵⁷ Hillsborough Independent Panel, 10.

⁵⁸ Hillsborough Independent Panel, 10.

video evidence show fan congestion and a crowd density well above the threshold of seven persons per square meter, indicating dangerous crowd conditions.⁵⁹ Crowd surges and pressure waves can be seen in several videos. The crowd waiting to enter the stadium was approximately 5,000 strong, so the limited turnstiles were a pinch point that caused massive congestion. Requests were made to delay the game to provide time for the fans to get through, as the police were becoming worried that a crush situation was developing at the turnstiles. After repeated requests, Gate C, a large side exit, was opened, letting a massive influx of people into the lower West Stand area (see Figure 1).⁶⁰

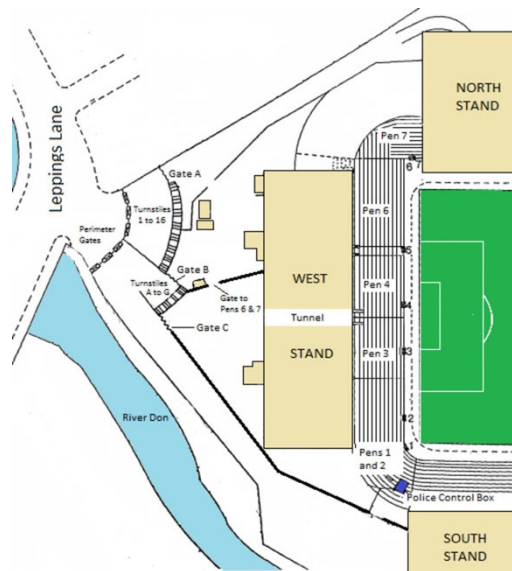


Figure 1. Map of Hillsborough Stadium and Surrounding Area.⁶¹

The fatalities and injuries occurred at the lower level of the West Stand, an area with standing room only separated into four enclosures called pens. The pens were susceptible to high crowd densities.⁶² To prevent field incursions and to limit crowd crush issues, the pens were enclosed with security fencing and horizontal waist-high crush

⁵⁹ Conn, “Hillsborough Disaster.”

⁶⁰ Nolan et al., “Compression Asphyxia and Other Clinicopathological Findings,” 798.

⁶¹ Source: Nolan et al., 799.

⁶² Nolan et al., 798.

railing. Fans could access Pens 3 and 4 in the center only through a single tunnel that sloped toward the pens. Witness accounts indicate there was little signage giving seating directions, and no staff were assigned to control the fans, causing most fans to enter the tunnel. No attempt was made to stop further traffic from going into the central pens, which caused the crowd density in Pens 3 and 4 to rapidly exceed critical density.⁶³ To make matters worse, as the game started, the fans felt a sense of urgency to reach the viewing area, which surged the crowd forward and increased pressure on fans in the front of Pens 3 and 4.⁶⁴

As the Hillsborough Independent Panel indicated, the match started on time at 3:00 p.m., and the conditions were ripe for injuries, as high-density crowds beyond seven persons per square meter were evident. Witness accounts identified a crowd crush at this time as people began succumbing to the exerted pressure. Complaints from the crowd were not initially recognized by police or the staff on the field. At 3:04 p.m., a goal shot and fan excitement caused a surge forward, breaking a railing inside the pen that resulted in crowd collapse and a pressure wave of people against the field security fencing (see Figure 2). By 3:05 p.m. it was evident to field staff that a crowd crush was occurring in the central pens, and the game was halted.⁶⁵

⁶³ Conn, “Hillsborough Disaster.”

⁶⁴ “How the Hillsborough Disaster Happened,” BBC News, April 14, 2009, http://news.bbc.co.uk/2/hi/uk_news/7992845.stm.

⁶⁵ Hillsborough Independent Panel, *Hillsborough*, 133.



Figure 2. Spectators Crushed at Hillsborough Stadium.⁶⁶

The police, ambulance crews, and field staff were quickly overwhelmed as they realized the number of those injured and the magnitude of the situation. At this point, Pens 3 and 4 contained approximately double the allowed capacity, placing fans in high-density crowd crush conditions. An expert later looking at photographs estimated that Pen 3 had 1,296 fans, double the safe level of 678 for that area.⁶⁷ Conditions were complicated by the fact that each pen had only one small emergency gate to remove victims and high fencing around the exterior to prevent field intrusion. The access issue made rescue difficult and prolonged the extrication and treatment of victims. Almost all injuries were related to compressive asphyxia. Bystanders started caring for the injured and dying, assisting police and the limited EMS personnel on site.⁶⁸

⁶⁶ Source: Nico Hines, “U.K. Court Blames Police, Not Soccer Fans, for Hillsborough Disaster,” Daily Beast, April 13, 2017, <https://www.thedailybeast.com/articles/2016/04/26/uk-court-blames-police-not-soccer-fans-for-hillsborough-disaster>.

⁶⁷ “Hillsborough Pen Was Packed to ‘Twice’ Its Safe Capacity, Says Expert,” BBC News, June 25, 2014, <https://www.bbc.com/news/uk-england-merseyside-28017910>.

⁶⁸ Hillsborough Independent Panel, *Hillsborough*, 140.

As the Independent Panel pointed out, patients and the dying were transported to a nearby gym repurposed as a casualty collection point. SYMAS eventually dispatched 42 ambulances to the stadium of which only two made it onto the field to assist with treatment. The remaining ambulance crews transported victims to area hospitals. A total of 149 people were transported. Victims who succumbed to their injuries were placed in the gym, which had become a makeshift morgue.⁶⁹

2. Identifying and Understanding the Mistakes

This section examines the mistakes made at Hillsborough, with an emphasis on areas that affect fire and EMS response. The Hillsborough disaster has been well documented, and the numerous investigations, inquiries, and reports as a whole form a reliable picture of what happened. The Hillsborough Independent Panel's and Justice Taylor's reports provide some of the most accurate findings.⁷⁰ Detailed journal articles provide eyewitness accounts that key in on specific locations and actions that day.

Organization and planning between the major stakeholders at Hillsborough were dysfunctional. The responsibility of managing the crowd and ensuring crowd safety at the Hillsborough Stadium in Sheffield that day was distributed among law enforcement, EMS providers, and the operators of the stadium—SYP, SYMAS, and the Sheffield Wednesday Football Club. Reports indicated these and other stakeholders did not foster a good working relationship at Hillsborough. Crowd crush issues had arisen at a 1981 FA Cup semi-final match and other events before the fatal match in 1989.⁷¹ Sheffield Wednesday, the operator of Hillsborough Stadium, was often at odds with other stakeholders including police and fire. These parties frequently disagreed over crowd management, crowd safety, stadium

⁶⁹ Hillsborough Independent Panel, 142.

⁷⁰ Hillsborough Independent Panel, *Hillsborough*; Home Office, *The Hillsborough Stadium Disaster: 15 April 1989 Inquiry by the Rt Hon Lord Justice Taylor: Final Report* (London: Stationery Office, 1990), https://www.jesip.org.uk/uploads/media/incident_reports_and_inquiries/Hillsborough%20Stadium%20Disaster%20final%20report.pdf.

⁷¹ Martin Robinson, "Fans 'Were Crushed at Hillsborough Eight Years before Disaster,'" *Daily Mail*, February 25, 2019, <https://www.dailymail.co.uk/news/article-6597927/Fans-crushed-Hillsborough-eight-years-disaster.html>.

construction, and staffing levels, and lessons learned from previous matches were not embraced by the stadium operator.⁷²

There must be a working relationship between all organizations and agencies involved in such large entertainment venues. An organizational structure that involves all major stakeholders, with representatives collocated and working together, is the most effective way to manage any emergency. As Fruin states, “Most major crowd disasters can be prevented by simple crowd management strategies. The primary crowd management objectives are the avoidance of critical crowd densities and the triggering of rapid group movement.”⁷³ An atmosphere of trust fostered in the planning process works to reduce the competing forces of economics, crowd safety, and crowd management. In the case of Hillsborough, the collocation of police with EMS command staff could have led to a quicker recognition and response to the crowd disaster. Working together, the decision to implement the major incident plan (MIP) could have been made and implemented more quickly. Such a working dynamic might have counteracted the tunnel vision on hooliganism, as history had shown it a prime concern, particularly of law enforcement at the stadium.⁷⁴ In Sheffield, the major stakeholders worked independently and failed to communicate or make decisions effectively, causing needless delays in responding to a major catastrophe. Unified command and planning allow stakeholders to work collectively to address risks and implement a unified response to deliver safety rapidly to the public.⁷⁵

The MIP was never implemented at Hillsborough. As the Taylor report indicated, MIP activation was the responsibility of the SYP in the control box. Initially command personnel in the control box viewed the incident as a crowd disturbance. Their focus changed as the enormity of the situation became evident.⁷⁶ Senior ambulance personnel,

⁷² Hillsborough Independent Panel, *Hillsborough*, 7.

⁷³ Fruin, “The Causes and Prevention of Crowd Disasters,” 10.

