



HARRIS COUNTY OFFICE OF HOMELAND SECURITY & EMERGENCY MANAGEMENT (HCOHSEM) INFORMATION MANAGEMENT ANALYSIS

**EXECUTIVE MASTER OF PUBLIC SERVICE AND
ADMINISTRATION, HOMELAND SECURITY CAPSTONE
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HCOHSEM Information Management Analysis Capstone Project

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Abstract

The Harris County Office of Homeland Security and Emergency Management (HCOHSEM) is faced with a significant challenge in managing the flow of information during emergencies. This research project examines how HCOHSEM utilizes the five components of the information cycle based on the following research questions:

1. What opportunities exist to improve the information management process within HCOHSEM to maximize emergency notification delivery and citizen protective action?
2. How do we apply automation to make the information collection processing more efficient within HCOHSEM?
3. How do we maximize the integration of information sources to promote timely analysis and coordination?
4. How do we use social sciences to craft notifications for more effective dissemination to the public?
5. How can we more effectively incorporate near real-time feedback into the reassessment process?

This project generated 13 recommendations for HCOHSEM by employing an Action Research model using Purposeful Design. It also observed the occurrence and first stages of response by HCOHSEM to Hurricane Harvey. First-hand information and lessons learned from the response to Hurricane Harvey are incorporated into this project and its recommendations. Incorporating this information also helps pave the way for additional research opportunities, especially the unprecedented community response to the disaster. The recommendations provide a range of

options for HCOHSEM to implement in order to improve their information management and the emergency notification process during emergency management operations.

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List of Abbreviations

AIIM	Association for Information and Image Management
APIO	Assistant Public Information Officer
ASL	American Sign Language
CAP	Common Alerting Protocol
CERC	Crisis and Emergency Risk Communication
COP	Common Operating Picture
DHS	Department of Homeland Security
EAS	Emergency Alert System
EEI	Essential Elements of Information
EMI	Emergency Management Institute
EOC	Emergency Operations Center
FB	Facebook
FEMA	Federal Emergency Management Agency
FWS	Flood Warning System
GIS	Geographic Information System
HCFCF	Harris County Flood Control District
HCOHSEM	Harris County Office of Homeland Security and Emergency Management
HSC	Homeland Security Council
HSM	Heuristic-systematic Model
HSPD	Homeland Security Presidential Directive
IC	Incident Commander

IDCN	Interorganizational Disaster Coordination Networks
IEEE	Institute of Electrical and Electronics Engineers
IoE	Internet of Everything
IoT	Internet of Things
IPAWS	Integrated Public Alert and Warning System
IT	Information Technology
IWT	Integrated Warning Teams
JIC	Joint Information Center
JICAAR	Joint Information Center After Action Report
NERRTC	National Response and Rescue Training Center
NEWS	Neighborhood Early Warning System
NG911	Next Generation 911
NIMS	National Incident Management System
NOAA	National Oceanic and Atmospheric Administration
NPG	National Preparedness Goal
NPS	National Preparedness System
NRF	National Response Framework
NRP	National Response Plan
NWS	National Weather Service
OEM	Office of Emergency Management
PIO	Public Information Officer
RJIC	Regional Joint Information Center

SAME	Specific Area Message Encoding
SOG	Standard Operating Guidelines
SOP	Standard Operating Procedures
STEAR	State of Texas Emergency Assistance Registry
TAMIO	Texas Association of Municipal Information Officers
VOST	Virtual Operations Support Team

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Introduction

The Harris County Office of Homeland Security and Emergency Management (HCOHSEM) requested a research project to develop “timeless principles” which could be applied to the information management process in emergency management.¹ Specifically, this team focused its research on how HCOHSEM can effectively and efficiently find the nuggets of information in a vast sea of data, and make that information available to the appropriate audiences.² Emergency managers are charged with making “high-impact, high-consequence decisions in a condensed time frame.”³ Previously, these decisions would be made with little to no information, but today, emergency managers are inundated with information via social media, traditional news outlets, and various other sources.⁴ The information available to emergency managers exceeds their ability to sift through and find the “nuggets” of truth-data to use in their decision-making matrix.⁵ Ultimately, emergency managers must have a process by which they can automate capturing those vital bits of information, integrate how it is shared, and effectively deliver it to the citizens of Harris County using social sciences to produce the appropriate citizen protective action against the threat. After reviewing the client’s request for research, and meeting with a HCOHSEM representative to clarify the focus of this project, the research team generated five questions, which were subsequently approved by the representative:

1. What opportunities exist to improve the information management process within HCOHSEM to maximize emergency notification delivery and citizen protective action?

¹ Wheeler, Bill. 2017. Personal Interview. June 28. College Station: Texas A&M University.

² Harris County Office of Homeland Security and Emergency Management. 2017. “Client Input.” In conjunction with Texas A&M University.

³ HCOHSEM. “Client Input.”

⁴ HCOHSEM. “Client Input.”

⁵ HCOHSEM. “Client Input.”

2. How do we apply automation to make the information collection processing more efficient within HCOHSEM?
3. How do we maximize the integration of information sources to promote timely analysis and coordination?
4. How do we use social sciences to craft notifications for more effective dissemination to the public?
5. How can we more effectively incorporate near real-time feedback into the reassessment process?

Harris County boasts the largest population in the State of Texas with an estimated population of 4.7 million residents, representing the most ethnically diverse large metropolitan area in the country.⁶ Harris County's demographics demonstrate a diverse blend of socioeconomic characteristics that make the county unique. Harris County is an ever-expanding economic hub of oil refineries, ports, hospitals, and other assets vital to the economic success of the state, region, and nation. This poses a significant challenge in terms of critical infrastructure protection and emergency management. In addition, Harris County's proximity to the Gulf of Mexico, along with its many areas of low elevation, make it particularly vulnerable to tropical storms, hurricanes, and flooding. It is the responsibility of the Harris County Office of Homeland Security and Emergency Management (HCOHSEM), the county's chief agency for emergency management response, to prepare the county and its residents for a wide range of potential threats, both natural and man-made.⁷

⁶ Kever, Jeannie. 2012. "Houston region is now the most diverse in the U.S." *Houston Chronicle*, March 5.

<http://hcohsem.orghttp://www.chron.com/news/houston-texas/article/Houston-region-is-now-the-most-diverse-in-the-U-S-3384174.php> (July 25, 2017).

⁷ Harris County Office of Homeland Security and Emergency Management. 2017. "Harris County Office of Homeland Security and Emergency Management."

<http://hcohsem.org> (October 13, 2017).

The overall mission of HCOHSEM is to protect the lives and property of those who make Harris County their home from the effects of these disasters.⁸ HCOHSEM has established itself as a national leader in emergency management, yet the office recognizes that technological advancements and citizen expectations necessitate continuous improvement in the organization's emergency management activities and its methods. This research project examines HCOHSEM's current doctrines and practices in the field of Emergency and Disaster Management and compares them to best practices in the industry. Through an Action Research methodology, this paper focuses on improving the flow of information to and from HCOHSEM before, during, and after an emergency. By employing a Purposeful Design based on purposive sampling, this project examines and evaluates published federal doctrine governing emergency management, academic sources, case studies for emergency responses in comparable regions, and first-hand observations regarding the initial and on-going response to Hurricane Harvey. The inclusion of the response to Hurricane Harvey showcases the most current practices and procedures of HCOHSEM.

The information management process will focus on four major components as described by the FEMA information cycle:

⁸ HCOHSEM. "Harris County Office of Homeland Security and Emergency Management."

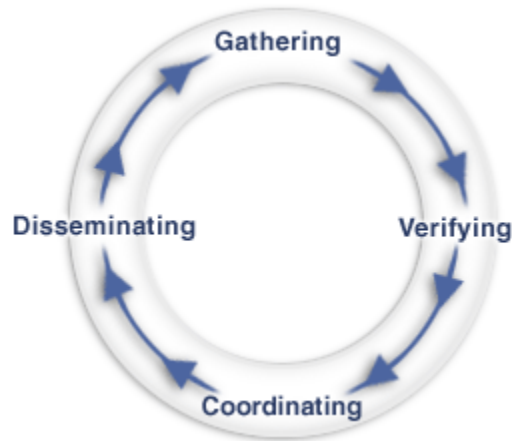


Figure 1. The public information cycle.⁹

This cycle provides a template from which the project could be divided into several functional components:

- Human Behavior and Response,
- Emergency Message Crafting,
- Feedback of Response,
- Automation,
- The Internet of Things,
- Information Push and Pull, and
- Integration and Information Management.

These components were analyzed as potential contributors or partial solutions to the client-described information management challenge, recognizing there is no single answer to the problem. These focus areas formed the basis of the five research questions for this project.

Lastly, this report concludes with recommendations for potential improvements to HCOHSEM regarding emergency management communications. These recommendations cover a broad gamut of potential courses of action. The overarching goal of this research project is to further arm HCOHSEM with the tools it needs to critically evaluate how the organization is

⁹ Emergency Management Institute (EMI). *n.d. IS-702.A – NIMS Public Information*. Emmitsburg, MD: Federal Emergency Management Agency. <https://emilms.fema.gov/IS702A/PIOsummary.htm> (August 25, 2017).

conducting emergency operations and to ensure that it remains as adaptable as possible by integrating new innovations and technologies in emergency management. This will help HCOHSEM to optimize their information management process for maximum effect in an emergency situation, thereby strengthening the county's ability to quickly and efficiently notify its residents of emergency situations. In turn, this will ultimately save lives.

Literature Review

Policy and Doctrine

On February 28, 2003, President George W. Bush signed Homeland Security Presidential Directive-5, *Management of Domestic Incidents*, into effect. HSPD-5 was developed “to enhance the ability of the United States to manage domestic incidents by establishing a single, comprehensive national incident management system.”¹⁰ This policy directed the development and administration of the National Incident Management System (NIMS) and the National Response Plan (NRP), the latter of which has since evolved into the National Response Framework (NRF).^{11 12} HSPD-5 established the Secretary of Homeland Security as “the principal Federal official for domestic incident management,” and stated that, concerning domestic incidents, “the United States Government treats crisis management and consequence management as a single integrated function.”¹³ In addition to unifying response efforts, HSPD-5 serves to define the scope for when Federal resources should be utilized in response to terrorist attacks, major disasters, or other emergencies. Federal resources are made available for use in incident response when one of the following four conditions exists:

1. A Federal department or agency acting under its own authority has requested the assistance of the Secretary.
2. The resources of State and local authorities are overwhelmed, and Federal assistance has been requested by the appropriate State and local authorities;

¹⁰ Bush, George W. 2003. *Homeland Security Presidential Directive/HSPD-5—Management of Domestic Incidents*. February 28. Washington, D.C.: Government Publishing Office. <https://www.gpo.gov/fdsys/pkg/PPP-2003-book1/pdf/PPP-2003-book1-doc-pg229.pdf> (August 25, 2017). 229.

¹¹ U.S. Department of Homeland Security. 2008. *National Incident Management System*. Washington: Department of Homeland Security.

¹² U.S. Department of Homeland Security. 2016. *National Response Framework*. Washington: Department of Homeland Security.

¹³ Bush. *HSPD-5*. 230.

3. More than one Federal department or agency has become substantially involved in responding to the incident.
4. The Secretary has been directed to assume responsibility for managing the domestic incident by the President.¹⁴

HSPD-5 also serves to recognize the significant role private and non-governmental sectors play in emergency response.¹⁵ HSPD-5 emphasizes building partnerships and relationships to facilitate the response efforts by government, non-governmental, and private entities.

Along with issuing policy guidance, HSPD-5 tasked the Secretary of Homeland Security with developing, submitting for review, and administering a National Incident Management System (NIMS).¹⁶ NIMS provides a guide or template for agencies at all levels of government “to prevent, protect against, respond to, recover from, and mitigate the effects of incidents.”¹⁷ This system may be applied independently of the cause, size, location, or complexity of an event.¹⁸ NIMS represents the collaborative approach, which includes personnel and resources from:

- Multiple jurisdictions,
- A combination of specialties or disciplines,
- Several levels of government,
- Nongovernmental organizations, and
- The private sector.¹⁹

This system represents the doctrinal agreements between the various levels of government, organizations, and entities, which are all integral to response management.

¹⁴ Bush. *HSPD-5*.

¹⁵ Bush. *HSPD-5*.

¹⁶ Bush. *HSPD-5*.

¹⁷ DHS. *NIMS*. i.

¹⁸ DHS. *NIMS*.

¹⁹ Emergency Management Institute (EMI). *n.d. IS-700.A – National Incident Management System (NIMS), An Introduction*. Emmitsburg, MD: Federal Emergency Management Agency.

<https://emilms.fema.gov/IS700aNEW/NIMS01summary.htm> (August 25, 2017).