⁷⁴ Politics.co.uk, “Football Hooliganism.”

⁷⁵ Federal Emergency Management Agency, *Developing and Maintaining Emergency Operations Plans*, Comprehensive Preparedness Guide 101, version 2.0 (Washington, DC: Department of Homeland Security, 2010), 9.

⁷⁶ Hillsborough Independent Panel, *Hillsborough*, 138.

who were trained to recognize crowd dynamics, failed to identify the need to implement the MIP, and no senior personnel verified that the MIP had been implemented.

Emergencies that exceed the available resources on hand need to have a contingency plan that sends predetermined resources to augment rescue operations. The MIP would have alerted fire and ambulance agencies that an incident was developing.⁷⁷ Also, an MIP declaration would have alerted local hospitals of the incident and deployed medical teams with resuscitative equipment.⁷⁸ Normally this augmented response takes time to mobilize. Most municipalities have adequate resources to meet the needs of day-to-day operations but are hard-pressed to meet the needs of large-scale events.

The police and EMS staff did not recognize the crowd crush quickly enough, and the managing authority was focused on crowd control, not crowd management.⁷⁹ According to the after-action reports, this lack of awareness caused a delay in response. Before kickoff, fans were already complaining that they were experiencing crushing forces. The panel concluded from the documentary evidence that the authorities had failed to recognize the nature of the disaster.⁸⁰ Eyewitnesses indicated that the police were predisposed to think that any crowd issues were due to hooliganism. Indeed, the Hillsborough Independent Panel confirmed that law enforcement's fixation on football hooliganism and drunkenness was a causal factor in the incident.⁸¹

Indications of an impending crowd crush were present before the incident occurred at the front of the pens. The stadium's authorities should have watched for the warning signs of high-density levels in the West Stand, in a standing spectator area with uncontrolled fan access. Notably, crowd density had been at critical levels before the start of the match and caused crush conditions outside the Leppings Lane gate. Clear indications of critical crowd densities, congestion, and pinch points should have provided clues that

⁷⁷ Hillsborough Independent Panel, 139.

⁷⁸ Hillsborough Independent Panel, 136.

⁷⁹ Hillsborough Independent Panel, 133.

⁸⁰ Hillsborough Independent Panel, 133.

⁸¹ "Hillsborough Investigation," Independent Office for Police Conduct, January 7, 2018, <https://www.policeconduct.gov.uk/investigations/hillsborough-investigation>.

further problems would occur. The West Stand’s lower terrace, which housed the pens, was notorious for crowd crush issues, so the organizations should have keyed in on the critical crowd density inside Pens 3 and 4 and taken appropriate steps to limit the fans to their known capacities.⁸² The uncontrolled flow of fans from open exit Gate C should have been an indicator that significant numbers of fans would be pouring into a small area quickly. Moreover, the history of crowd crush incidents the world over has shown a high incidence of crowd crush on fan ingress of games.⁸³

Victims did not receive the appropriate level of care and were presumed dead prematurely though treatment might have saved their lives. Police officers who witnessed the incident were frustrated because they could not get to the fans in time to save their lives due to the fencing.⁸⁴ Initially, the fire department had only been requested for its cutting equipment to open the perimeter fencing. Furthermore, the first hospital response team did not arrive until 3:50—by that time, most victims had already died.⁸⁵ A later investigation by medical experts found that not all victims had died from “classic traumatic asphyxia” and might have survived longer than first thought.⁸⁶ Specifically, the victims’ postmortem reports indicated they had not suffered traumatic asphyxia with obstruction of blood flow, suggesting death might have taken longer. Indeed, in 31 victims, there was evidence that their circulation and breathing continued after the crush had been relieved.⁸⁷

Definitive and appropriate medical care needs to be administered in the field.⁸⁸ Medical experts indicated that many victims were still viable after they had been removed from the crowd crush. Appropriate care at the right levels, administered on the field, might have provided a better patient outcome. Supplying the necessary care for victims would have meant rapidly deploying personnel with advanced life support training and equipment

⁸² BBC News, “Hillsborough Pen Was Packed.”

⁸³ Fruin, “The Causes and Prevention of Crowd Disasters,” 2.

⁸⁴ Hillsborough Independent Panel, *Hillsborough*, 141.

⁸⁵ Hillsborough Independent Panel, 139.

⁸⁶ Hillsborough Independent Panel, 163–64.

⁸⁷ Hillsborough Independent Panel, 167.

⁸⁸ Hillsborough Independent Panel, 144.

to the scene.⁸⁹ The time component is critical in effectively resuscitating a victim of compressive asphyxia. Persons in respiratory and cardiac arrest need lifesaving interventions.⁹⁰

B. ASTROWORLD MUSIC FESTIVAL

The United States experienced a significant crowd crush incident at Travis Scott’s Astroworld music festival on November 5, 2021, in Houston, Texas. A total of 10 people died, including a nine-year-old boy.⁹¹ This was the first significant crowd crush incident in the United States since The Who concert on December 3, 1979.⁹² The tragedy was well documented on social media feeds and in almost instantaneous news coverage online. The concert’s event action plan (EAP), which was published on the internet within the first 24 hours of the tragedy, received immediate scrutiny.⁹³ Music concerts, though different from sporting events, make up a significant share of large events and are an important component of this study.⁹⁴ Thirty-two years separate Hillsborough from the Houston tragedy, yet the events share many similarities that demonstrate gaps in mitigating crowd crush deaths and injuries.

1. Sequence of Events

Astroworld is a music series founded by American rapper Travis Scott. The popular music festival was returning to full attendance following the COVID-19 pandemic, and attendance was expected to reach 100,000 for the two-day event. The concert was promoted

⁸⁹ Nolan et al., “Compression Asphyxia and Other Clinicopathological Findings.”

⁹⁰ Wanis H. Ibrahim, “Recent Advances and Controversies in Adult Cardiopulmonary Resuscitation,” *Postgraduate Medical Journal* 83, no. 984 (October 2007): 649–54, <https://doi.org/10.1136/pgmj.2007.057133>.

⁹¹ Texas Task Force on Concert Safety, *Report from the Texas Task Force on Concert Safety* (Austin: Texas Task Force on Concert Safety, 2022), 4, https://gov.texas.gov/uploads/files/press/2022_Report_Texas_Task_Force_on_Concert_Safety.pdf.

⁹² Working with Crowds, “The Who Concert Tragedy.”

⁹³ NRG Park, *Astroworld 2021 Event Operations Plan (EOP)* (Houston: NRG Park, 2021), <https://ca-times.brightspotcdn.com/bf/57/11bc2a094c9886f3407cc641e1e7/astroworld-2021-eop-1.pdf>.

⁹⁴ T. Dinesh, K. Aniket, and D. Roshan, *Events Industry Market*, report overview (Portland: Allied Market Research, 2022), <https://www.alliedmarketresearch.com/events-industry-market>.

and managed by ScoreMore Shows, a subsidiary of Live Nation, a national entertainment company.⁹⁵ The major stakeholders for the event included ScoreMore Shows; the Houston Police Department (HPD); the Houston Fire Department (HFD); NRG Park, which was managed by the Harris County Sports and Convention Corporation; and Paradocs, a private medical company contracted to provide EMS response for the venue.⁹⁶ A unified command was established between the HPD, festival security, production staff, Paradocs dispatchers, and Harris County Emergency Corps dispatchers. However, the festival director and concert producer were the only authorities allowed to stop the concert.⁹⁷

Private contractors provided medical services and security for the event. Paradocs, which was contracted by Live Nation to supply medical personnel for the event, frequently delivers paramedical services to concerts and other major events.⁹⁸ Its staff that day comprised medical doctors, registered nurses, paramedics, and emergency medical technicians.⁹⁹ Four different security companies were contracted to provide security officers for the event. Reports indicate that many security officers were hired the day of the concert and had minimal training in crowd management and crowd control.¹⁰⁰

People started lining up to enter the concert venue at 3:30 a.m., with a thousand people already in line.¹⁰¹ There were reports of fans jumping barricades and breaking

⁹⁵ Live Nation Entertainment, “Live Nation Acquires Premier Texas Concert Promoter and Festival Producer, ScoreMore Shows,” PR Newswire, May 30, 2018, <https://www.prnewswire.com/news-releases/live-nation-acquires-premier-texas-concert-promoter-and-festival-producer-scoremore-shows-300656060.html>.

⁹⁶ “Home Page,” Paradocs Event Medical Services, accessed February 17, 2023, <https://www.paradocsworldwide.com>.

⁹⁷ NRG Park, *Astroworld 2021 Event Operations Plan*, 11.

⁹⁸ Paradocs Event Medical Services, “Home Page.”

⁹⁹ Amir Vera et al., “Medical Staff at Astroworld Responded to 11 Cardiac Arrests at the Same Time, CEO of Medic Company Says,” CNN, November 16, 2021, <https://www.cnn.com/2021/11/15/us/astroworld-paradocs-medic-company-cardiac-arrests/index.html>.

¹⁰⁰ “Astroworld Security Guard Felt Unprepared, Training Day before Festival,” TMZ, November 9, 2021, <https://www.t TMZ.com/2021/11/09/astroworld-security-guard-felt-unprepared-training-day-before-festival/>.

¹⁰¹ Ryan Wood, “Astroworld Timeline: How Tragedy Unfolded at Travis Scott Concert,” ABC Dallas, November 9, 2021, <https://www.wfaa.com/article/news/local/how-did-the-astroworld-travis-scott-tragedy-happen-heres-a-timeline-before-during-and-after/287-3beb1e52-1328-444c-aa84-8d737c015179>.

through fencing to circumvent security. The HFD established a command post outside the concert security perimeter. Before the start of the concert, lead HFD personnel attempted to enter through security to tour the concert grounds for facility preplanning but were denied access by concert security. Additionally, concert radios had been requested for fire personnel, but none were issued by ScoreMore.¹⁰² As the day progressed, the crowd size grew to approximately 50,000. By early afternoon, HPD personnel were reporting dangerous crowd conditions.¹⁰³ By 8:15 p.m., medical personnel were overwhelmed with medical issues and injuries and reports of others within the crowd.¹⁰⁴ Just prior to Travis Scott's performance, which was scheduled to start at 8:45 p.m., personnel received reports of heavy crowd conditions, trampling, and injuries.¹⁰⁵

Travis Scott had delayed the start of his performance, so the announcement of his appearance at 9:06 p.m. caused a crowd surge toward the stage.¹⁰⁶ Reports suggest that the main stage was breached at 9:11 p.m., and people in the southern quadrant were screaming for help. Cell phone footage showed numerous people down and unconscious near the stage.¹⁰⁷ By 9:30 p.m., an ambulance crew was seen trying to access the injured near the stage.¹⁰⁸ The HFD called a mass casualty incident at 9:38, as the size of the tragedy began to unfold. By 10:10 p.m., concert officials halted the concert.¹⁰⁹

¹⁰² Ted Oberg and Sarah Rafique, "Concert from Hell: 13 Investigates Looks at Warning Signs Ahead of Astroworld Tragedy," ABC 13 Houston, accessed February 2, 2023, <https://abc13.com/feature/astroworld-2021-festival-travis-scott-astro-fest-security/11213442/>.

¹⁰³ Travis Caldwell and Keith Allen, "Within Minutes, the Astroworld Festival Turned Deadly. Here's What We Know about the Show's Timeline," CNN, November 8, 2021, <https://www.cnn.com/2021/11/08/us/astroworld-festival-crowd-surge-timeline/index.html>.

¹⁰⁴ Amir Vera et al., "Astroworld Investigation: Medical Staff at Astroworld Responded to 11 Cardiac Arrests at the Same Time, CEO of Medic Company Says," CNN, November 16, 2021, <https://www.cnn.com/2021/11/15/us/astroworld-paradocs-medic-company-cardiac-arrests/index.html>.

¹⁰⁵ EJ Dickson et al., "People Are Dying': Witnesses Describe Horror of Astroworld Tragedy," *Rolling Stone*, November 6, 2021, <https://www.rollingstone.com/music/music-news/eyewitnesses-astroworld-houston-travis-scott-1254208/>.

¹⁰⁶ Collman, "I'm Going to Die Because This Man Is Not Stopping the Concert."

¹⁰⁷ Washington Post, "Most of the Dead Astroworld Festival Victims Were in One Highly Packed Area, November 24, 2021, YouTube, video, 13:38, <https://www.youtube.com/watch?v=LGXwJnZSIkQ>.

¹⁰⁸ Wood, "Astroworld Timeline."

¹⁰⁹ Wood.

2. Identifying and Understanding the Mistakes

Governor Greg Abbot established the Texas Task Force on Concert Safety (TTFCS) to investigate the Astroworld incident.¹¹⁰ The investigation was extensive, but the published findings were brief. Five key areas were identified: unified command and control (UCC), training, planning, risk assessment, and centralized resources. The central theme of the report was that all stakeholders hold responsibility in event safety.¹¹¹ Among the themes highlighted by the TTFCS, the most relevant to crowd dynamics and fire department response are UCC, training, and planning. The findings of the TTFCS were similar to those of the Hillsborough Independent Panel—UCC, training, and planning recommendations serve to illustrate key points in crowd dynamics and fire department response.¹¹²

The Astroworld concert lacked UCC.¹¹³ Specifically, the major stakeholders were not all collocated for a successful operation, nor were they all represented in the command structure.¹¹⁴ In one glaring example, the HFD was not positioned in the command center, nor did it have the ability to communicate with other stakeholders. The commission argued that the function of UCC should have been to establish clear lines of authority and a clear process for pausing and stopping a performance.¹¹⁵ Nevertheless, the concert continued while victims were exposed to crushing forces, resulting in 10 deaths.¹¹⁶

The major stakeholders for this event were ScoreMore Shows, NRG management, the HPD, the HFD, Paradocs, and event security. Establishing a unified command in this

¹¹⁰ Office of the Texas Governor, “Governor Abbott Forms Texas Task Force.”

¹¹¹ “Governor Greg Abbott’s Texas Task Force on Concert Safety—April 2022 Report,” Texas Music Office, April 19, 2022, <https://gov.texas.gov/music/page/governor-abbotts-texas-task-force-on-concert-safety-april-2022-report>.

¹¹² Nick Hall, “‘No Way Out’: The Astroworld Tragedy Explained,” Man of Many, November 9, 2021, <https://manofmany.com/entertainment/music/astroworld-tragedy-explained>.

¹¹³ Juan A. Lozano, “Task Force Calls for Unified Command Center in Wake of Astroworld Tragedy,” Police1, December 1, 2022, <https://www.police1.com/mass-casualty/articles/task-force-calls-for-unified-command-center-in-wake-of-astroworld-tragedy-bx6k2hOxFrcVdgD0/>.

¹¹⁴ Lozano.

¹¹⁵ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹¹⁶ Dickson et al., “People Are Dying.”

case would have meant that representatives of each agency and organization were collocated to collaborate and respond as needed to emergencies. Moreover, all agencies would have needed to maintain situational awareness during the event, and managers and leaders would have shared status reports and anticipated needs. As the dangerous situation developed, the indications of a crush event should have been recognized. High crowd density, crowds in movement, and standing room only were indicators that injuries were likely.¹¹⁷ Furthermore, rapid decisions between UCC members to stop the show and alleviate problematic crowd conditions would have led to better outcomes. Indecision and a lack of leadership at key trigger points contributed to the poor outcome.¹¹⁸ The mass casualty incident (MCI) plan could have been implemented sooner. Even though the HFD called for an MCI at 9:32 p.m., there were indications of multiple injuries much earlier, particularly when the Paradocs staff were overwhelmed. An MCI response would have brought much-needed resources to the scene sooner and alerted other components such as trauma hospitals that significant numbers of injured were on the way.¹¹⁹

The TTFCS expressed that event staff and public agencies had not been adequately trained in crowd safety. The commission emphasized that training should have involved protocols for communications and trigger points to stop shows when dangerous situations arise.¹²⁰ The crowd conditions up to and after the start of Travis Scott’s performance indicated the point at which the show should have been stopped and the crowd crush addressed.¹²¹ According to reports, many of the security staff were same-day hires with little to no training in crowd safety.¹²² At large events, however, a significant portion of event staff and local agencies should be trained in crowd safety and able to identify key

¹¹⁷ Audie Cornish, Mano Sundaresan, and Christopher Intagliata, “After Astroworld, a Crowd Scientist Explains the Deadly Dynamics of Crowd Surges,” NPR, November 10, 2021, <https://www.npr.org/2021/11/10/1054428087/after-astroworld-a-crowd-scientist-explains-the-deadly-dynamics-of-crowd-surges>.

¹¹⁸ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹¹⁹ Renee L. DeNolf and Chadi I. Kahwaji, *EMS Mass Casualty Management* (Treasure Island, FL: StatPearls, 2023), <https://www.ncbi.nlm.nih.gov/books/NBK482373/>.

¹²⁰ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹²¹ Office of the Texas Governor, “Governor Abbott Forms Texas Task Force.”

¹²² Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

elements of crowd dynamics that lead to crowd crush injuries. The indications of crowd crush (e.g., high fan density and surging) and complaints from fans should have given event staff and attending agencies pause and spurred decisions to prevent or limit injuries to the public. Such training should extend to performers who have a significant effect on the crowd. Their actions, directions, and guidance to the crowd can influence the outcome of these events.¹²³

Though some stakeholders planned for the event and an EAP was in place before the concert began, not all stakeholders were involved.¹²⁴ The commission found that the Astroworld event had unique challenges that required unique contingency plans. Because the festival took place in a parking lot, it was susceptible to breaches in security that could overwhelm available resources.¹²⁵ For example, security personnel dealt with a continuing barrage of perimeter breaches that overwhelmed staff and drew their attention away from crowd safety.¹²⁶ Among the taskforce’s insights was the recommendation to include a risk assessment that considered all reasonable threats. In this case, however, even defining communications between agencies and transferring command to responding agencies when the situation intensified went beyond the event organizer’s capability.¹²⁷

The planning process and documented plans originated with the event organizer, ScoreMore Shows, but each of the major stakeholders should have been integrated into the plan and clear lines of communications and decision-making defined and codified.¹²⁸ In this case, the security roles and responsibilities of ScoreMore staff, the HPD, the HFD, Paradocs, and the casualty collection point should have been clearly defined in the EAP, but they were not. Planned response routes, designated casualty collection points, and

¹²³ Madeleine Virginia Gannon, “Exploring Innovative Ways to Address Crowd Surge after Astroworld,” *Michigan Daily*, November 29, 2021, <http://www.michigandaily.com/music/exploring-innovative-ways-to-address-crowd-surge-after-astroworld/>.