Additionally, NIMS is scalable, so it is applicable for any incident (from day-to-day emergencies to large-scale disasters).²⁰ It is important to note that while NIMS provides a basis for emergency response, it is not a response plan in and of itself, nor a command and control chart,²¹ nor a static system.²² In fact, the composition of NIMS lends itself to change, and best practices along with lessons learned are constantly incorporated into the system's architecture. For example, NIMS was constructed in 2004, but was revised in 2008 to include important lessons learned from significant emergency events.²³ NIMS has five components which encompass all aspects of emergency management:

- Preparedness,
- Communications and Information Management,
- Resource Management,
- Command Management, and
- Ongoing Management and Maintenance.²⁴

HSPD-5 also made the adoption of NIMS a federal requirement, to the extent permitted by law, to be eligible to receive federal assistance through grants and contracts.²⁵ NIMS represents groundbreaking standardization in the dynamic environment of emergency management. The structures, preparedness concepts, and interoperability principles outlined in NIMS form the core competencies of the emergency management enterprise.

In 2008, the first National Response Framework (NRF) replaced the NRP. The NRF incorporated the best practices of the NRP and also included lessons learned from Hurricane

²⁰ DHS. *NIMS*.

²¹ DHS. *NIMS*.

²² EMI. *IS-700.A - National Incident Management System (NIMS), An Introduction*.

²³ EMI. *IS-700.A - National Incident Management System (NIMS), An Introduction*.

²⁴ EMI. *IS-700.A - National Incident Management System (NIMS), An Introduction*.

²⁵ Bush. *HSPD-5*.

Katrina and other incidents.²⁶ Unlike NIMS, the NRF is a guide to “how the Nation responds to all types of disasters and emergencies.”²⁷ The NRF “is always in effect and describes the doctrine under which the Nation responds to incidents.”²⁸ Like NIMS, the NRF is also scalable, flexible, and adaptable to create an all-hazards approach to emergency management by integrating all levels of government, incorporating all response entities, and coordinating response efforts.²⁹ The doctrines, roles, and procedures outlined in NIMS form the basis for the NRF, as such, “the response protocols and structures described in the NRF align with NIMS.”³⁰ Furthermore, the five doctrinal components of NIMS support the response framework. These components are vital to response operations because they stress six essential elements of incident management:

1. Developing a single set of objectives,
2. Using a collective, strategic approach,
3. Improving information flow and coordination,
4. Creating a common understanding of joint priorities and limitations,
5. Ensuring that no agency’s legal authorities are compromised or neglected, and
6. Optimizing the combined efforts of all participants under a single plan.³¹

The core competencies and structures created from the interaction between NIMS and the NRF form the guiding principles of emergency response. The NRF explicitly states, “The priorities of response are to save lives, protect property and the environment, stabilize the

²⁶ DHS. *NRF*.

²⁷ DHS. *NRF*.

²⁸ DHS. *NRF*. i.

²⁹ DHS. *NRF*. i.

³⁰ DHS. *NRF*. 3.

³¹ DHS. *NRF*.

incident, and provide for basic human needs.”³² To this end, five guiding principles form the fundamental doctrine for emergency response:

1. Engaged Partnership
2. Tiered Response
3. Scalable, Flexible, and Adaptable Operational Capabilities
4. Unity of Effort through Unified Command
5. Readiness to Act³³

These principles inform the various components of the NRF through defining roles and responsibilities to coordinating structures and integration. There are several significant doctrinal references other than the templates outlined in NIMS and the response framework described in NRF. Individual framework documents exist for each of the additional core capabilities of disaster response, in addition to Response: Prevention, Protection, Mitigation, and Disaster Recovery.³⁴ These materials form the core of the National Preparedness System (NPS), which is the process employed to build, sustain, and deliver essential capabilities to achieve the objectives outlined in the National Preparedness Goal (NPG).³⁵

The NPG was established by HSPD-8 on 17 December 2003, as a companion to HSPD-5.³⁶ HSPD-8 stated “the Secretary [of Homeland Security] will submit the national preparedness goal to me [the President] through the Homeland Security Council (HSC) for review and

³² Emergency Management Institute (EMI). *n.d. IS-230.c – Fundamentals of Emergency Management*. Emmitsburg, MD: Federal Emergency Management Agency. <https://emilms.fema.gov/IS230c/FEMsummary.htm> (August 25, 2017).

³³ DHS. *NRF*.

³⁴ U.S. Department of Homeland Security. 2016. *Overview of the National Planning Frameworks*. Washington, D.C.: Department of Homeland Security.

³⁵ U.S. Department of Homeland Security. 2015. *National Preparedness System*. Washington, D.C.: Department of Homeland Security.

³⁶ Bush, George W. 2003. “Homeland Security Presidential Directive/HSPD-8—National Preparedness.” *Public Papers of the Presidents*. December 17. <https://www.gpo.gov/fdsys/pkg/PPP-2003-book2/pdf/PPP-2003-book2-doc-pg1745.pdf> (August 25, 2017).

approval.”³⁷ HSPD-8 specifically contained the intent of establishing measurable readiness priorities and targets that also includes metrics, standards, and assessment strategies to evaluate the Nation’s overall preparedness to respond to major events.³⁸ The NPG explains that “preparedness is the shared responsibility of our entire nation,” and the national goal is:

“A secure and resilient Nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from threats and hazards that pose the greatest risk.”³⁹

These pieces work hand-in-hand to form the Nation’s core doctrine for emergency management: The NPG outlines the direction; the NPS describes the core components for how to achieve the NPG; NIMS provides the template for how incident management should occur, and the NRF, a subset of the NPS, provides a plan specifically for incident response. These documents constitute the foundation for the “whole community”⁴⁰ approach to emergency management and are fundamental to understanding the real-world practices of emergency management agencies.

HCOHSEM is the principal emergency management entity for the greater Houston area. Harris County encompasses more than 4.7 million residents in 34 cities and has 57 fire departments, 125 law-enforcement agencies, and more than 1,200 municipal and public utility districts.⁴¹ With all of these separate organizations potentially playing a role during a major

³⁷ Bush. *HSPD-8*. 1747.

³⁸ Bush. *HSPD-8*.

³⁹ U.S. Department of Homeland Security. 2015. *National Preparedness Goal*. Washington, D.C.: Department of Homeland Security. 1.

⁴⁰ EMI. *IS-230.c – Fundamentals of Emergency Management*.

⁴¹ Harris County Office of Homeland Security and Emergency Management. 2016. *2016 Annual Report*. Houston: Harris County Government.

http://prepare.readyharris.org/Portals/24/Documents/2016_HCOHSEM_AR.pdf?ver=2017-06-%2019-181208-%20420 (July 20, 2017). 9.

disaster or incident, it is imperative that agencies “speak the same language.” Underlying contracts, memorandums of understanding, and standard operating procedures/guidelines (SOP/SOGs) are in effect to pre-coordinate response efforts. By conforming to the doctrinal requirements described by NIMS and implementing the core competencies detailed by the NPS, Harris County can ensure the nation’s third most populous county is prepared, as a whole community, to prevent, protect against, mitigate, respond to, and recover from threats and hazards.⁴²

Finally, conformance to the published doctrine is crucial to receiving and employing federal aid and resources to assist in emergency response if local resources are insufficient to handle the response efforts. Therefore, it is necessary to fully understand and evaluate the practices described in the standard operating guidelines (SOGs) used by HCOHSEM through the doctrinal lens and to ensure their best practices conform to published guidelines. It is also important that doctrine does not stifle the ability to incorporate new lessons learned.



⁴² HCOHSEM. *Annual Report*. 9.

Figure 2. Directives of Doctrine.⁴³



Figure 3. NPG and NPS.⁴⁴

Human Behavior and Response

The proximity of Harris County to the Gulf of Mexico makes it vulnerable to tropical storms and hurricanes, though severe weather events like flash floods and winter storms impact the area more frequently. HCOHSEM has the challenging task of planning, coordinating, and implementing all of the homeland security and emergency management related activities for the more than 4.7 million residents that live in the county. The large number of people residing in the county represents the most ethnically diverse large metropolitan area in the country.⁴⁵ Effective emergency notification must attempt to predict human behavior to inform residents and to begin taking protective action. This process recognizes that people need detailed information as early

⁴³ Hendrickson, Andrew. 2008. "National Incident Management System." *Region 10 NIMS NRF Workshop 2008*. Bothell, WA: Federal Emergency Management Agency. https://nwtemc.org/documents/2008_NWTEMC_Conf/presentations/FY%202008%20Tribal%20NIMS%20Overview%20Briefing.ppt (August 25, 2017).

⁴⁴ EMI. *IS-230.c – Fundamentals of Emergency Management*.

⁴⁵ Kever, Jeannie. 2012. "Houston region is now the most diverse in the U.S." *Houston Chronicle*, March 5. <http://www.chron.com/news/houston-texas/article/Houston-region-is-now-the-most-diverse-in-the-U-S-3384174.php> (July 25, 2017).

as possible to initiate and inform their response. The availability of warning information encourages people to accept the emergency procedures and to improve their familiarity with the required response.⁴⁶

Accurately predicting this response can be an extreme challenge given the reaction to a crisis or catastrophic event varies considerably from person to person. Human response to disasters and emergencies can be characterized as a decision-making process that involves people receiving information from their environment, interpreting it according to new and previously held information, and responding based on how they understand the situation from the information.⁴⁷ This process is greatly influenced by the conditions faced during the event along with the experiences and personal attributes of the residents involved. These elements combine to form the decision-making process and the individual's response.⁴⁸ The wide range of experiences and personal attributes represented in the large and diverse metropolitan area of Harris County make it a challenge for HCOHSEM to predict how all of the county's residents will respond to an event. Understanding the factors that influence human response can help HCOHSEM to craft more effective notifications that inform this decision-making process. To this end, it is critical for emergency management officials provide accurate, credible information and avoid an information vacuum.

⁴⁶ Kuligowski, Erica D., Steven M. V. Gwynne, Kathryn M. Butler, Bryan L. Hoskins, and Carolyn R. Sandler. 2012. *Developing Emergency Communication Strategies for Buildings*. Washington, D.C.: U.S. Department of Commerce.
http://ws680.nist.gov/publication/get_pdf.cfm?pub_id=910248 (August 23, 2017). 3.

⁴⁷ Lindell, Michael K., and Ronald W. Perry. 2004. *Communicating Environmental Risk in Multiethnic Communities*. Thousand Oaks: Sage Publications.

⁴⁸ Omori, Hidemi, Erica D. Kuligowski, Kathryn M. Butler, and Steven M. V. Gwynee. 2017. "Human Response to Emergency Communication: A review of guidance on alerts and warning messages for emergencies in buildings." *Fire Technology* (53): 1641-1668. Springer Science (August 22, 2017). 1645.

It is essential to examine three topics that help with understanding human response: threat denial; the social processes associated with warnings; and the characteristics of those receiving the messages. One key principle to understand when crafting emergency messages to warn the public of a disaster is the initial response to any warning is denial.⁴⁹ Many people tend to deny that an emergency or disaster is a personal threat until they are affected by it. Part of this is due to a tendency referred to as “normalcy bias.” Normalcy bias causes people to underestimate the possibility of a disaster occurring and its possible effects, which results in situations where people fail to prepare for a disaster adequately.⁵⁰ The Gulf Coast is constantly threatened with natural disasters, but a relatively small number of incidents affect the vast majority of Harris County residents annually. As residents become predisposed to expecting to remain unaffected following extended periods without incident, threat denial becomes entrenched in the psyche of residents.⁵¹

Warnings become social processes since groups, rather than individuals, are likely to process most disaster warnings.⁵² When citizens receive warning messages regarding emergency situations, the first response is to talk to those around them and to reach out to family and friends to fully comprehend the warning. Warning message emails from HCOHSEM stress the importance of family emergency plans and instruct individuals to “discuss evacuation plans with your family.”⁵³ Understanding warning information becomes a social process to determine the

⁴⁹ Drabek, Thomas E. 1999. “Understanding disaster warning responses.” *Social Science Journal* (36:3). Business Source Ultimate. (August 22, 2017).

⁵⁰ Korn, Denis. 2011. “Normalcy Bias – Why People are Attached to Inaction.” <http://learntoprepare.com/2011/05/normalcy-bias-why-people-are-attached-to-inaction> (August 22, 2017).

⁵¹ Korn. “Normalcy Bias – Why People are Attached to Inaction.”

⁵² Drabek. “Understanding disaster warning responses.”

⁵³ HCOHSEM. 2017. *Personal correspondence*.

validity and impact of the information and to build consensus on a plan for response. Groups rarely reach an immediate consensus on what should be done, so beyond denial, there is often debate. The danger in this is emergency management professionals at HCOHSEM, and lay people within the community, may have different perceptions of what information is relevant, important, or what actions are appropriate to take.