¹²⁴ NRG Park, *Astroworld 2021 Event Operations Plan*.

¹²⁵ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹²⁶ Associated Press, “Astroworld Operations Plan Failed to Include Crowd Surge Protocol,” *Guardian*, November 9, 2021, <https://www.theguardian.com/us-news/2021/nov/09/astroworld-houston-music-festival-travis-scott-protocol>.

¹²⁷ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹²⁸ Texas Music Office.

predetermined communications plans should have been embedded into the plan to facilitate a mass casualty response. This planning process would have facilitated a smoother operation among participating stakeholders and a quicker response to the crowd crush. In sum, better planning would have resulted in personnel recognizing the crowd crush, stopping further harm, and deploying EMS to the victims quickly.

C. ITAEWON, SEOUL, SOUTH KOREA

On October 29, 2022, Halloween celebrations turned deadly in the capital of South Korea when 159 people were killed and over 196 injured in a nighttime crowd crush tragedy. The Itaewon tragedy demonstrates the diverse nature of venues where crowd crushes occur.¹²⁹ The Itaewon district in Seoul, South Korea, is a major entertainment and dining attraction.¹³⁰ As in most major cities with a vibrant downtown nightlife, the potential for a crowd crush existed in Itaewon. A similar scenario occurred in Hong Kong in the Lan Kwai Fong district in 1993, leading to 21 deaths.¹³¹ The use of cell phones and social media by victims and witnesses helped to illuminate what developed.¹³² The documentation for this case study largely comes from journal articles and news interviews with experts.

1. Sequence of Events

Two days before the event, local authorities anticipated close to 100,000 people in the Itaewon entertainment district for the Halloween festivities. Fueling the numbers of revelers was the recent relaxing of COVID masking and social distancing requirements.¹³³

¹²⁹ Agence France-Presse, “Timeline of a Disaster: Seoul’s Fatal Crowd Crush,” France 24, November 1, 2022, <https://www.france24.com/en/live-news/20221101-timeline-of-a-disaster-seoul-s-fatal-crowd-crush>.

¹³⁰ “Itaewon,” Seoul Guide, accessed February 20, 2023, <https://www.theseoulguide.com/itaewon/>.

¹³¹ Park Ji-won, “Hong Kongers Find Itaewon Tragedy Reminiscent of Past, Question Lack of Crowd Control in Seoul,” *Korea Times*, November 2, 2022, https://www.koreatimes.co.kr/www/nation/2023/02/281_338943.html.

¹³² “Video Shows Panic as Seoul Crowd Surges,” BBC News, October 29, 2022, <https://www.bbc.com/news/av/world-asia-63442529>.

¹³³ Junhyup Kwon et al., “‘They Completely Failed’: The Fatal Mistakes That Led to South Korea’s Halloween Tragedy,” *Vice*, November 4, 2022, <https://www.vice.com/en/article/7k8mab/south-korea-itaewon-stampede-halloween-disaster>.

No official planning took place for the large numbers of people entering the area as no sanctioned event had been planned. Police assigned 200 officers to the area that night.¹³⁴ The local police substation had requested the help of the police’s mobile field force, which had been used in the area to enforce COVID protocols in the years prior. The mobile police personnel on the day of the crush had been deployed to protests in other parts of Seoul.¹³⁵

The Itaewon entertainment area coalesces around numerous night clubs, restaurants, and a major hotel—a district popular among younger crowds and international tourists.¹³⁶ The area’s physical characteristics are predisposed to crowd crush conditions. For one, streams of people from four directions converge at a bottleneck situated on a significant incline.¹³⁷ Also, one major street to the south, Itaewon Street, funnels people into the alleyways that lead to the World Food Street’s dining and entertainment venues. Furthermore, Itaewon’s subway station entrance is within a short five-minute walk of the area, and people normally access it through one of two narrow alleys to the restaurants. The alleyway where the crush occurred is approximately three meters wide at its narrowest point and situated on a steep decline from World Food Street down to Itaewon Street.¹³⁸ While no event was planned at this popular dining and entertainment area, larger-than-typical crowds were anticipated due to Halloween revelers and the end of COVID restrictions.¹³⁹

The South Korean 1–1-2 emergency number, along with eyewitness accounts, played a major role in laying out the sequence of events. Eleven calls to police over an

¹³⁴ Agence France-Presse, “Timeline of a Disaster.”

¹³⁵ Sarah Kim, “Police Chain of Command Didn’t Work on Halloween,” *Korea JoongAng Daily*, November 3, 2022, <https://koreajoongangdaily.joins.com/2022/11/03/national/politics/Korea-National-Police-Agency-Itaewon-crowd-crush/20221103190335626.html>.

¹³⁶ Seoul Guide, “Itaewon.”

¹³⁷ Samantha Lock, “Crowd Crushes: How Disasters like Itaewon Happen, How Can They Be Prevented, and the ‘Stampede’ Myth,” *Guardian*, November 1, 2022, <https://www.theguardian.com/world/2022/nov/01/how-do-crowd-crushes-happen-stampede-myth-what-happened-in-the-seoul-itaewon-halloween-crush>.

¹³⁸ Kwon et al., “They Completely Failed.”

¹³⁹ Michelle Ye Hee Lee et al., “Crucial Lapses Led to Tragically Delayed Rescue in a Seoul Alley,” *Washington Post*, November 17, 2022, <https://www.washingtonpost.com/investigations/2022/11/16/seoul-crowd-crush-itaewon-victims/>.

approximate four-hour period showed the development of the crowd crush danger and people’s fear.¹⁴⁰ In the first, at 6:34 p.m., the caller expressed worry over a possible crush situation. By 8:33 p.m., a caller described people shoving and crowding. Within 20 minutes, another caller stated, “They are getting crushed.”¹⁴¹ In the final call before the crowd collapse, the caller said, “I think we are going to get crushed.”¹⁴² Eyewitness accounts indicate that at around 10:15 p.m., a crowd surge and collapse occurred when multiple victims piled up at the alleyway pinch point. Unaware of the conditions in the alleyway, crowds continued to push to get through from both directions as people tried to leave the congested area.¹⁴³

The police substation and a local fire station were within the same block of the alley where the incident occurred. The fire department started making notifications for the disaster at 10:30 p.m. and declared a Level 3 response at 10:48 p.m., the department’s highest level for resources, with notifications to the National Medical Center (NMC). South Korea’s response to mass casualty incidents had undergone a change since a 2015 building collapse. This change meant that the response system relied on an NMC that, when notified of an event, dispatched a disaster medical assistance team (DMAT) from local area hospitals to the disaster. The team members included a doctor and assistants that could treat victims on scene. A total of 15 DMATs were sent to Itaewon, the last arriving by 11:30 p.m.

Responders on scene, including police and fire resources, reported difficulty in reaching patients and extricating them from the alleyway.¹⁴⁴ Accessing the injured was hampered by the large crowd still trying to pass through or leave the narrow path.

¹⁴⁰ Seo Ji-Eun, “Calls to Fire Department Were Some Victims’ Last,” *Korea JoongAng Daily*, November 8, 2022, <https://koreajoongangdaily.joins.com/2022/11/08/national/socialAffairs/Korea-Itaewon-crowd/20221108183931053.html>.

¹⁴¹ Danielle Song, “Full Transcripts of Desperate Police Report Calls from the Night of the Itaewon Disaster Revealed,” *Koreaboo*, November 1, 2022, <https://www.koreaboo.com/news/full-transcripts-police-reports-calls-night-itaewon-disaster-revealed/>.

¹⁴² Song.

¹⁴³ Kwon et al., “They Completely Failed.”

¹⁴⁴ Kwon et al.

Extricating the victims was difficult because many had piled up, and the alley was extremely narrow. As a result, many victims could not be removed, and emergency personnel and private citizens were still performing CPR several hours after the start of the incident. National authorities announced that by the end of the incident, over 400 emergency responders had been sent to the catastrophe.¹⁴⁵

2. Identifying and Understanding the Mistakes

Mistakes similar to those at Astroworld and Hillsborough abounded in the Itaewon crowd crush. As detailed in the findings of all three cases, planning, command and control, and training proved shortcoming for responders to the disaster.