One of the most difficult of the three areas to consider when crafting a warning is the diversity of the target audience receiving the message. When HCOHSEM crafts warning messages, it must take into account receiver characteristics such as the range of experiences found in the population, age, ethnicity, and income levels. Previous experiences will influence individual response to the message. For example, residents who were impacted by Hurricane Ike in 2008 will be more likely to heed evacuation warnings issued before the expected arrival of a hurricane.

On the other hand, life experience can also negatively impact warning response as older persons may feel that they have “seen it all” and will react more slowly than younger persons.⁵⁴ In addition to having a different perspective than younger members of the population, the elderly have unique needs that must be taken into account by emergency managers. HCOHSEM must also plan to serve Harris County's growing racial and ethnic communities. Language barriers, especially for Asian Americans and Hispanic Americans (the two largest minority groups in Harris County), must be addressed by HCOHSEM to ensure messages, instructions, evacuation,

⁵⁴ Drabek. “Understanding disaster warning responses.”

disaster claims information, sheltering, and assistance reaches these communities.⁵⁵ Minorities and immigrants may also be reluctant to trust official warnings based on generations of life experiences with authorities. Poorer people also evidence delays in warning responses for similar reasons – officials may be perceived as having lower credibility and might be less trusted.⁵⁶

These are some of the contributing factors, which influence the human response to a disaster and the decision-making processes that distinguish between important and unimportant pieces of information. Factors such as threat denial, social processes, and receiver characteristics influence this process. People receive information from their external environment, interpret it according to new and previously held information, then respond based on their unique interpretation of the situation formed from this information. Human response is dependent upon the conditions faced during the incident as well as the experiences and personal attributes of those involved.⁵⁷ All of this combines to influence the decision-making process and the subsequent response. This process is depicted in Figure 3.

⁵⁵ Federal Emergency Management Agency. 2011. *U.S. Demographic Shifts*. Washington, D.C.: FEMA.

https://www.fema.gov/pdf/about/programs/oppa/demography_%20paper_051011.pdf (August 23, 2017). 4.

⁵⁶ Drabek. “Understanding disaster warning responses.”

⁵⁷ Omari, *et al.* “Human Response to Emergency Communication: A review of guidance on alerts and warning messages for emergencies in buildings.”

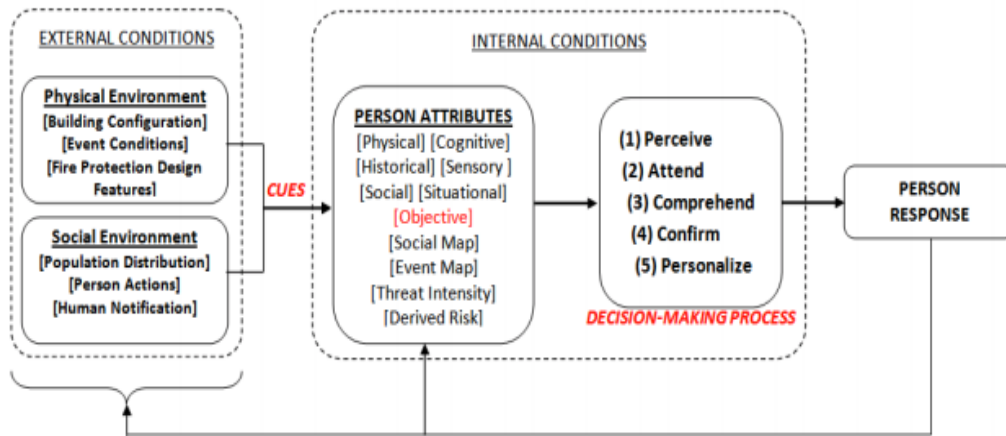


Figure 3. Simplified Decision-making Process.⁵⁸

Emergency Message Crafting

Knowing the audience is one of the key elements factoring into effective message development. Understanding how people receive the message and how they perceive the threat can provide insight into how they will respond. Race and gender, along with mechanisms for dissemination, are important characteristics to consider in message development. A 2012 study conducted in Verona, Missouri found that the local Hispanic Spanish speaking population received emergency information from the Honduran priest at their church.⁵⁹ Comprehensive understanding of the target audience is not just estimating how people will react, but also approximating the decision-making process used to rationalize their decisions.⁶⁰ Understanding “how race, gender, life circumstances, and communications” affect perspectives in disasters is

⁵⁸ Kuligowski, *et al.* “Developing Emergency Communication Strategies for Buildings.” 3.

⁵⁹ Donner, William R. 2012. “Tornado Warnings in Three Southern States: A Qualitative Analysis of Public Response Patterns,” *Journal of Homeland Security and Emergency Management* 9(2). EBSCOhost (August 22, 2017).

⁶⁰ Vermeulen, Karla. 2014. “Understanding Your Audience: How Psychologists Can Help Emergency Managers Improve Disaster Warning Compliance.” *Homeland Security & Emergency Management* 11(3): 309-315.

vital to reaching the intended audience.⁶¹ Additionally, understanding how people receive their information along with how they perceive the threat and risk informs emergency managers on the best approach for crafting and disseminating a warning message.

Message crafting is of particular interest to HCOHSEM; specifically, what information should be contained in an emergency message, as well as when it should be broadcast to the public. One such example is determining the best time to issue an evacuation alert to maximize its effect on the intended population. In light of this need for information, current research is being conducted to determine how people respond to warnings and the point at which they take action.⁶² Emergency managers would benefit from understanding the thought process or decision-making process that leads to people's "cycle of denial or confirmation bias."⁶³ Understanding the psychological aspect of the audience will aid in the emergency manager's ability to make better decisions in developing their message and the triggers associated with its broadcast. The psychology of "understanding of persuasive communication" can have significant application to emergency management and how authorities can improve response to issued alerts.⁶⁴ Additionally, when delivering the message, it is vital for the message be clear, timely, and well publicized.^{65 66}

⁶¹ West, Darrell M., and Marion Orr. 2007. "Race, Gender, and Communications in Natural Disasters." *The Policy Studies Journal* 35(4): 569-586. EconLit (August 21, 2017).

⁶² Cova, Thomas J., P.E. Dennison, D. Li, F. A. Drews, L. K. Siebeneck, and K. M. Lindell. 2017. "Warning Triggers in Environmental Hazards: Who Should be Warned to do What and When?" *Risk Analysis* 37(4): 601-611. Scopus (August 22, 2017).

⁶³ Vermeulen. "Understanding Your Audience: How Psychologists Can Help Emergency Managers Improve Disaster Warning Compliance." 312.

⁶⁴ Vermeulen. "Understanding Your Audience: How Psychologists Can Help Emergency Managers Improve Disaster Warning Compliance." 310.

⁶⁵ West, *et al.* Race, Gender, and Communications in Natural Disasters. 580.

⁶⁶ Vermeulen. "Understanding Your Audience: How Psychologists Can Help Emergency Managers Improve Disaster Warning Compliance." 314.

Additional factors play into communicating with the public through emergency messaging. Barriers to communication often interfere with the communication process. Generational experience with authorities in ethnic communities has created mistrust with official message sources resulting in “empirical findings of delay and resistance to evacuate become interpretable within a larger pattern of social constraint.”⁶⁷ This lends greater credence that emergency managers must find a way to build credibility when crafting messages to overcome these barriers of denial and confirmation bias. It is important to “understand how various groups process information and react to disaster warnings” in order to craft messages that produce the intended response.⁶⁸ Failure to do so can lead to massive loss of life, disruption in people’s personal lives, and dramatic political consequences.⁶⁹

Disaster communication is more than the emergency manager sending out a warning, activating sirens, or prompting the national emergency broadcast system. Technology has drastically changed how messages get delivered. The advent of social media, cell phones, and other devices provides HCOHSEM with a multitude of platforms that provide the opportunity to reach a large number of people very quickly.

Feedback of Response

The robustness inherent to the information flow from HCOHSEM allows for a complete and thorough review of emergency messages to be conveyed to the public. This flow is facilitated through a network of partnerships including the National Weather Service (NWS),

⁶⁷ Drabek. “Understanding disaster warning responses.”

⁶⁸ West, *et al.* “Race, Gender, and Communications in Natural Disasters.” 582.

⁶⁹ West, *et al.* “Race, Gender, and Communications in Natural Disasters.” 582.

Harris County Flood Control District (HCFCD), and the Flood Warning System (FWS).⁷⁰

Communication during an emergency event and throughout the recovery process can be complicated to manage. “Standard all-hazards emergency preparedness risk and response communications efforts do not always reach people with barriers relating to literacy, language, culture, or disability.”⁷¹ For example, dealing with the deaf and hard of hearing community is challenging during an emergency. This is a significant problem since there are 32 million deaf people, and one out of every five people living in the United States are characterized as hard of hearing. An additional 90 million Americans have low-literacy skills. It is beneficial to use a participatory, community-directed approach to improve all-hazards preparedness.⁷² Whether or not a message is received and understood directly related to the following actions they take. DeafHope, a non-profit group specializing in assisting the deaf and hard-of-hearing population, conducted training for the Oakland Police Department on the best methods for interacting with the Deaf community. The results of the training were very positive; there was a marked improvement from pretest to posttest results in attitudes and communication strategies.⁷³

⁷⁰ Harris County Office of Homeland Security and Emergency Management. 2016. *2016 Annual Report*. Houston: Harris County Government.
http://www.readyharris.org/Portals/43/PDFs/2017/2016_HCOHSEM_AR_web.pdf?ver=2017-06-15-085326-637 (July 17, 2017).

⁷¹ Engelman, Alina Anna. 2012. *Addressing Disparities in Emergency Communication with the Deaf and Hard-of-Hearing: Cultural Competence and Preparedness for First Responders*. Berkeley: University of California.
http://digitalassets.lib.berkeley.edu/etd/ucb/text/Engelman_berkeley_0028E_12184.pdf (July 7, 2017). 1.

⁷² Engelman. *Addressing Disparities in Emergency Communication with the Deaf and Hard-of-Hearing: Cultural Competence and Preparedness for First Responders*.

⁷³ Engelman. *Addressing Disparities in Emergency Communication with the Deaf and Hard-of-Hearing: Cultural Competence and Preparedness for First Responders*.

Multiple factors influence decisions about evacuating, including residents' age, gender, how long they have lived in their homes, and their feelings of responsibility for friends and family members who decide not to move. Often, people who remain are poor and highly vulnerable to the effects of a disaster. One of the most important factors in predicting whether or not someone will heed the warning to evacuate is previous disaster experience. Another factor to consider is the cost to evacuate such as food, fuel, and hotel costs, along with lost wages. "By understanding who is likely to obey or ignore evacuation orders, authorities can use the data to reduce the number of false alarms."⁷⁴ This emphasizes the need for public education and understanding why people may, in fact, understand the evacuation warning, but may not have the resources to self-evacuate. Another more insidious factor could be that certain segments of the population may not believe the seriousness of the event since reporters who stay in the area and report in real-time never seem to have any issues or have to be rescued.

The relationship between gathering accurate information and making timely decisions using that information is among the various problems Harris County faces during emergencies. Real-time information will be the most effective for the information's consumers, as a stale report of flooding on a now passable roadway delays traffic, while a stale report that a roadway is passable when it no longer is could be life-threatening. Accordingly, for information to be valuable in an emergency, it must reflect current circumstances facing citizens. Such a need for timeliness may discourage extensive, time-consuming efforts to corroborate data and reports, as time spent confirming begins to age the information. Alternatively, information must also be

⁷⁴ Horney, Jennifer. 2016. "Why Don't More People Evacuate Before Hurricanes?" Texas A&M Today: October 19.
<http://today.tamu.edu/2016/10/19/why-dont-more-people-evacuate-before-hurricanes>
(July 7, 2017).

accurate. Reporting that a particular roadway is impassable or passable when the opposite is correct could have grave implications. Thus, the need for information that is both as accurate as possible and disseminated in real-time creates a dichotomy of a sort.⁷⁵ Every second that is spent confirming information diminishes its timeliness and its value, while every unconfirmed message sent increases the risk of harmfully inaccurate messages reaching the public. However, the utilization of a computer application to crowd-source information may facilitate the spread of accurate information in near real-time.⁷⁶

Computer applications for use with mobile devices like smartphones and tablets may already provide the platform for use in emergency management. Mobile applications like Waze, for example, uses crowdsourced data to alert other drivers of traffic congestion, road debris, stalled vehicles, or the presence of police officers on the roadway. Further, Waze now operates its “Connected Citizens Program” whereby local governments partner with the application to send and receive data regarding traffic and related transit issues. While the use of this system has been limited in emergency management, the same tools used to report a collision-based road closure could be utilized to notify citizens of a flooding-caused road closure. Waze launched its “Connected Citizens Program,” which it calls its “data-driven partnership” in October of 2014 with ten local government partners. The success of the program has allowed its expansion to more than 100 partners including, city, state, and county government agencies around the world.

⁷⁵ Steen, Margaret. 2014. “Emergency Management: There’s an App for That.” *Emergency Management*.
<http://www.govtech.com/em/training/Emergency-Management-App.html> (August 2, 2017).