There was no official planning done to prevent the crowd crush at Itaewon. Officials stated there had been no event scheduled in the Itaewon entertainment district, so no additional planning for crowd control had been anticipated. No private group or organization was responsible for the throng of 100,000 descending on one spot. The police anticipated they would have to address crime issues including theft and drug use. Nevertheless, while the police had anticipated a crowd of 100,000, some estimates put the actual size at 130,000.¹⁴⁶ General mass casualty plans were in place with local agencies and in accordance with the national plan through the NMC.

The mass gathering that occurred at Itaewon should have been handled as a significant event with a unified command established between all concerned stakeholders. Moreover, the planning process should have been carried out before the day of the event. A written operational plan should have reflected clear lines of authority, communication, crowd control, and trigger points for activations of mass casualty plans.

There was no command-and-control element present at Itaewon to address the large crowd specifically. Operations were typically handled at the local level, so police and fire units engaged at the tactical level were required to make decisions to upgrade the response

¹⁴⁵ Gavin Blair and Jon Henley, “At Least 153 Killed in Crowd Crush during Halloween Festivities in Seoul,” *Guardian*, October 30, 2022, <https://www.theguardian.com/world/2022/oct/29/dozens-of-people-crushed-by-large-crowd-at-halloween-festivities-in-south-korea>.

¹⁴⁶ Blair and Henley.

and make notifications as the situation grew progressively worse. No command post was established to make decisions and direct incoming resources.¹⁴⁷ The response has been criticized heavily for its slow reaction due to a poor command-and-control structure and a lack of communication, from the local to the national level. Indeed, slow communications delayed the necessary response for patient care, and no one seemed to be in control at the scene.¹⁴⁸ One source said there was no one to take charge and delegate assignments during the emergency, not to mention the poor communications between fire, medical personnel, and law enforcement.¹⁴⁹

A command-and-control organization with a command post should have been established at Itaewon. As a result of a planning process, as discussed earlier, representatives from the major stakeholders could have been present to make quick decisions. With such a structure and planning, the decision process, communications, and notifications would have taken place much more quickly to deliver resources to the injured and dying victims. Decisions and notifications that took hours at Itaewon could have been handled in minutes.¹⁵⁰

Local authorities at Itaewon did not fully understand the dangers of a crowd crush incident. A basic understanding of crowd density, congestion, and chokepoints would have prompted local officials to control crowd levels and pedestrian flow in and out of World Food Street and the adjoining alleyways.¹⁵¹ A simple risk assessment based on crowd dynamics would have identified the choke points of the alleyways and the steep incline as danger points. The few ingress and egress points could have been controlled easily to keep crowd levels below critical densities.¹⁵²

¹⁴⁷ Lee Hyo-jin, “Korea’s Emergency Medical Response to Disasters Needs Improvement,” *Korea Times*, November 10, 2022, https://www.koreatimes.co.kr/www/nation/2023/02/119_339538.html.

¹⁴⁸ Cho Jung-Woo, “Emergency Medical Team Arrived in Itaewon at 11:20 p.m.,” *Korea JoongAng Daily*, November 2, 2022, <https://koreajoongangdaily.joins.com/2022/11/02/national/socialAffairs/korea-itaewon-itaewon-halloween/20221102192414221.html>; Lee, “Korea’s Emergency Medical Response to Disasters Needs Improvement.”

¹⁴⁹ Lee, “Korea’s Emergency Medical Response to Disasters Needs Improvement.”

¹⁵⁰ Lee.

¹⁵¹ Kwon et al., “They Completely Failed.”

¹⁵² Lee et al., “Crucial Lapses Led to Tragically Delayed Rescue.”

Police, fire, and medical personnel who work with large crowds should be familiar with key contributors to a crowd crush situation. A working knowledge of crowd density, congestion, and choke points should be incorporated into personnel training. Personnel at all levels should be aware of these signs and prompt the command staff when the risk of a crowd crush is significant.¹⁵³ The warning signs of obvious crowd densities above five persons per square meter, known choke points, and significant inclines in pedestrian areas should have raised the alarm.¹⁵⁴ Furthermore, the importance of responding to emergency calls that detail crush conditions cannot be overstated.¹⁵⁵ Cell phones in the hands of almost every person at an event makes calls to dispatchers a valuable resource for responders in identifying the conditions of crowd crush. Dispatchers can then prompt personnel on scene to act immediately.

¹⁵³ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹⁵⁴ Choe Sang-Hun, “Halloween Crowd Crush in Seoul Was ‘Absolutely Avoidable,’ Experts Say,” *New York Times*, October 31, 2022, <https://www.nytimes.com/2022/10/31/world/asia/seoul-halloween-crowd-accountability.html>.

¹⁵⁵ Song, “Full Transcripts of Desperate Police Report Calls.”

THIS PAGE INTENTIONALLY LEFT BLANK

IV. CONCLUSIONS AND RECOMMENDATIONS

This thesis has explored the concepts of crowd dynamics and psychology and how they contribute to crowd crush events. How fire departments can improve their response to these events as well as patient care was the primary focus of this study. Key elements of crowd dynamics and psychology were detailed with a particular emphasis on definitions that can be utilized across a wide domain of crowd events and issues. Crowd crush events continue to happen around the world on a regular basis. Experts agree that crowd incidents can be avoided in most cases by crowd management plans.¹⁵⁶ Avoiding critical crowd densities and rapid group movements is key to crowd management.¹⁵⁷ However, events involving large crowds always have some level of risk of myriad issues, including dynamic crowd events. If a crowd crush does happen, time is the critical factor in responding to injuries. It bears repeating that quickly recognizing, responding, and treating crush injuries is paramount. Once a crowd crush occurs, victims can succumb to compression asphyxia within minutes.¹⁵⁸ In case after case, responders did not recognize the signs of crowd crush. If, however, they know the signs, they can initiate a series of decisions and notifications to stop further harm and get definitive treatment to the victims.

A. CONCLUSIONS

The case studies examined three different crowd crush events—Hillsborough, Astroworld, and Itaewon—each at a different venue—a sporting event, a music concert, and an entertainment/dining district. Each venue represents a legitimate mass gathering that any fire department or EMS agency might support, the primary stakeholders being municipal agencies and private companies responsible for crowd management and crowd safety.

Nearly 33 years separate the disasters at Hillsborough Stadium and the Itaewon entertainment district. In the intervening years, the understanding of crowd dynamics has

¹⁵⁶ Fruin, “The Causes and Prevention of Crowd Disasters,” 9.

¹⁵⁷ Fruin, 6.

¹⁵⁸ Fruin, 7.

improved considerably. Event planning and management have seen standardization in the National Incident Management System, the Incident Command System (ICS), and other such systems.¹⁵⁹ The case studies consistently found there were issues in planning, command and control, and training.

1. Planning

In all three case studies, planning was insufficient for the events that spawned the emergencies. At Hillsborough, law enforcement had a mass incident plan and operational support plan but nothing that resembled a unified plan representing all stakeholders. Clear lines of authority and communication did not exist between police, fire, and EMS. Similarly, event managers at Astroworld produced an EAP that did not incorporate local 9-1-1 responders, establish clear lines of authority, or designate proper communications.¹⁶⁰ The Itaewon crowd crush was not a sanctioned event, so local authorities did not have a plan to address the emergency. Planning for large events should involve dispatch centers, so they understand the plan and can minimize confusion between responders.¹⁶¹

There is a certain level of risk due to any mass gathering, but planning can make events safer.¹⁶² All stakeholders contribute to safe events. Part of planning considers managing the crowd and assessing a venue for crowd interaction before its use.¹⁶³ Planning provides for UCC, which establishes clear lines of authority and communications for pausing or canceling an event for a safety response.¹⁶⁴ Emergency services and private stakeholders should be part of the planning process.¹⁶⁵

There is a need for defined triggers for pausing and canceling performances. Risk management is an integral part of the planning process and considers most known hazards.

¹⁵⁹ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹⁶⁰ NRG Park, *Astroworld 2021 Event Operations Plan*.

¹⁶¹ Cooper, “The Crowd Machine,” 83.

¹⁶² Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹⁶³ Fruin, “The Causes and Prevention of Crowd Disasters,” 6.

¹⁶⁴ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹⁶⁵ Griggs, “Crowd Dynamics and Safety at Outside Events,” 85.

It establishes communication channels with local agencies and protocols for transferring command in emergencies. Appropriate, planned communications with the public can be used to facilitate the crowd's assistance in the collective safety of everyone at the event.¹⁶⁶

2. Command and Control

Deficiencies in command and control were noted in all three case studies. There were no clear lines of authority between upper management and line personnel or between agencies and event staff. Communications were insufficient to meet the needs of a rapid response to a critical incident. There was no coordination of incoming resources to assist in treating the injured and dying. In all three cases, communications, entrance locations, travel routes, and casualty collection points were major factors in delaying treatment.

A centralized command post can track the real-time status of crowd conditions, coordinate actions, and direct communications between all stakeholders. As part of the ICS, a unified command should be used in a multiagency response.¹⁶⁷ There should be comprehensive communications between event staff and local police, fire, and EMS.¹⁶⁸ The reason behind UCC is to establish clear lines of authority and communications for pausing or canceling an event for a safety response.¹⁶⁹ Prepositioned command staff in communication with engaged units at the event can coordinate incoming resources for better effectiveness.¹⁷⁰ The UCC, with representatives from law enforcement, fire, EMS, and event management, should have a “show stop” capability. Event organizers should determine who the local 9-1-1 responders are and include them in the UCC as members. UCC members should interact before events to strengthen their communications when an emergency event occurs. Local first responders have preexisting relationships with other public agencies that make emergency communications and notifications more efficient.¹⁷¹

¹⁶⁶ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹⁶⁷ Griggs, “Crowd Dynamics and Safety at Outside Events,” 83.

¹⁶⁸ Fruin, “The Causes and Prevention of Crowd Disasters,” 7.

¹⁶⁹ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

¹⁷⁰ Cooper, “The Crowd Machine,” 84.

¹⁷¹ Texas Music Office, “Governor Greg Abbott’s Texas Task Force on Concert Safety.”

3. Training

Recognizing that a crowd crush can happen or is happening is paramount to responding to the incident. In each of the case studies, critical crowd dynamic indicators for crowd crush were not recognized. The incident could have been prevented in most cases if someone with authority had recognized that critical crowd densities had been reached.¹⁷² When the crush commenced but was not perceived, there were critical delays in rescue and medical care.

First responders and other assisting agencies should be familiar with crowd dynamics and indications of crowd crush. Planning and specific training are closely related in providing for the emergency needs of people attending the venue.¹⁷³ Event staff should be trained in crowd management techniques and should be able to recognize crowd issues and other emergencies.¹⁷⁴ Competence and knowledge of personnel at an emergency event are the result of preplanning and training. Multiagency training creates associations between partners that improve the overall effectiveness of the response.¹⁷⁵ Crowd safety training and resources are readily available to event staff and first responders. Training between public agencies and hired security and event staff can increase operational awareness between them.¹⁷⁶

B. RECOMMENDATIONS

1. Fire Departments Should Take the Lead in Crowd Safety

Fire departments and EMS agencies have the primary responsibility of ensuring life safety. They provide EMS in the field and transport patients to the hospitals. When contracted medical services become overwhelmed, local fire and EMS are called on to back up or take over patient rescue and treatment. As the TTFCS mentions, all stakeholders are

¹⁷² G. Keith Still, "Crowd Density—Moving Crowds," *Crowd Safety and Crowd Risk Analysis* (blog), June 9, 2018, <https://www.gkstill.com/Support/crowd-flow/MovingDensity.html>.

¹⁷³ Griggs, "Crowd Dynamics and Safety at Outside Events," 86.

¹⁷⁴ Fruin, "The Causes and Prevention of Crowd Disasters," 5.

¹⁷⁵ Griggs, "Crowd Dynamics and Safety at Outside Events," 82.

¹⁷⁶ Texas Music Office, "Governor Greg Abbott's Texas Task Force on Concert Safety."

responsible for a safe event.¹⁷⁷ Police, security, and event managers all have event safety in mind, but their focus may not be on crowd dynamics and the indications of crowd crush. Law enforcement has its eye on crowd control and crime prevention while event managers must ensure that the show goes on. As a primary stakeholder in the UCC process, fire departments are well positioned to keep crowd dynamics in focus and speak up when dangerous situations develop.

2. Provide Awareness-Level Crowd Safety Training for Fire Department and EMS Personnel

Crowd management courses and certifications should be a part of the fire department training process. Awareness-level training should be incorporated into the recruit training process. Most fire departments have adopted an all-hazards training approach, and this is another theme that could be addressed. Nevertheless, the needed training involves simple warning signs developed to alert personnel to a possible crowd crush. Such guidance and associated firefighting orders have proven successful in wildland firefighting and can be applied to crowd dynamics, too.¹⁷⁸ The orders give a segmented approach to dealing with risk from firefighting. The “watchouts” expand on the orders and alert personnel to high-risk situations to be avoided, thus preventing injuries. The watchouts and orders, based on historical scenarios that have resulted in fatalities, have a proven track record in the firefighting community.

3. Leverage Emerging Technologies

Emerging technologies have shown promise in detecting dangerous crowd dynamics more rapidly and alerting crowd managers and first responders to risks before they turn into tragedy. Developing crowd monitoring systems that can scrutinize real-time crowd conditions to evaluate crowd dynamics—analyzing crowd density, movement, and

¹⁷⁷ Office of the Texas Governor, “Governor Abbott Forms Texas Task Force.”

¹⁷⁸ “18 Watch Out Situations, PMS 118,” National Wildfire Coordinating Group, January 25, 2023, <https://www.nwcg.gov/publications/pms118>.

behavior—will prove beneficial in preventing crowd crush in the first place.¹⁷⁹ Camera and optical recognition systems are becoming the norm in large venues and entertainment districts. Video streaming helps to pass information to the emergency control center, dispatch centers, and unified command post. This technology, keyed in on known choke points, can give a real-time indication of crowd density, alerting managers to the need for strategies to reduce crowd-related injuries.

Additionally, machine learning and automatic speech recognition software can assist dispatch centers as keywords and phrases used by callers indicate a crowd crush is imminent. Similar technology has been used to alert call takers to heart-related issues and cardiac arrests that need further attention and specific care.¹⁸⁰ As the call logs from Itaewon highlighted, the callers used words that indicated an imminent crowd crush.¹⁸¹

C. FINAL THOUGHTS

The aim of this study was to improve the fire department response to crowd crush incidents. Certain key factors emerged in the case reviews of three prominent crush disasters. Understanding what factors lead to and cause a crush is important and should be addressed by training at all levels of the fire department. Moreover, events such as the ones detailed in this thesis require a unified command with all major private and public stakeholders present, utilizing a clear decision process and lines of communications for all personnel. This interorganizational structure will ensure the rapid recognition of and response to a crush event, thus offering the best possible outcome for the crowd, who has entrusted the venue with its safety.

¹⁷⁹ Victoria Hutchison, “Crowd Source,” *NFPA Journal*, August 2020, <https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2020/July-August-2020/Features/Crowd-Control>.

¹⁸⁰ Fredrik Byrsell et al., “Machine Learning Can Support Dispatchers to Better and Faster Recognize Out-of-Hospital Cardiac Arrest during Emergency Calls: A Retrospective Study,” *Resuscitation* 162 (2021): 218–26, <https://doi.org/10.1016/j.resuscitation.2021.02.041>.

¹⁸¹ Song, “Full Transcripts of Desperate Police Report Calls.”

LIST OF REFERENCES

- Agence France-Presse. "Timeline of a Disaster: Seoul's Fatal Crowd Crush." France 24, November 1, 2022. <https://www.france24.com/en/live-news/20221101-timeline-of-a-disaster-seoul-s-fatal-crowd-crush>.
- Associated Press. "Astroworld Operations Plan Failed to Include Crowd Surge Protocol." *Guardian*, November 9, 2021. <https://www.theguardian.com/us-news/2021/nov/09/astroworld-houston-music-festival-travis-scott-protocol>.
- BBC News. "Hillsborough Pen Was Packed to 'Twice' Its Safe Capacity, Says Expert." June 25, 2014. <https://www.bbc.com/news/uk-england-merseyside-28017910>.
- . "How the Hillsborough Disaster Happened." April 14, 2009. http://news.bbc.co.uk/2/hi/uk_news/7992845.stm.
- . "Video Shows Panic as Seoul Crowd Surges." October 29, 2022. <https://www.bbc.com/news/av/world-asia-63442529>.
- Blair, Gavin, and Jon Henley. "At Least 153 Killed in Crowd Crush during Halloween Festivities in Seoul." *Guardian*, October 30, 2022. <https://www.theguardian.com/world/2022/oct/29/dozens-of-people-crushed-by-large-crowd-at-halloween-festivities-in-south-korea>.
- Byrsell, Fredrik, Andreas Claesson, Mattias Ringh, Leif Svensson, Martin Jonsson, Per Nordberg, Sune Forsberg, Jacob Hollenberg, and Anette Nord. "Machine Learning Can Support Dispatchers to Better and Faster Recognize Out-of-Hospital Cardiac Arrest during Emergency Calls: A Retrospective Study." *Resuscitation* 162 (2021): 218–26. <https://doi.org/10.1016/j.resuscitation.2021.02.041>.
- Caldwell, Travis, and Keith Allen. "Within Minutes, the Astroworld Festival Turned Deadly. Here's What We Know about the Show's Timeline." CNN, November 8, 2021. <https://www.cnn.com/2021/11/08/us/astroworld-festival-crowd-surge-timeline/index.html>.
- Cho Jung-Woo. "Emergency Medical Team Arrived in Itaewon at 11:20 p.m." *Korea JoongAng Daily*, November 2, 2022. <https://koreajoongangdaily.joins.com/2022/11/02/national/socialAffairs/korea-itaewon-itaewon-halloween/20221102192414221.html>.
- Choe Sang-Hun. "Halloween Crowd Crush in Seoul Was 'Absolutely Avoidable,' Experts Say." *New York Times*, October 31, 2022. <https://www.nytimes.com/2022/10/31/world/asia/seoul-halloween-crowd-accountability.html>.