⁷⁶ Fox, Andrea. 2017. “Hyperlocal emergency Apps Streamline Emergency Management.” *Efficient Gov*.
<https://efficientgov.com/blog/2017/06/14/emergency-apps-streamline-emergency-management> (August 1, 2017).

In 2016, Waze released quantitative results to the public, documenting the various successes crowdsourcing information has provided to its government partners.⁷⁷ The report explains how their study compared the amount of time it takes for an emergency response center to make information available to first responders and the speed with which the same information appears in Waze. The study found in 70% of the instances studied, vehicle collisions that may obstruct emergency response were reported to Waze an average of four and a half minutes faster than they were to 9-1-1 or other official emergency channels. This allows first responders to plan their routes faster, potentially saving lives of ill or injured persons or allowing the capture of criminals.

Further, the State of South Carolina utilized Waze during Hurricane Joaquin, which facilitated real-time information sharing regarding over 1,000 road closures and the status of nearly 70 emergency relief shelters to more than 1.9 million Waze users in and around the impacted areas. The governments of Pennsylvania, the District of Columbia, and Kentucky used the same platform to allow inter-agency sharing during Tropical Storm Jonas. During Hurricane Matthew, which struck the southeastern United States in September and October 2016, Waze facilitated the real-time updating of emergency relief shelters, and allowed nearly 12,000 users to locate the almost 400 area shelters and then receive real-time directions to the shelters.

By combining the accuracy of multiple reports with the speed of digital data transmission, crowdsourcing may prove a reliable tool for use by emergency managers. Specifically, when integrated into emergency management, this information may allow cities to

⁷⁷ Waze. 2016. "CCP Case Studies." <https://docs.google.com/document/d/1GgYM6IDuKjuubZPe88-kkx4GGJ6279TiPxmotTNL48c/edit> (August 27, 2017).

know about floods sooner or first responders to learn of delays and allow detours to avoid them. Further, the use of such tools may also allow persons needing specific assistance, to be picked up by boat, for example, and to indicate their need for such assistance by dropping a pin on a map. These uses may only be the beginning of employing crowdsourcing techniques in the emergency management industry.

Automation

Technology is at the forefront of any modern endeavor. The tools that are available to emergency managers to help them more efficiently engage their constituency also allow for the population to be better informed and to save lives. However, one of the challenges in the communication and notification process is inherent to the use of these cutting-edge tools: the integration of automated technological resources. Individuals interpret their data uniquely during an emergency. Some may add value to one particular source over another. Sarah Vieweg, a Human-Computer Interaction, linguistics, and Social Computing researcher, discusses how people review and interpret data during an emergency.⁷⁸ In receiving information from various media sources, individuals tend to put more faith in one method of receipt over another, which suggests that people will revert to trusting more familiar sources. In her example, Vieweg's research subjects focused on their individual social media preference to allow for their notification delivery vice seeking out the primary source.

⁷⁸ Vieweg, Sarah, and Adam Hodges. 2014. "Rethinking Context: Leveraging Human and Machine Computation in Disaster Response." *Computer* 47(4): 22–27.
<http://ieeexplore.ieee.org/document/6798550> (July 24, 2017).

The challenge presented in Vieweg's case is that subjects are reliant on both the social media source and the delivery vehicle. The delivery vehicle, for instance, a mobile device or computer, is solely dependent on power and infrastructure to support it. Provided these systems remain operational before or during the event requiring notification, it is a useful tool. Emergency personnel are also able to source data from social media, querying the public postings and aggregating the data. The addition of automation and artificial intelligence into the toolset of the emergency personnel streamlines the work of emergency responders. The challenge for emergency response personnel is to fine-tune the automation to best suit their decision-making process. Automation through deployed sensors may allow for a minimization of the human factors affecting the acquisition and retention of raw data. Vieweg's data acquisition model relies on users at both the government and individual level being social media responders. Removing the human factor and focusing on automated services allows for standardizing the automated analysis. Lin and Liaw outline the utilization of remote sensing technology in a nuclear power station in China. Their analysis leads to a greater discussion on "Big Data" analysis and reporting.⁷⁹

In Harris County, automation can be applied to flood sensors to monitor water levels, road and traffic sensors to assess the flow of traffic leaving through critical choke points egressing the city and connect sensors around the regional infrastructure, including the nuclear

⁷⁹ Lin, Tzu-Husan, and Der-Cherng Liaw. 2014. "Development of an Intelligent Disaster Information-Integrated Platform for Radiation Monitoring." *Natural Hazards* 76(3): 1711–25. EBSCOHost.
<https://link.springer.com/article/10.1007/s11069-014-1565-x> (July 8, 2017).

power station in Bay City. This information sources could be used to notify the Joint Information Center and decision-making personnel on the status of the things connected to these sensors. Absent from Lin and Liaw's analysis is the consideration of tampering or loss of data. Cyber threats are a persistent concern and could result in the absence of the information in a decision-making process, leading to poor decisions resulting from incomplete data. These same cyber threats lend to an even more insidious problem: the clandestine manipulation of data, which could result in decisions made on the basis of skewed or manipulated data.

The Internet of Things

The connection of complex systems linking people to information is a developing concept. The technology necessary to accomplish this connectivity is not readily available to the users within every market or demographic. Over time, it will grow to be a common occurrence in everyday life. A digital transformation is necessary to accommodate the Internet of Things (IoT), and society has several waypoints between its current state and the point of total interconnectedness.⁸⁰ Bornheim and Fletcher discuss the impact of these technologies and emphasize the requirement that Public Safety applications be near universal.⁸¹ If they are ubiquitous vice being unique to a particular standard, they are available to more individuals and therefore more useful on a large scale. Operationally, IoT will enable agencies to introduce new data streams and enable better decision-making. Key considerations will be to understand how

⁸⁰ Bornheim, Markus, and Mark Fletcher. 2016. *Public Safety Digital Transformation: The Internet of Things (IoT) and Emergency Services*. European Emergency Number Association. http://www.eena.org/download.asp?item_id=170 (July 7, 2017).

⁸¹ Bornheim and Fletcher. *Public Safety Digital Transformation: The Internet of Things (IoT) and Emergency Services*.

the data can be applied, how to ensure that it is vetted during a crisis, and how to verify its meaning when it is finally received.

The development and integration of information sources during emergency operations is a key focus of Data Management Organizations.⁸² The focus on interoperability leads back to the earlier discussion of ubiquitous systems. If two organizations are unable to communicate with each other, or are unable to dismiss duplicate reports, their clear understanding of the event is impossible to obtain.⁸³ This interoperability and system latency prevents responders and managers from orchestrating their responses. The Internet of Everything (IoE) adds a layer of machine logic to IoT and feeds into the decision-making process.⁸⁴

This addition of a layer of machine logic plays into the addition of automation of external and remote sensors to the decision-making process. By integrating this machine logic into the process, decision makers can integrate a preprogrammed list of heuristics into their analysis. Decision-makers can integrate the automated sensors into their response and add vetting to their analysis of the program by understanding the data being ingested and how it was acquired. They will be able to process more information with minimal integration of human error. Analysis suggests that these sensors will be applied to systems and when their integration allows for multiple system integration, the decision makers are better enabled to respond.

⁸² Zdravkovic, Milan, Ovidiu Noran, Hervé Panetto, and Miroslav Trajanovic. 2015. "Enabling Interoperability as a Property of Ubiquitous Systems for Disaster Management." *Computer Science and Information Systems* 12(3): 1009–31.

<https://hal.inria.fr/hal-01142096/document> (July 28, 2017).

⁸³ Zdravkovic, *et al.* "Enabling Interoperability as a Property of Ubiquitous Systems for Disaster Management."

⁸⁴ Zdravkovic, *et al.* "Enabling Interoperability as a Property of Ubiquitous Systems for Disaster Management."

The Internet of Things is part of an innovative solution to the understanding and execution of emergency management.⁸⁵ Yang and Ling's research suggests that IoT fits the identified information requirements to supply the information necessary to understand an emergency event. Further, they suggest IoT technology adds value to emergency response operations by coordinating resources and consolidating situational awareness. Based on their research, quantitative data can be aggregated into this process and will allow for a better understanding of the qualitative information coming from other sources. Their research also highlights the value of integrating near real time data and dynamic reporting about a crisis as efficiently as possible. Further, this integration allows for easier sharing across partnerships at all administrative levels.

When considered as a resource, information is an asset. The presence or absence of any asset critical to the successful execution of an emergency response can be the key to preventing loss of life or damage to property. In this context, the Internet of Things can be a tool to enable essential communications between the public and emergency responders. Peterson suggests that the IoT can provide a minimal communication network that allows connectivity between the public and the responders.⁸⁶

Another team of researchers, Peterson and Baccelli, focused their key discussion on autonomous communication consisting of devices that work without any specific interaction from the user. These devices can relay information to responders. Having a substantial resiliency

⁸⁵ Yang, Lili, and Shuang-Hua Ling. 2013. *How the internet of things technology enhances emergency response operations*. Technological Forecasting and Social Change. <http://www.sciencedirect.com/science/article/pii/S0040162512001801> (July 6, 2017).

⁸⁶ Petersen, Hauke, and Emmanuel Baccelli. 2014. *The Role of the Internet of Things in Network Resilience*. Berlin, Germany: Freie Universitat. <https://arxiv.org/abs/1406.6614> (July 6, 2017).

in the design and operation, they will be able to provide information to managers through automated processes, saving critical time in the understanding of the data. A third researcher discusses a similar technology through automated Ad Hoc Networks.⁸⁷ Ray developed and deployed a mobile network of low/lower power transmitters around a depreciated infrastructure. These individual nodes allowed for automation of disaster reporting in difficult conditions. The challenge is the deployment of sensor and digestion of the data. Through automation and Big Data processing capabilities, the sensors would be more valuable to the emergency managers.

Deak discusses the value of adding IoT devices and integrating them with Device-Free Passive Localization.⁸⁸ He also outlines a similar approach to layered technological solutions and the integration of passive communication devices. These are similarly affected by human factors but are not without their unique challenges. Personal computers are easy to use but, they do have the potential to impact the passive location devices' ability to communicate back to emergency responders; this is a systemic problem with any consumer computing devices. Deak states that passive localization during emergency events allows for the integration of multiple collection methods and the development of micro networks. Wi-Fi, Bluetooth, Infrared, and Wireless Local Area Networks enable disaster management in the localized networks, allowing for a significant understanding of the environment around a disaster, without human interaction. Further interaction of personal and consumer electronics may impact their effectiveness. Some of the

⁸⁷ Ray, Niranjana Kumar, and Ashok Kumar Turu. 2017. "A Framework for Post-Disaster Communication using Wireless Ad Hoc Networks." *Integration, the VLSI Journal* 58: 274–85.

<http://www.sciencedirect.com/science/article/pii/S0167926016301675> (July 14, 2017).

⁸⁸ Deak, Gabriel, Kevin Curran, Joan Condell, Eleana Asimakopoulou, and Nik Bessis. 2013. "IoTs (Internet of Things) and DfPL (Device-Free Passive Localisation) in a disaster management scenario." *Simulation Modelling Practice and Theory* 35: 86–96. ScienceDirect (July 15, 2017).

goals Deak discusses are the development of active sensors which would be activated by passive sensors like cameras, pressure or flooding changes, and manual activation.

Knowles expands on the emerging trust implications for data rich systems.^{89 90} His analysis discusses the characteristics necessary for trust to be established in data systems. Their connection to decision makers allows for a significant reliance to be applied to their presence in decision-making processes. Understanding the path of the data, confirming its veracity and security, and providing it for decision-makers builds foundation of trust. If there is a lack of resiliency in the systems, the decision makers must be made aware of any potential degradation or vulnerability in the system. If they do not know what they do not know, then decision-makers may unknowingly make poor decisions. Knowles opines that this trust is a difficult thing to gain from the public and is very easy to lose.

Information Push and Pull

“Information is an essential resource during a disaster. Without information, responders cannot effectively manage a disaster, and those affected by the disaster cannot best adapt to the threats they face.”⁹¹

Steelman provides a thorough examination of information flow and communication mediums between sources and recipients before, during, and after an emergency event, as well as exploring peer-reviewed literature from several areas of study. Of particular note, Steelman

⁸⁹ Knowles, Bran. 2016. “Emerging Trust Implications of Data-Rich Systems.” *IEEE Pervasive Computing* 15(4): 76–84.

<http://ieeexplore.ieee.org/document/7676170> (July 14, 2017).

⁹⁰ Lin and Liaw. “Development of an Intelligent Disaster Information-Integrated Platform for Radiation Monitoring.”

⁹¹ Steelman, Todd A., Sarah M. McCaffrey, Anne-Lise Knox Velez, and Jason Alexander Briefel. 2015. “What Information Do People Use, Trust, and Find Useful During a Disaster? Evidence from Five Large Fires.” *Natural Hazards* 76(March): 615-34.

<https://www.nrs.fs.fed.us/pubs/47743> (August 27, 2017). 615.

examines the salience of mass media during disasters, as well as the veracity and trustworthiness of various communication mediums. To this end, “a substantial body of work has developed around public response to warnings.”⁹² However, it is highlighted that research specific to information veracity and trustworthiness is not centralized; it is sourced from several studies that span a gamut of threats to life safety, including natural disasters, health crises, water quality crisis, and threats associated with chemical facilities.

“Mass media is often found to be a highly used information source... in disaster situations.”⁹³ However, “several studies have found that the perceived tendency of television media to sensationalize stories, rather than providing specific local emergency information, reduced its usefulness and trustworthiness as an information source.”⁹⁴ Conversely, Steelman determined that information received from family, friends, and neighbors was the most used, useful, and trustworthy communication medium to receive disaster-related information. Legacy communication mediums (print, TV, and radio) are a close second, with high use and usefulness, but with only medium trustworthiness. Interestingly, social media (Twitter and Facebook, among others) were the least used and least trusted sources of information.

The body of literature also emphasizes a growing focus on the use of social media to enable emergency managers to source information from relevant social media posts and incorporate that information into the decision-making processes. Some approaches show promise in improving the ability of emergency managers to mine social media for relevant user posts,

⁹² Steelman. “What Information Do People Use, Trust, and Find Useful During a Disaster? Evidence from Five Large Fires.” 617.

⁹³ Steelman. “What Information Do People Use, Trust, and Find Useful During a Disaster? Evidence from Five Large Fires.” 618.

⁹⁴ Steelman. “What Information Do People Use, Trust, and Find Useful During a Disaster? Evidence from Five Large Fires.” 618.

including volunteer crowdsourcing, syntax analysis, and GIS integration. These approaches have marked potential in mitigating the negative impact that information overload has in the emergency management process. “So much information is now broadcast during mass emergencies that it is infeasible for humans to effectively find it, much less organize, make sense of, and act on it.”⁹⁵

The use of volunteer crowdsourcing in the emergency management process is a recently developed concept that has proved to be successful in supporting the information gathering process and combating information overload.⁹⁶ Attempting to filter and categorize the gamut of social media posts in near real time is an overwhelming task for emergency managers without ad-hoc support. Various emergency incidents examined in the literature demonstrate how the use of crowdsourced volunteers to process and categorize the troves of publicly-available data produced on social media and develop the data into actionable information during a disaster has benefited the emergency management process.

A related and more mature development in the information acquisition and dissemination process is the use of language processing technology to filter and categorize social media posts automatically.⁹⁷ Several studies identified by Hiltz and Plotnick discuss text analysis software to measure multiple aspects of a message, including subjectivity, style, and linguistic register.

“When evaluated by hand-coding of a sample of approximately 500 tweets from each of the

⁹⁵ Hiltz, Roxanne S., and Linda Plotnick. 2013. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.” Baden-Baden, Germany: International ISCRAM Conference.
<http://www.iscramlive.org/ISCRAM2013/files/114.pdf> (August 27, 2017).

⁹⁶ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.” 824.

⁹⁷ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

disasters that were categorized as “on topic” and then analyzed by their natural language, the system was able to achieve over 80% accuracy on categorizing tweets.”⁹⁸

Another technology that is being developed is collaborative filtering software. Collaborative filtering is defined as “a technique for extracting meaning from the aggregate behavior of a large number of users by using aspects of both individual and collective actions.” Of particular note, a large sample of social media posts related to a protest was analyzed by collaborative filtering software program. The program was able to successfully categorize nearly 68 percent of the social media posts as originating from the protest location. This is in stark contrast to the five percent of posts that were successfully categorized when analyzed manually.⁹⁹

GIS “geo-analytics” is another recent technological development in the information management process. GIS geo-analytics is a method to synergize social media posts with visual data (maps, photos, and graphs) to increase the event awareness of emergency managers with layered and expandable visual displays of analyzed data.¹⁰⁰ An example of this described in the literature is a “heat map” that visually depicts the frequency of various topics of social media posts and overlays that data onto a near-real-time map.¹⁰¹

While the technologies and concepts described in the research are innovative, the body of research is quick to state that these concepts are in the incipient stages of development. However,

⁹⁸ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.” 825.

⁹⁹ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.” 824.

¹⁰⁰ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

¹⁰¹ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

it is also widely accepted that social media use will continue to grow and become a primary communication medium for the public and emergency managers alike. As such, effective use of social media to collect viable disaster related intelligence and incorporate that information into the decision-making process will increase in priority moving forward.

Integration and Information Management

Integrating countless data sources is an essential element of effective and efficient disaster management.¹⁰² One of the key roles of emergency managers and homeland security professionals is connecting disparate pieces of information and forming a common situational awareness of the incident, known as the common operating picture (COP).¹⁰³ Emergency Operations Centers (EOCs) serve as a focal point for collaborating with stakeholders to perform this function.¹⁰⁴ An essential component to EOCs when performing this function is the Joint Information Center (JIC). JICs serve to coordinate the crafting of public information for dissemination and also to collect information from various sources, such as traditional media and social media.¹⁰⁵

Regarding public warnings, public doctrine and studies recommend the use of Integrated Warning Teams (IWTs) to coordinate public warnings across multiple organizations and

¹⁰² Huder, Roger. 2012. *Disaster Operations and Decision making*. Hoboken, NJ: John Wiley & Sons.

¹⁰³ Huder. *Disaster Operations and Decision making*.

¹⁰⁴ National Emergency Response & Rescue Training Center (NERRTC). 2013. *Emergency Operations Center Operations and Planning for All-Hazards Events*. College Station: Texas Engineering Extension Service.
https://www.capcog.org/public/upload/files/training/EOC_Planning_and_Operations-1-29-2015.pdf (September 15, 2017).

¹⁰⁵ Emergency Management Institute (EMI). 2016. *JIS/JIC Planning for Tribal, State and Local PIOs*. Emmitsburg, MD: Federal Emergency Management Agency.

agencies.^{106 107} FEMA recommends the formation of IWTs to facilitate information sharing and coordination of all public warnings.¹⁰⁸ Characteristics of effective IWTs include:

1. Lead warning agency should ensure responsibilities of all involved are known and shared.
2. Lead agency should estimate the resources needed for implementing a warning and assess/inventory what resources are and are not available. When deficiencies exist, linkages should be established to share resources or a plan should be developed to obtain permanent or emergency resources.
3. Lead agency should assume responsibility for developing smooth-running relationships between all organizations in the system.¹⁰⁹

This integration is conducted via policy and procedure, as opposed to automated methods. This baseline capability is required before any technology can be used to support the level of integration necessary.¹¹⁰

During emergency situations, managers are under extreme pressure to make decisions quickly and responsibly, while being flexible enough to change in mid-stream should the situation evolve. According to Carver and Turoff, managers must absorb information and make judgments with confidence.¹¹¹ However, even the most seasoned managers have experienced threat rigidity syndrome, which is caused by a loss of control or reduced understanding of what

¹⁰⁶ Mileti, Dennis, and John Sorensen. 1990. *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment* (No. ORNL-6609). Oak Ridge, TN: Oak Ridge National Lab.

<https://www.osti.gov/scitech/biblio/6137387> (September 15, 2017).

¹⁰⁷ Emergency Management Institute (EMI). 2012. *Warning Coordination*. Emmitsburg, MD: Federal Emergency Management Agency.

¹⁰⁸ EMI. *Warning Coordination*.

¹⁰⁹ Mileti and Sorensen. *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment* (No. ORNL-6609). 4-11.

¹¹⁰ EMI. *Warning Coordination*.

¹¹¹ Carver, Liz, and Murray Turoff. 2007. "Human-computer interaction." *Communications of the ACM* 50(3), 33-34.

<http://doi.org/10.1145/1226736.1226761> (July 13, 2017).

is happening.¹¹² To overcome this, managers must realize they may not know everything about a given situation. When their situational awareness is low, they must seek assistance or look for more information so that they can make necessary decisions.

Tools and systems can be very effective in increasing the level of information sharing and integration.¹¹³ This can be accomplished automatically through the use of Information Technology (IT) products.¹¹⁴ While the technology does not create the integration and information sharing, it enables and enhances the capability already instituted in coordinating and responding organizations. One of the aspects of integration that IT can assist with is the simplification of the information sharing process.¹¹⁵ IT can automate steps that otherwise would have to be completed by already task-saturated personnel.¹¹⁶

Additionally, these systems can be used to overcome some of the negative tendencies of human behavior during such incidents. There is a tendency for individuals to concern themselves “with obtaining information from others rather than providing their information to others.”¹¹⁷ To combat the problem of information overload, systems can be implemented to assist with information prioritization, decision modeling, and support, while others focus on situational

¹¹² Carver and Turoff. “Human-computer interaction.”

¹¹³ Bharosa, Nitesh, JinKyu Lee, and Marijn Janssen. (2010). “Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises.” *Information Systems Frontiers*, 12(1), 49-65. ISI Web of Science (September 15, 2017).

¹¹⁴ Bharosa, Lee, and Janssen. “Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises.”

¹¹⁵ Bharosa, Lee, and Janssen. “Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises.”

¹¹⁶ Bharosa, Lee, and Janssen. “Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises.”

¹¹⁷ Bharosa, Lee, and Janssen. “Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises.” 63.

awareness.¹¹⁸ Other applications are beginning to emerge with the ability to manage data flow, which may reduce the information overload many managers experience during a disaster. Carver and Turoff point out that a “user-centric systemic approach” is needed to solve this problem, and emphasis must be placed on user requirements and lessons learned.¹¹⁹ Only by focusing on these aspects will automation be effective in reducing information overload and will ultimately improve the decision-making of authorities under extreme pressure.

Another group of applications that can assist emergency managers to facilitate information synthesis for improved decision-making is Interorganizational Disaster Coordination Networks (IDCNs). IDSNs, as described by Abbasi and Kapucu, simulate how networks form and optimize in the dynamic evolution of natural disasters.¹²⁰ Their approach emphasizes a quantifiable, engineering-centric method to evaluate the information sharing process as coordination networks develop during an emergency event.¹²¹ Understanding these networks may yield valuable information on ways to optimize information networks and increase information processing capability.

Other research focuses on optimizing the decisions made by emergency managers during a disaster by using tools to assist managers in sensemaking and visualization. In one study, a team used an application called AVALANCHE, which allows the users to develop and frame hypotheses, analyze their hypotheses in the experimental domain, and provide cases for

¹¹⁸ Carver and Turoff. “Human-computer interaction.”

¹¹⁹ Carver and Turoff. “Human-computer interaction.” 38.

¹²⁰ Abbasi, Alireza, and Naim Kapucu. 2016. “A longitudinal study of evolving networks in response to natural disaster.” *Computational & Mathematical Organization Theory*, 22(1): 47-70. Ebscohost (July 11, 2017).

¹²¹ Abbasi and Kapucu. “A longitudinal study of evolving networks in response to natural disaster.”

simulation experiments with the goal of improving their “sensemaking abilities.”¹²² The authors define sensemaking as “a cognitive process that allows people to interpret information in context to derive knowledge for actions.”¹²³ Finally, visualization is analyzed as an important factor in a manager’s decision-making process because it allows the individual to “see in their mind” what is going on. This visualization technique allows the decision-maker to use that image for context. The improvement to sensemaking and visualization may yield improved decisions in stressful situations.¹²⁴

In addition to improving the input streams of information and the decisions based on that information, there is much to be learned from how decisions are communicated to the public. To this end, Sheppard, Janoske, and Liu describe how improving risk communication practices, “through developing, testing, and refining communications theories and models” has been an ongoing process for decades.¹²⁵ The continued research has made attempts to model the expected and unexpected behavior of message recipients across three main distinctions: preparedness, response, and recovery.¹²⁶ In essence, if the communication of a decision is not presented

¹²² Ntuen, Celestine A., Eui H. Park, and Kim Gwang-Myung. 2010. “Designing an Information Visualization Tool for Sensemaking.” *International Journal of Human-Computer Interaction* 26(2-3): 189–205. <http://dx.doi.org/10.1080/10447310903498825> (July 21, 2017). 193.

¹²³ Ntuen, Park, and Gwang-Myung. “Designing an Information Visualization Tool for Sensemaking.” 189.

¹²⁴ Ntuen, Park, and Gwang-Myung. “Designing an Information Visualization Tool for Sensemaking.”

¹²⁵ Sheppard, Ben, Melissa Janoske, and Brooke Liu. 2012. *Understanding Risk Communication Theory: A guide for emergency managers and communicators*. College Park, MD: National Consortium for the Study of Terrorism and Responses to Terrorism, University of Maryland. <https://hazdoc.colorado.edu/bitstream/handle/10590/4362/C021260.pdf?sequence=1> (July 7, 2017). 2.