- Clark County Fire Department, Las Vegas Metropolitan Police Department, and Federal Emergency Management Agency. *1 October After-Action Report*. Washington, DC: Federal Emergency Management Agency, 2018.
- Cocking, Chris, John Drury, and Steve Reicher. “The Psychology of Crowd Behaviour in Emergency Evacuations: Results from Two Interview Studies and Implications for the Fire and Rescue Services.” *Irish Journal of Psychology* 30, no. 1–2 (2009): 59–73. <https://doi.org/10.1080/03033910.2009.10446298>.
- Collman, Ashley. “‘I’m Going to Die Because This Man Is Not Stopping the Concert’: How the Deadly Crowd Surge at Astroworld Unfolded.” *Insider*, November 13, 2021. <https://www.insider.com/how-travis-scott-astroworld-crowd-surge-unfolded-2021-11>.
- Conn, David. “Hillsborough Disaster: Deadly Mistakes and Lies That Lasted Decades.” *Guardian*, April 26, 2016. <https://www.theguardian.com/football/2016/apr/26/hillsborough-disaster-deadly-mistakes-and-lies-that-last-ed-decades>.
- Cooper, Craig M. “The Crowd Machine: Leveraging Emergent Crowd Behavior in Policy and Response.” Master’s thesis, Naval Postgraduate School, 2021. <https://hdl.handle.net/10945/67119>.
- Cooper, Donald C., ed. *The Event Safety Guide: A Guide to Health, Safety and Welfare at Live Entertainment Events in the United States*. Scottsdale, AZ: Event Safety Alliance, 2013.
- Cornish, Audie, Mano Sundaresan, and Christopher Intagliata. “After Astroworld, a Crowd Scientist Explains the Deadly Dynamics of Crowd Surges.” NPR, November 10, 2021. <https://www.npr.org/2021/11/10/1054428087/after-astroworld-a-crowd-scientist-explains-the-deadly-dynamics-of-crowd-surges>.
- DeNolf, Renee L., and Chadi I. Kahwaji. *EMS Mass Casualty Management*. Treasure Island, FL: StatPearls, 2023. <https://www.ncbi.nlm.nih.gov/books/NBK482373/>.
- Denton, Jack. “Yes, the Dangerous Crowd Crush at Astroworld Was Probably Preventable.” *Vice*, November 9, 2021. <https://www.vice.com/en/article/bvnx7a/the-dangerous-crowd-crush-at-astroworld-was-probably-preventable>.
- Dickson, EJ, Daniel Kreps, Nancy Dillon, and Bryan C. Parker. “‘People Are Dying’: Witnesses Describe Horror of Astroworld Tragedy.” *Rolling Stone*, November 6, 2021. <https://www.rollingstone.com/music/music-news/eyewitnesses-astroworld-houston-travis-scott-1254208/>.
- Dinesh, T., K. Aniket, and D. Roshan. *Events Industry Market*. Report overview. Portland: Allied Market Research, 2022. <https://www.alliedmarketresearch.com/events-industry-market>.

- Drury, John, Holly Carter, Chris Cocking, Evangelos Ntontis, Selin Tekin Guven, and Richard Amlôt. “Facilitating Collective Psychosocial Resilience in the Public in Emergencies: Twelve Recommendations Based on the Social Identity Approach.” *Frontiers in Public Health* 7, no. 141 (2019): 1–21. <https://doi.org/10.3389/fpubh.2019.00141>.
- Federal Emergency Management Agency. *Developing and Maintaining Emergency Operations Plans*. Comprehensive Preparedness Guide 101. Version 2.0. Washington, DC: Department of Homeland Security, 2010.
- Fruin, John J. “The Causes and Prevention of Crowd Disasters.” Paper presented at the First International Conference on Engineering for Crowd Safety, London, England, March 1993.
- Gannon, Madeleine Virginia. “Exploring Innovative Ways to Address Crowd Surge after Astroworld.” *Michigan Daily*, November 29, 2021. <http://www.michigandaily.com/music/exploring-innovative-ways-to-address-crowd-surge-after-astroworld/>.
- Graham, Gordon. “High-Risk, Low-Frequency Events in Public Safety.” *Lexipol* (blog), July 15, 2020. <https://www.lexipol.com/resources/blog/high-risk-low-frequency-events-in-public-safety/>.
- Griggs, Rick. “Fire Department Perspective: Crowd Dynamics and Safety at Outside Events.” Master’s thesis, Naval Postgraduate School, 2017. <https://hdl.handle.net/10945/56930>.
- Guardian*. “Timeline of Tragedies during Hajj Pilgrimage in Mecca.” September 24, 2015. <https://www.theguardian.com/world/2015/sep/24/timeline-of-tragedies-in-mecca-during-hajj>.
- Haasch, Palmer. “Crowd Surges like the One at Travis Scott’s Astroworld Concert Have a Long History.” *Insider*, November 11, 2021. <https://www.insider.com/crowd-astroworld-crush-surge-travis-scott-concert-festival-disaster-history-2021-11>.
- Hall, Nick. “‘No Way Out’: The Astroworld Tragedy Explained.” *Man of Many*, November 9, 2021. <https://manofmany.com/entertainment/music/astroworld-tragedy-explained>.
- Helbing, Dirk, and Pratik Mukerji. “Crowd Disasters as Systemic Failures: Analysis of the Love Parade Disaster.” *EPJ Data Science* 1 (2012): 7. <https://doi.org/10.1140/epjds7>.
- Hillsborough Independent Panel. *Hillsborough: The Report of the Hillsborough Independent Panel*. London: Stationery Office, 2012.

- Hines, Nico. "U.K. Court Blames Police, Not Soccer Fans, for Hillsborough Disaster." *Daily Beast*, April 13, 2017. <https://www.thedailybeast.com/articles/2016/04/26/uk-court-blames-police-not-soccer-fans-for-hillsborough-disaster>.
- Home Office. *The Hillsborough Stadium Disaster: 15 April 1989 Inquiry by the Rt Hon Lord Justice Taylor: Final Report*. London: Stationery Office, 1990. https://www.jesip.org.uk/uploads/media/incident_reports_and_inquiries/Hillsborough%20Stadium%20Disaster%20final%20report.pdf.
- Hutchison, Victoria. "Crowd Source." *NFPA Journal*, August 2020. <https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2020/July-August-2020/Features/Crowd-Control>.
- Ibrahim, Wanis H. "Recent Advances and Controversies in Adult Cardiopulmonary Resuscitation." *Postgraduate Medical Journal* 83, no. 984 (October 2007): 649–54. <https://doi.org/10.1136/pgmj.2007.057133>.
- Independent Office for Police Conduct. "Hillsborough Investigation." January 7, 2018. <https://www.policeconduct.gov.uk/investigations/hillsborough-investigation>.
- Johnston, Hamish. "'Crowd Turbulence' Has Deadly Consequences." *Physics World*, January 25, 2007. <https://physicsworld.com/a/crowd-turbulence-has-deadly-consequences/>.
- Kim, Sarah. "Police Chain of Command Didn't Work on Halloween." *Korea JoongAng Daily*, November 3, 2022. <https://koreajoongangdaily.joins.com/2022/11/03/national/politics/Korea-National-Police-Agency-Itaewon-crowd-crush/20221103190335626.html>.
- Kwon, Junhyup, Hanako Montgomery, Rachel Cheung, and Alan Wong. "'They Completely Failed': The Fatal Mistakes That Led to South Korea's Halloween Tragedy." *Vice*, November 4, 2022. <https://www.vice.com/en/article/7k8mab/south-korea-itaewon-stampede-halloween-disaster>.
- Lee Hyo-jin. "Korea's Emergency Medical Response to Disasters Needs Improvement." *Korea Times*, November 10, 2022. https://www.koreatimes.co.kr/www/nation/2023/02/119_339538.html.
- Lee, Michelle Ye Hee, Meg Kelly, Atthar Mirza, Grace Moon, Min Joo Kim, and Stefanie Le. "Crucial Lapses Led to Tragically Delayed Rescue in a Seoul Alley." *Washington Post*, November 17, 2022. <https://www.washingtonpost.com/investigations/2022/11/16/seoul-crowd-crush-itaewon-victims/>.
- Leverone, Robert H. "Crowds as Complex Adaptive Systems: Strategic Implications for Law Enforcement." Master's thesis, Naval Postgraduate School, 2016. <https://hdl.handle.net/10945/48549>.

- Live Nation Entertainment. “Live Nation Acquires Premier Texas Concert Promoter and Festival Producer, ScoreMore Shows.” PR Newswire, May 30, 2018. <https://www.prnewswire.com/news-releases/live-nation-acquires-premier-texas-concert-promoter-and-festival-producer-scoremore-shows-300656060.html>.
- Lock, Samantha. “Crowd Crushes: How Disasters like Itaewon Happen, How Can They Be Prevented, and the ‘Stampede’ Myth.” *Guardian*, November 1, 2022. <https://www.theguardian.com/world/2022/nov/01/how-do-crowd-crushes-happen-stampede-myth-what-happened-in-the-seoul-itaewon-halloween-crush>.
- Lozano, Juan A. “Task Force Calls for Unified Command Center in Wake of Astroworld Tragedy.” *Police1*, December 1, 2022. <https://www.police1.com/mass-casualty/articles/task-force-calls-for-unified-command-center-in-wake-of-astroworld-tragedy-bx6k2hOxFrcVdgD0/>.
- Lynch, Joe. “Check Out These Surprising Stats about U.S. Music Festivals.” *Billboard*, April 22, 2015. <https://www.billboard.com/culture/events/music-festival-statistics-graphic-6539009/>.
- Mauri, Matteo. “LETSCROWD Server—LETSCROWD Tool Presentation Cards #7.” LETSCROWD, November 8, 2019. <https://letscrowd.eu/server-toolcard/>.
- Mawson, Anthony R. “Understanding Mass Panic and Other Collective Responses to Threat and Disaster.” *Psychiatry: Interpersonal and Biological Processes* 68, no. 2 (Summer 2005): 95–113. <https://doi.org/10.1521/psyc.2005.68.2.95>.
- National Wildfire Coordinating Group. “18 Watch Out Situations, PMS 118.” January 25, 2023. <https://www.nwccg.gov/publications/pms118>.
- Nolan, Jerry P., Jasmeet Soar, Nathaniel Cary, Nigel Cooper, Jack Crane, Ashley Fegan-Earl, William Lawler, Philip Lumb, and Guy Ruttly. “Compression Asphyxia and Other Clinicopathological Findings from the Hillsborough Stadium Disaster.” *Emergency Medicine Journal* 38, no. 10 (October 2021): 798–802. <https://doi.org/10.1136/emmermed-2020-209627>.
- NRG Park. *Astroworld 2021 Event Operations Plan (EOP)*. Houston: NRG Park, 2021. <https://ca-times.brightspotcdn.com/bf/57/11bc2a094c9886f3407cc641e1e7/astroworld-2021-eop-1.pdf>.
- . “Home Page.” Accessed April 10, 2023. <https://www.nrgpark.com/>.
- Oberg, Ted, and Sarah Rafique. “‘Concert from Hell’: 13 Investigates Looks at Warning Signs Ahead of Astroworld Tragedy.” ABC 13 Houston. Accessed February 2, 2023. <https://abc13.com/feature/astroworld-2021-festival-travis-scott-astro-fest-security/11213442/>.

- Office of the Texas Governor. "Governor Abbott Forms Texas Task Force on Concert Safety following Astroworld Festival Tragedy." November 10, 2021. <https://gov.texas.gov/news/post/governor-abbott-forms-texas-task-force-on-concert-safety-following-astroworld-festival-tragedy>.
- Paradocs Event Medical Services. "Home Page." Accessed February 17, 2023. <https://www.paradocsworldwide.com>.
- Park Ji-won. "Hong Kongers Find Itaewon Tragedy Reminiscent of Past, Question Lack of Crowd Control in Seoul." *Korea Times*, November 2, 2022. https://www.koreatimes.co.kr/www/nation/2023/02/281_338943.html.
- Politics.co.uk. "Football Hooliganism—All You Need to Know." Accessed January 30, 2023. <https://www.politics.co.uk/reference/football-hooliganism/>.
- Quarantelli, E. L. *Emergent Behaviors and Groups in the Crisis Time Periods of Disasters*. Newark: University of Delaware, Disaster Research Center, 1994. <http://udspace.udel.edu/handle/19716/591>.
- Raineri, Aldo. "The Causes and Prevention of Serious Crowd Injury and Fatalities at Outdoor Music Festivals." In *Proceedings of the SIA 12th Annual Occupational Health and Safety VISIONS Conference*, 1–14. Brisbane: Safety Institute of Australia, 2005. <https://doi.org/10.13140/2.1.3036.0005>.
- Robinson, Martin. "Fans 'Were Crushed at Hillsborough Eight Years before Disaster.'" *Daily Mail*, February 25, 2019. <https://www.dailymail.co.uk/news/article-6597927/Fans-crushed-Hillsborough-eight-years-disaster.html>.
- Seabrook, John. "Crush Point." *New Yorker*, January 30, 2011. <http://www.newyorker.com/magazine/2011/02/07/crush-point>.
- Seo Ji-Eun. "Calls to Fire Department Were Some Victims' Last." *Korea JoongAng Daily*, November 8, 2022. <https://koreajoongangdaily.joins.com/2022/11/08/national/socialAffairs/Korea-Itaewon-crowd/20221108183931053.html>.
- Seoul Guide. "Itaewon." Accessed February 20, 2023. <https://www.theseoulguide.com/itaewon/>.
- Song, Danielle. "Full Transcripts of Desperate Police Report Calls from the Night of the Itaewon Disaster Revealed." *Koreaboo*, November 1, 2022. <https://www.koreaboo.com/news/full-transcripts-police-reports-calls-night-itaewon-disaster-revealed/>.
- Sports Grounds Safety Authority. "Guide to Safety at Sports Grounds: 'Green Guide.'" Accessed March 29, 2021. <https://sgsa.org.uk/greenguide/>.

- Still, G. Keith. “Crowd Density—Moving Crowds.” *Crowd Safety and Crowd Risk Analysis* (blog), June 9, 2018. <https://www.gkstill.com/Support/crowd-flow/MovingDensity.html>.
- . “Crowd Dynamics.” PhD diss., University of Warwick, 2000. https://www.gkstill.com/Support/Links/Documents/2000_still.pdf.
- . *Introduction to Crowd Science*. London: CRC Press, 2014. <https://doi.org/10.1201/b17097>.
- Texas Music Office. “Governor Greg Abbott’s Texas Task Force on Concert Safety—April 2022 Report.” April 19, 2022. <https://gov.texas.gov/music/page/governor-abbotts-texas-task-force-on-concert-safety-april-2022-report>.
- Texas Task Force on Concert Safety. *Report from the Texas Task Force on Concert Safety*. Austin: Texas Task Force on Concert Safety, 2022. https://gov.texas.gov/uploads/files/press/2022_Report_Texas_Task_Force_on_Concert_Safety.pdf.
- TMZ. “Astroworld Security Guard Felt Unprepared, Training Day before Festival.” November 9, 2021. <https://www.tMZ.com/2021/11/09/astroworld-security-guard-felt-unprepared-training-day-before-festival/>.
- U.S. Travel Association. “The Impact of Sports on the Travel Industry.” Washington, DC: U.S. Travel Association, 2019. https://www.ustravel.org/system/files/media_root/document/2019_Sports-Travel_07.11.19.pdf.
- Vera, Amir, Natasha Chen, Rosa Flores, Stephanie Becker, and Paul Vercammen. “Astroworld Investigation: Medical Staff at Astroworld Responded to 11 Cardiac Arrests at the Same Time, CEO of Medic Company Says.” CNN, November 16, 2021. <https://www.cnn.com/2021/11/15/us/astroworld-paradocs-medic-company-cardiac-arrests/index.html>.
- . “Medical Staff at Astroworld Responded to 11 Cardiac Arrests at the Same Time, CEO of Medic Company Says.” CNN, November 16, 2021. <https://www.cnn.com/2021/11/15/us/astroworld-paradocs-medic-company-cardiac-arrests/index.html>.
- Washington Post. “Most of the Dead Astroworld Festival Victims Were in One Highly Packed Area. YouTube, November 24, 2021. Video, 13:38. <https://www.youtube.com/watch?v=LGXwJnZSIkQ>.
- Wood, Ryan. “Astroworld Timeline: How Tragedy Unfolded at Travis Scott Concert.” ABC Dallas, November 9, 2021. <https://www.wfaa.com/article/news/local/how-did-the-astroworld-travis-scott-tragedy-happen-heres-a-timeline-before-during-and-after/287-3beb1e52-1328-444c-aa84-8d737c015179>.

Working with Crowds. “Compression Asphyxia.” Accessed January 8, 2023. <https://www.workingwithcrowds.com/compression-asphyxia/>.

———. “1979: The Who Concert Tragedy.” Accessed January 21, 2023. <https://www.workingwithcrowds.com/1979-the-who-concert-tragedy/>.

———. “The Victoria Hall Disaster 1883.” Accessed January 1, 2023. <https://www.workingwithcrowds.com/1883-the-victoria-hall-disaster-sunderland/>.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
Ft. Belvoir, Virginia
2. Dudley Knox Library
Naval Postgraduate School
Monterey, California



DUDLEY KNOX LIBRARY

NAVAL POSTGRADUATE SCHOOL

WWW.NPS.EDU

WHERE SCIENCE MEETS THE ART OF WARFARE