¹²⁶ Sheppard, Janoske, and Liu. “Understanding Risk Communication Theory: A guide for emergency managers and communicators.” 2.

properly, citizens may ignore the warning or fail to act on it in the desired way. Notification of a warning is necessarily combined with crisis communication, and by combining these two elements, the messages are more likely to elicit the desired citizen response. An essential element of information integration is incorporating best practices that account for risk perceptions by the population being targeted for notification.¹²⁷ Several studies analyze and model the communication methods used during emergencies and disasters, including:

- Crisis and Emergency Risk Communication (CERC) Model, which facilitates decisions that must be made within severe time constraints
- Situational theory of publics (STP), which aims to help identify who should get the info, how they process it and how they will react to it.
- Heuristic-systematic model (HSM), which allows communicators to see and understand the connections between a person's desire for accurate and sufficient information and the motivation for processing that information.¹²⁸

Understanding how to apply each of these theories is paramount in achieving the desired effects of an emergency message from decision-makers to the population.

Recent literature has incorporated new technological developments in public information related to social media. The advent of social media has changed the landscape of public warnings in new and unique ways.¹²⁹ Over 20% of the population uses social media for interacting with news agencies and local jurisdictions.¹³⁰ As the technology has advanced and matured, public warnings are created from data gathered and subsequently disseminated through this medium.

Integrating social media into the information push and pull process may create added efficiencies

¹²⁷ Sheppard, Janoske, and Liu. "Understanding Risk Communication Theory: A guide for emergency managers and communicators."

¹²⁸ Sheppard, Janoske, and Liu. "Understanding Risk Communication Theory: A guide for emergency managers and communicators." 6-10

¹²⁹ Natural Disaster Preparedness Training Center (NDPTC). 2016. *Social Media for Natural Disaster Response and Recovery*. Honolulu, HI: University of Hawaii.

¹³⁰ NDPTC. *Social Media for Natural Disaster Response and Recovery*.

that are otherwise not realized through traditional information gathering processes.¹³¹ This method of data integration serves to inform warning decisions and the continued warning process as feedback from citizens' social media posts is observed.¹³² When combined with automated sensors throughout the jurisdiction, emergency managers can react to updates in a more efficient fashion than using traditional means alone.¹³³

Incorporating social media into warning decisions requires policies and procedures in place to collect and analyze that information effectively. Public information professionals use tools such as "trap lines" to collect the appropriate information to the response.¹³⁴ This information, when integrated into traditional and automated sources, can create a real-time picture for decision-makers to base their warning decisions.¹³⁵ This analysis is typically performed in high-pressure environments, and it therefore must be tested and vetted thoroughly with well-trained professionals.¹³⁶

In the world of viral updates with social media responses having the capacity to come in at a breakneck pace, emergency managers must utilize unconventional resources that are available to manage the influx of information, as well as the need for interaction with social

¹³¹ Foresti, G.L., M. Farinosi, and M. Vernier. 2015. "Situational awareness in smart environments: socio-mobile and sensor data fusion for emergency response to disasters." *Journal of Ambient Intelligence and Humanized Computing*, 6(2): 239-257. <https://link.springer.com/article/10.1007/s12652-014-0227-x> (July 22, 2017).

¹³² EMI. *Warning Coordination*.

¹³³ NDPTC. *Social Media for Natural Disaster Response and Recovery*.

¹³⁴ NDPTC. *Social Media Tools and Techniques*.

¹³⁵ Alamdar, Farzad, Mohsen Kalantari, and Abbas Rajabifard. 2016. "Towards multi-agency sensor information integration for disaster management." *Computers, Environment and Urban Systems* 56: 68-85. ScienceDirect (September 15, 2017).

¹³⁶ NDPTC. *Social Media Tools and Techniques*.

media posters.^{137 138} Social media has created a unique two-way connectivity between emergency managers and the public directly.¹³⁹ One emerging method for dealing with this information overload is crowdsourcing volunteers, known as “voluntweeters” or digital volunteers.¹⁴⁰ The use of these vetted and technologically savvy volunteer groups provide a force multiplier to both the collection and analysis of the troves of information that can be found on social media platforms.¹⁴¹ Synthesizing this data via geographic means has been successful during such disasters as the 2010 Haiti earthquake and 2012 Pacific Northwest wildfires.¹⁴²

Integrating new technologies, like social media, is not without its challenges. Research has identified problems in implementing social media into any operation.¹⁴³ Accountability in the anonymous world of the Internet is difficult to achieve and must be addressed by robust policy.¹⁴⁴ Standing policies help to define the procedures for how to confirm information pulled from social media, such as confirming data via multiple sources.¹⁴⁵ Coordination is needed, especially when employing virtual volunteers. The bandwidth of information flow can quickly

¹³⁷ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

¹³⁸ NDPTC. *Social Media for Natural Disaster Response and Recovery*.

¹³⁹ NDPTC. *Social Media for Natural Disaster Response and Recovery*.

¹⁴⁰ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

¹⁴¹ NDPTC. *Social Media for Natural Disaster Response and Recovery*.

¹⁴² Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

¹⁴³ Stem, Eric K. 2017. “Unpacking and Exploring the Relationship between Crisis Management and Social Media in the Era of ‘Smart Devices’.” *Homeland Security Affairs* 13(4). <https://www.hsaj.org/articles/13986> (July 6, 2017).

¹⁴⁴ Stem. “Unpacking and Exploring the Relationship between Crisis Management and Social Media in the Era of ‘Smart Devices’.”

¹⁴⁵ NDPTC. *Social Media for Natural Disaster Response and Recovery*.

overwhelm more conventional means of gathering data. Without a robust policy to direct its use, the veracity of the message generated from social media sources is liable to break down.¹⁴⁶

¹⁴⁶ NDPTC. *Social Media Tools and Techniques*.

Methodology

Overall Method

The research team has chosen Action Research for its research process and staging of recommendations for Harris County Office of Homeland Security and Emergency Management (HCOHSEM). Action Research is the process of inquiry conducted by and for those taking action.¹⁴⁷ The primary reason for engaging Action Research is to assist the actionable parties in improving or refining their operations or processes.¹⁴⁸ This process, described by Richard Sagor in his guide for using Action Research and adapted to the information management problem presented by Harris County, will include the following steps:

1. Selecting a focus
2. Clarifying theories
3. Identifying research questions
4. Collecting data
5. Analyzing data
6. Reporting results
7. Providing recommendations to HCOHSEM

Action Research provides a collaborative solution for the research team and the client enabling a mutually beneficial outcome. Unlike other research methodologies, Action Research focuses on the actions to be taken, rather than research understanding.¹⁴⁹ It is capable of adapting to a changing research environment and fits well with the dynamic and evolving environment which HCOHSEM operates.¹⁵⁰ With the advent of Hurricane Harvey, Action Research provides the

¹⁴⁷ Sagor, Richard. 2000. "Guiding School Improvement with Action Research." Alexandria, VA: Association for Supervision and Curriculum Development. EBSCOhost (September 9, 2017).

¹⁴⁸ Sagor. "Guiding School Improvement with Action Research."

¹⁴⁹ Dick, Bob. 2000. "A beginner's guide to Action Research."
<http://www.aral.com.au/resources/guide.html> (September 9, 2017).

¹⁵⁰ Dick. "A beginner's guide to Action Research."

team with the flexibility to address issues identified during that response without the need to completely re-engineer the research method.

The first step in the Action Research process is to select the focus.¹⁵¹ The contracting process and resulting discussions with the client narrowed the team's focus: to provide feedback and actionable recommendations for HCOHSEM to implement, thereby improving their information flow capabilities during an emergency. Following the identification of the focus and setting the scope of the research, the team conducted extensive research and established a knowledge base to clarify the underlying theories of emergency management. This research entailed the identification of values, beliefs, and perspectives held by the research team related to the research focus. These first steps comprise the comparison gradient the team will reference to make recommendations throughout the research process. This comparison gradient consists of the experiences and expertise of the research team as well as the theoretical constructs clarified in Step 2 of the Action Research process.¹⁵²

Research questions were identified by the team and vetted through HCOHSEM leadership. The research questions were further refined to provide the most valuable elements to client decision-making processes. The five research questions are:

6. What opportunities exist to improve the information management process within HCOHSEM to maximize emergency notification delivery and citizen protective action?
7. How do we apply automation to make the information collection processing more efficient within HCOHSEM?
8. How do we maximize the integration of information sources to promote timely analysis and coordination?
9. How do we use social sciences to craft notifications for more effective dissemination to the public?

¹⁵¹ Sagor. "Guiding School Improvement with Action Research."

¹⁵² Sagor. "Guiding School Improvement with Action Research."

10. How can we more effectively incorporate near real-time feedback into the reassessment process?

These five questions encompass the information cycle and were emphasized in the client's initial request for research. By answering these questions, recommendations can be made to improve information management during an emergency event.

The next step in the Action Research process is to begin collecting data.¹⁵³ The research team heavily leveraged data solicited from and provided by HCOHSEM, in addition to extracting data from relevant published case studies and personal anecdotal experiences. This data-driven approach was critical to supplement the research team's understanding of published research and established doctrine, as well as how each pertains to the research questions. Whenever possible, data were correlated against additional sources for validity and verified for reliability. For example, the team used observed actions of the Spanish-speaking community in other emergency events to determine how that particular community receives their emergency information. The team conducted data analysis based on the theoretical framework, case studies, and information provided by the client to derive hypotheses on the applicable courses of action for improving HCOHSEM's information flow.

The next step of reporting results of the research and analysis will occur in two forms: a written report and a presentation (to be recorded and available for use by HCOHSEM).¹⁵⁴ The final step in the Action Research process is incumbent on HCOHSEM to leverage resources to impact change. This vital step in the process is the reason this team employed an Action

¹⁵³ Sagor. "Guiding School Improvement with Action Research."

¹⁵⁴ Sagor. "Guiding School Improvement with Action Research."

Research methodology. The resulting recommendations, once implemented, should improve efficiency and increase the safety of all citizens across Harris County.

Research Design

This team chose a Purposeful Design based on purposive sampling for its research. Purposeful Design utilizes selected cases applicable to the research questions and problem sets, which have information that may provide valuable data to the research.¹⁵⁵ Unlike other research designs seeking to randomly select data for analysis, as is the case for Cross-Sectional or Experimental Design, Purposeful Design allows the research team to focus their research on case studies with which practitioners can visualize and identify.¹⁵⁶ As with the Action Research, Purposeful Design works well in dynamic research environments. Making Purposeful Design choices allowed the research team to effectively respond to the continually changing research environment.

Our research focuses on case studies with which most emergency managers are familiar. The team chose significant hurricane incidents since Hurricane Katrina (2005) for collection and analysis. Those chosen are Hurricanes Rita, Ike, and Harvey. Each of these storms provides unique opportunities for research and lessons learned. Additionally, these cases provided a chronological record of the changes made by Harris County as they have learned from these major emergency incidents. This was critical to including Hurricane Harvey's into the final product. The team expects new information to be made available throughout the course of the

¹⁵⁵ USC Libraries. 2017. "Organizing your social science research paper: qualitative methods." Los Angeles: University of Southern California.

<http://libguides.usc.edu/writingguide/qualitative> (September 9, 2017).

¹⁵⁶ USC Libraries. "Organizing your social science research paper: qualitative methods."

research project, and by choosing Purposeful Design, this information will more easily be incorporated in a timely manner.

Data Collection

A dynamic system focuses on process as part of a continually changing system.¹⁵⁷ In the context of data collection, this describes any changing influx of data throughout the research process. This concept is especially important considering the dynamic nature of emergency management. While the data collected was primarily comprised of documents, both academic and professional doctrine, emphasis was placed on incorporating the most up-to-date processes employed by HCOHSEM. With the occurrence of Hurricane Harvey during this project, the team was able to incorporate data from the disaster. In addition, the team conducted an extensive literature review of academic sources on various aspects of emergency information flow. The academic literature was compiled through a search of the Texas A&M University Library, the personal libraries of emergency management practitioners on the team, search engines to locate previously published research, and requests for information from HCOHSEM and other emergency management organizations. The professional doctrine was located through internet searches of professional websites and training documents offered by the Emergency Management Institute at the Federal Emergency Management Agency. Additionally, the team was provided operational copies of plans, policies, and procedures from HCOHSEM related to emergency information management. Incorporating these sources using the dynamic system ensured that as new information became relevant, it could be easily incorporated into the research design. This method offered the team an opportunity to adapt to a changing

¹⁵⁷ USC Libraries. "Organizing your social science research paper: qualitative methods."

environment throughout the entire project. Each source was labeled and sorted into the following categories:

1. Policy and Doctrine
2. Human Behavior and Response
3. Emergency Message Crafting
4. Feedback of Response
5. Automation
6. The Internet of Things
7. Information Push and Pull
8. Integration and Information Management

These categories were selected to advance the understanding of the current state of emergency notification and warnings, academic thought, and professional doctrine. The team also had the advantage of members who had observed, in person, HCOHSEM's response to Hurricane Harvey. These observations served to provide additional value to the analysis while also providing insights into the current response.

Analysis

The team's analysis is essential to providing actionable recommendations to solve the information management problem described by HCOHSEM in their request for research. The team chose to use an Inductive and Holistic Perspective analyses for this research. Inductive analysis is performed by delving into the details and processes of a topic to reveal patterns, themes, and interrelationships.¹⁵⁸ The team analyzed data captured in the literature review, and compared it against existing plans, policies, and procedures. This analysis formed the group's essential theory through induction.¹⁵⁹ To provide context, the group employed a holistic perspective by incorporating aspects from the aforementioned major hurricane responses. Holistic perspective is most effectively used to provide historical context to research and integrate the differing aspects found in research as part of the greater research narrative.^{160 161}

Both inductive and holistic analysis methodologies are essential elements of providing insightful recommendations to HCOHSEM. The detailed analysis and pattern recognition provided by inductive analysis provided a flexible methodology that is capable of adapting to changing situations.¹⁶² Given the dynamic environment of disaster response, inductive analysis was essential to ensuring new data, specifically from Hurricane Harvey, was incorporated into the research. With the addition of a holistic perspective, the team was able to provide context for recommendations which were consistent with historical findings from prior hurricane responses.

¹⁵⁸ USC Libraries. "Organizing your social science research paper: qualitative methods."

¹⁵⁹ Chambliss, Daniel F., and Russell K. Schutt. 2016. *Making Sense of the Social World: Methods of Investigation*. 5th ed. Thousand Oaks, CA: Sage Publications, Inc.

¹⁶⁰ Chambliss and Schutt. *Making Sense of the Social World: Methods of Investigation*.

¹⁶¹ Merriam, Sharan B., and Elizabeth J. Tisdell. 2015. *Qualitative Research: A Guide to Design and Implementation*. 4th ed. San Francisco: Jossey Bass. ProQuest. (September 11, 2017).

¹⁶² USC Libraries. "Organizing your social science research paper: qualitative methods."

Harris County Residents and Response

To enhance the human response to emergency communications, it is essential for HCOHSEM to consider a wide range of factors pertaining to Harris County. It is important to understand the demographic and socioeconomic factors of the county and how each group is likely to respond to emergency notifications. Understanding the unique differences between groups will allow HCOHSEM to improve the design of emergency notification and messaging systems by tailoring them to the targeted audience. Table 1 provides a quick look from July 1, 2016, provided by the U.S. Census Bureau for the people in Harris County:

Population	
Population estimates	4,589,928
Age and Sex	
Persons under 5 years	7.8%
Persons under 18 years	27.0%
Persons 65 years and over	9.8%
Female persons	50.3%
Race and Hispanic Origin	
White	70.0%
Black or African American	19.7%
American Indian or Alaska Native	1.1%
Asian	7.2%
Native Hawaiian or Other Pacific Islander	0.1%
Two or more races	1.9%

Hispanic or Latino	42.4%
White alone, not Hispanic or Latino	30.4%
Population Characteristics	
Veterans, 2011-2015	171,858
Foreign born persons	25.4%
Housing	
Housing Units	1,751,802
Owner-occupied housing unit rate	54.9%
Median value of owner-occupied housing units	\$137,800
Building permits, 2016	22,661
Families & Living Arrangements	
Households, 2011-2015	1,499,528
Persons per household, 2011-2015	2.88
Living in same house 1 year ago, percent of persons age 1 year+, 2011-2015	82.6%
Language other than English spoken at home, percentage of persons age 5 years+, 2011-2015	43.1%
Education	
High school graduate or higher, percentage of persons age 25 years+, 2011-2015	79.6%

Bachelor's degree or higher, percentage of persons age 25 years+, 2011-2015	29.5%
Health	
With a disability, under age 65 years	6.6%
Persons without health insurance, under age 65 years	21.1%
Economy	
In civilian labor force, total, percentage of population age 16 years+, 2011-2015	68.4%
In civilian labor force, female, percentage of population age 16 years+	59.8%
Income & Poverty	
Median household income (in 2015 dollars), 2011-2015	\$54,457
Per capita income in past 12 months (in 2015 dollars), 2011-2015	\$29,047
Persons in poverty	16.6%

Table 1. Quick Facts for people in Harris County, Texas¹⁶³

Moderate growth scenarios for the Houston Metropolitan area predict the area will add 4.1 million residents between 2010 and 2050 through natural increase (births minus deaths) and

¹⁶³ U.S. Census Bureau. 2016. "QuickFacts: Harris County, Texas." Washington, D.C.: U.S. Census Bureau.
<https://www.census.gov/quickfacts/fact/table/harriscountytexas/PST045216> (October 1, 2017).

from “net immigration” (people moving into the region minus people moving out).¹⁶⁴ The moderate growth scenario shows a balance between Anglo (white) and Hispanic populations in the early years of the forecast. Anglo populations will begin to decline and Hispanics will outnumber all other ethnic groups combined.¹⁶⁵ The moderate growth scenario for race and ethnicity is shown in Figure 5:

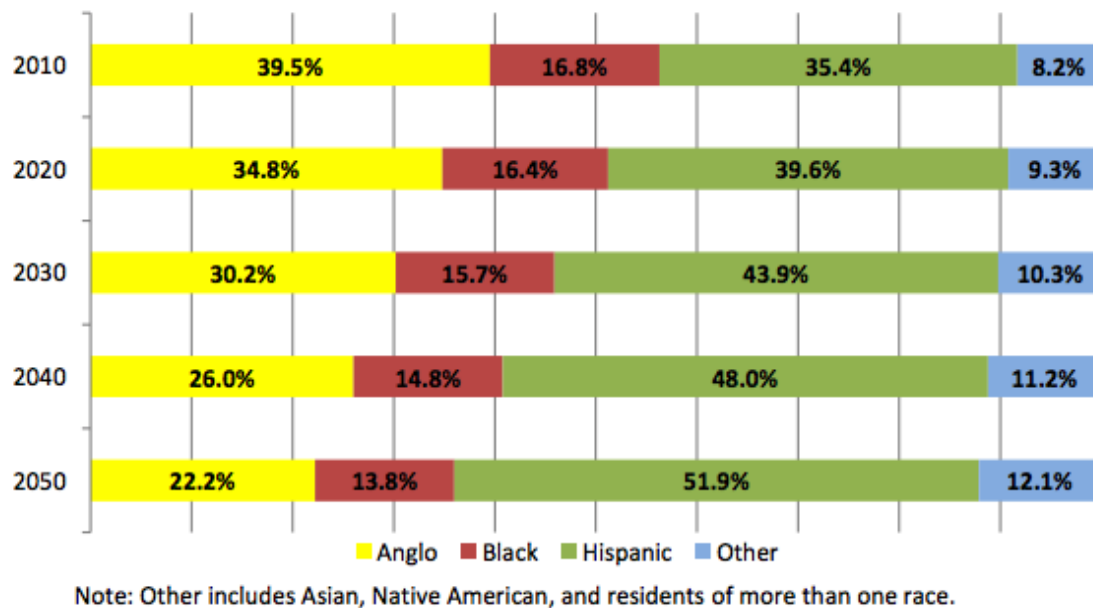


Figure 5. Race and Ethnicity Moderate Growth Scenario¹⁶⁶

Moderate growth scenarios also show the share of Houston’s population 18 years and younger will decline over the next few decades. It is expected that by 2050 there will be almost

¹⁶⁴ Greater Houston Partnership Research Department. 2017. “Metro Houston Population Forecast: Projections to 2050.” http://www.houston.org/pdf/research/quickview/Population_Employment_Forecast.pdf (October 2, 2017).

¹⁶⁵ Greater Houston Partnership. “Metro Houston Population Forecast: Projections to 2050.”

¹⁶⁶ Greater Houston Partnership. “Metro Houston Population Forecast: Projections to 2050.”

as many residents over the age of 65 as there will be under the age of 18.¹⁶⁷ The moderate growth scenario for age cohorts is shown in Figure 5:

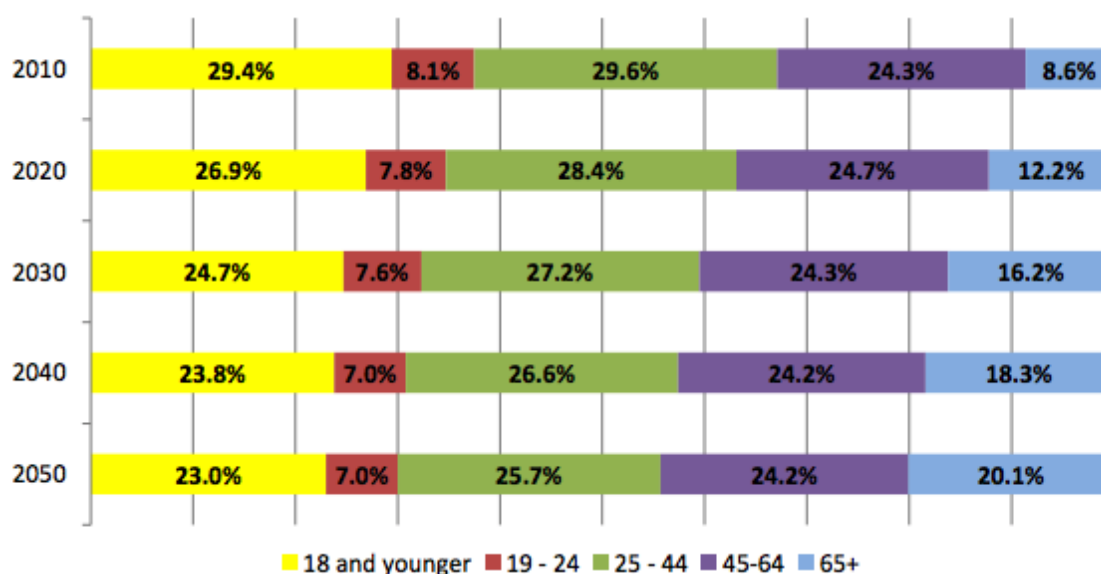


Figure 6. Age Cohorts Moderate Growth Scenario¹⁶⁸

Analyzing the population data for Harris County can provide HCOHSEM with clues to the characteristics of the population as message receivers. This is primarily due to the fact that people with different backgrounds respond differently to disaster warnings because their range of experiences differ.¹⁶⁹ Elderly people living alone and persons with disabilities are likely to be more vulnerable to disasters than the average population.¹⁷⁰ Harris County’s largest age cohort of 19-64 years of age accounts for 63.2% of the population. The 9.8% of the population over 65

¹⁶⁷ Greater Houston Partnership. “Metro Houston Population Forecast: Projections to 2050.”

¹⁶⁸ Greater Houston Partnership. “Metro Houston Population Forecast: Projections to 2050.”

¹⁶⁹ Drabek. “Understanding disaster warning responses.”

¹⁷⁰ Flanagan, Barry, Edward Gregory, Elaine Hallisey, Janet Heitgerd, and Brian Lewis. 2011. “A Social Vulnerability Index for Disaster Management.” *Journal of Homeland Security and Emergency Management* 8(1): 1-22.
<https://gis.cdc.gov/grasp/svi/A%20Social%20Vulnerability%20Index%20for%20Disaster%20Management.pdf> (October 3, 2017).

years represents an area that requires special consideration when considering emergency warning response. Such a vulnerability was evidenced in Louisiana and Mississippi during Hurricane Katrina. It is estimated that persons ages 65 and older represented over 70% of the fatalities from Hurricane Katrina.¹⁷¹

Women, who comprise 50.3% of the Harris County population, are typically quick to react to emergency warnings. Women tend to be poorer relative to men and may not have the necessary resources to respond to disasters.¹⁷² This problem is even more acute in the case of single mothers; poverty rates for single mothers exceed those of single women without children or married women, and must protect themselves and their children when threats emerge.¹⁷³ This difference in response for women is reduced as the level of education among females and their work experiences more closely approximates that of males.¹⁷⁴ 20.4% of the people in the county who are over 25 years of age have less than a high school education. The ability to read and comprehend the written material in warning messages will vary among this component of the population.¹⁷⁵

Ethnicity and language barriers can also contribute to delays in warning responses. The number of immigrants to Harris County from Latin America and Asia have substantially increased in recent decades. Many of these immigrants are not fluent in English, and have lower

¹⁷¹ Donner, W. and H. Rodriguez. 2011. "Disaster Risk and Vulnerability: The Role and Impact of Population and Society." Washington, D.C.: Population Research Bureau. <http://www.prb.org/Publications/Articles/2011/disaster-risk.aspx> (November 19, 2017).

¹⁷² Donner and Rodriguez. "Disaster Risk and Vulnerability: The Role and Impact of Population and Society."

¹⁷³ Donner and Rodriguez. "Disaster Risk and Vulnerability: The Role and Impact of Population and Society."

¹⁷⁴ Drabek. "Understanding disaster warning responses."

¹⁷⁵ Omari *et al.* "Human Response to Emergency Communication: A Review of Guidance on Alerts and Warning Messages for Emergencies in Buildings."

literacy rates than other groups, thus making communication during a disaster more difficult.¹⁷⁶ Some Latinos, who account for 42.4% of the population, may suffer higher vulnerability to disasters due to language barriers. Warnings, commonly issued in English, may be misunderstood or not understood at all by Spanish-speaking individuals.¹⁷⁷ Asians, who account for 7.2% of the population, are also similarly vulnerable. In addition to vulnerabilities created by language barriers, ethnic minorities tend to distrust official disaster warning agencies based on generations of life experience with authorities.^{178 179} Harris County has an ethnic minority population of around 70%, which includes the following races: black or African American, American Indian and Alaska native, Asian, native Hawaiian and other Pacific Islander, and Hispanic or Latino.

The socioeconomic status (income, poverty, employment, and education variables) Harris County residents is also diverse. 16.6% of the population is economically disadvantaged and living in poverty. These residents are less likely to have the income or assets needed to prepare for an emergency.¹⁸⁰ Similarly affected are the 5.7% of residents who are unemployed.¹⁸¹

¹⁷⁶ Donner and Rodriguez. "Disaster Risk and Vulnerability: The Role and Impact of Population and Society."

¹⁷⁷ Donner and Rodriguez. "Disaster Risk and Vulnerability: The Role and Impact of Population and Society."

¹⁷⁸ Bolin, B. 2007. "Chapter 5: Race, Class, Ethnicity, and Disaster Vulnerability." In *Handbook of Disaster Research*, eds. H. Rodriguez, E.L. Quanrantelli, and R.R. Dynes. New York, NY: Springer.

¹⁷⁹ Mileti, D.S., and P.W. O'Brien. 1992. "Warnings During Disaster: Normalizing Communicated Risk." *Social Problems* 39:40-57.

¹⁸⁰ Flanagan, *et al.* "A Social Vulnerability Index for Disaster Management."

¹⁸¹ U.S. Bureau of Labor Statistics. 2017. "Houston Area Economic Survey." Dallas: BLS Southwest Information Office.
https://www.bls.gov/regions/southwest/summary/blssummary_houston.pdf (October 17, 2017).

According to a 2017 Harris County “Homeless Count and Survey, there are 3,365 documented homeless residents.”¹⁸² Houston’s poor communities tend to live in segregated neighborhoods that are most vulnerable to flooding or near petrochemical plants, which can overflow during storms.¹⁸³ Research from Hurricane Katrina found that 54% of the poor households in New Orleans did not have their own means of transportation, and 65% of poor elderly households in New Orleans did not have a vehicle.¹⁸⁴ The lack of transportation made it more difficult for these residents to respond to emergency warnings to evacuate before the hurricane. This is just one example of the many vulnerable elements of the Harris County population that HCOHSEM must consider when crafting its approach to emergency communication.

Emergency Warning and Message Crafting

Effective communication for HCOHSEM is about breaking through the “noise,” or the external barriers to communication, getting the message from the sender to the receiver, and then eliciting the desired response or action. Depending on the context of an emergency situation, the desired response could be undertaking preparation efforts, sheltering in place, evacuating, or some other protective measure. It is the goal, in an emergency situation, “to inform the public and change behavior in ways that protect and improve the public health and safety.”¹⁸⁵

¹⁸² Coalition for the Homeless. 2017. “2017 Homeless Count.”

<http://www.homelesshouston.org/wp-content/uploads/2017/05/Final-2017-PIT-Fact-Sheet-Digital.pdf> (October 3, 2017).

¹⁸³ Misra, Tanvi. 2017. “A Catastrophe for Houston’s Most Vulnerable People.” *The Atlantic*, August 27. <https://www.theatlantic.com/news/archive/2017/08/a-catastrophe-for-houstons-most-vulnerable-people/538155> (October 3, 2017).

¹⁸⁴ Shapiro, Isaac, and Arloc Sherman. 2005. “Essential Facts About the Victims of Hurricane Katrina.” <https://www.cbpp.org/research/essential-facts-about-the-victims-of-hurricane-katrina> (October 3, 2017).

¹⁸⁵ Reynolds, Barbara and Seeger, Matthew W. 2005. Crisis and Emergency Risk Communication as an Integrative Model. *Journal of Health Communication*. 10: 43-55.

HCOHSEM cites, as part of its concept of operation, the “rapid dissemination and delivery of warning information and instructions may provide time for residents to take action to protect themselves and their property.”¹⁸⁶

Emergency communication, specifically the dissemination of public information, is meant to save lives.¹⁸⁷ An effective emergency manager keeps the information management cycle in mind, and ensures the inclusion of principles dealing with risk management, crisis communication, decision-making, and overcoming communication barriers.¹⁸⁸ These factors must all be considered by HCOHSEM management while they are crafting the timely dissemination of emergency information. To better understand how HCOHSEM accomplishes these goals, it is helpful to examine the policies and procedures detailed in the Harris County Basic Plan Annexes and to compare them to the recommended practices for emergency communication.

Communication Cycle

Understanding Harris County and its unique communication system of senders, receivers, transmitters, and feedback loops is vital to effective emergency communication by HCOHSEM. The feedback loop applies to the push and pull of information “from the receivers to the sources” which “can provide insight into the usefulness, timeliness, and value of the information agencies provide during the disaster.”¹⁸⁹ It is important to monitor and evaluate the feedback received

¹⁸⁶ Harris County Office of Homeland Security and Emergency Management. 2016. “Harris County Basic Plan Annex A Warning.” July.

¹⁸⁷ EMI. 2016. Public Information Officer Awareness. Emmitsburg, MD: Federal Emergency Management Agency.

¹⁸⁸ Huder, Roger. 2012. Disaster Operations and Decision making. Hoboken, NJ: John Wiley & Sons.

¹⁸⁹ Steelman *et al.* “What information do people use, trust, and find useful during a disaster? Evidence from five large wildfires.”

from those who have heard the emergency information message “because what may be meaningful information to those delivering information may not be meaningful to those who are in danger.”¹⁹⁰ Some good sources of feedback include social media networks like Facebook, Twitter, and Instagram, where the recipients can broadcast their actions live and in real time.

HCOHSEM maintains a presence on a variety of social media platforms, including Facebook and Twitter. This “allows emergency managers to disseminate information to wider audiences, [and] interact with the public,” while obtaining the vital feedback that helps HCOHSEM to “gain better situational awareness and improve collaboration in the county.”¹⁹¹ The HCOHSEM Regional Joint Information Center (RJIC) Plan recognizes social media as “a source of intelligence, providing valuable insight on weather conditions, unmet needs, and public perceptions” and allows “near-instantaneous communications with subscribers.”¹⁹²

There have been several reports in the media about how Hurricane Harvey is “the first major natural disaster of the social media age.”¹⁹³ At this time, there is very little data detailing HCOHSEM’s use of social media usage during the response to Hurricane Harvey, but after-action reports will provide valuable information for future research. There was significant traffic on social media during the initial phases of Hurricane Harvey, and HCOHSEM is still using these social media outlets to communicate with the public as recovery operations continue.

¹⁹⁰ Steelman, *et al.* “What information do people use, trust, and find useful during a disaster? Evidence from five large wildfires.” 616.

¹⁹¹ HCOHSEM. “2016 Annual Report.” 47.

¹⁹² Harris County Office of Homeland Security and Emergency Management. 2014. “Regional Joint Information Center Plan.” 5.

¹⁹³ Rhodan, Maya. 2017. “‘Please Send Help.’ Hurricane Harvey Victims Turn to Twitter and Facebook.” *Time*, August 30.
<http://time.com/4921961/hurricane-harvey-twitter-facebook-social-media> (September 14, 2017).

While Hurricane Harvey might be the most recent disaster to strike Harris County, HCOHSEM is no stranger leveraging the connectivity provided by social media during emergency incidents. The 2016 annual report shows that during two major flood events there were 1,257 social media posts.¹⁹⁴ This is a strong indication that HCOHSEM has an active social media presence and is continually engaged with the community during emergency events.

The Principles of Risk and Crisis Communication

During emergency situations, HCOHSEM's messages "seek to induce behavioral change by presenting a threat and describing a behavior or behavioral change that may alleviate the threat."¹⁹⁵ In the case of Hurricane Harvey, the ReadyHarris.org alert system showed a warning issued on August 17, 2017, indicating that Hurricane Harvey was the eighth named storm of the season.¹⁹⁶ The message structure was divided into sections identifying the hazard, protective action, and where additional information could be obtained. In the message on August 17, the recommended protective action encouraged residents to have a plan for inclement weather and to confirm whether or not the recipient resided in an evacuation zone. The next alert was issued on August 22 after Harvey crossed the Yucatan Peninsula. Again, it encouraged residents to monitor forecasts and provided detailed information on creating a family plan and disaster kit. It also provided instructions for those with functional and access needs.¹⁹⁷

¹⁹⁴ HCOHSEM. "2016 Annual Report." 47.

¹⁹⁵ Reynolds, *et al.* "Crisis and Emergency Risk Communication as an Integrative Model." 45.

¹⁹⁶ Harris County Office of Homeland Security and Emergency Management. 2017. "Tropical Storm Harvey Forms." ReadyHarris.Org. August 17.
<http://www.readyharris.org/News-Information/Harris-County-Alerts/Post/26418>
(October 10, 2017).

¹⁹⁷ Harris County Office of Homeland Security and Emergency Management. 2017. "Residents Encouraged to Monitor Forecast, Review Severe Weather Plans."
<http://www.readyharris.org/News-Information/Harris-County-Alerts/Post/26437> (October 10, 2017).

HCOHSEM Annex A discusses warning messages and indicates that when warnings are issued, they are generally pre-scripted, but can be modified to fit any given situation.¹⁹⁸ The messages essentially provide needed information to meet the standard of risk communication. The information is disseminated promptly as the storm's status changes. The pre-planning conducted by HCOHSEM in this area allowed the organization to concisely provide residents with updates as Hurricane Harvey approached Harris County. The content and timeliness of these messages reflects the ongoing lessons learned by HCOHSEM. Early messages asked residents to identify if they are in evacuation areas stemmed from emergency managers knowing the challenge of conducting a full-scale evacuation of Harris County. The lessons learned from previous incidents now drive emergency managers at HCOHSEM to begin communicating risk and possible courses of action as soon as possible, across a wide range of platforms, so that residents can begin preparing to take protective action. These platforms include broadcast radio, television, cellular or cable companies broadcasting the Emergency Alert System (EAS), local newspapers, and the Neighborhood Early Warning System (NEWS).¹⁹⁹

Risk communication is defined by the National Research Council as “an interactive process of exchange of information and opinion among individuals, groups, and institutions.”²⁰⁰

²⁰¹ The communication and notification cycle requires significant forethought by HCOHSEM well in advance of a message being sent so that the message, once received in a high-stress

¹⁹⁸ HCOHSEM. “Harris County Basic Plan Annex A Warning.” B-12.

¹⁹⁹ HCOHSEM. “Harris County Basic Plan Annex I: Emergency Public Information.”

²⁰⁰ National Oceanic and Atmospheric Administration. 2016. “Risk Communication and Behavior: Best Practices and Research Findings.”
<https://www.hsdl.org/?view&did=796609> (October 11, 2017). 8.

²⁰¹ National Research Council. 1989. “Improving Risk Communication.” Washington, D.C.: National Academy Press.

disaster situation, elicits the desired reaction. HCOHSEM's efforts to elicit the appropriate citizen protective action include public information campaigns for disaster awareness.

HCOHSEM's ReadyHarris efforts are also partnered with national campaigns. One such campaign is the National Weather Service's "Turn around, don't drown," which attempts to raise awareness about the dangers of driving through floodwaters.²⁰² Success in risk communication can be grounded in the preparation work done before a crisis happens.

The HCOHSEM Annex I, APPENDIX 3 defines some of the basic concepts of crisis communication. First, it states that a message must be "clear and consistent" and to use "damage control" to put down rumors and correct false information.²⁰³ HCOHSEM offers preparedness through crisis communications. The development of the ReadyHarris.org mobile app offered improved communications, "emergency preparedness, and resiliency for Harris County residents."²⁰⁴ In addition to the app, HCOHSEM conducts public education programs. According to the 2016 annual report, HCOHSEM participated in over "150 outreach events and presentations," as well as participation during National Preparedness Month by providing daily tips and giveaways on its social media sites, and several other brochures and publications available in multiple languages offering emergency preparedness information and checklists.²⁰⁵ HCOHSEM provides that ground work through public education and outreach programs informing the public about what they should do during a crisis.

²⁰² National Oceanic and Atmospheric Administration. 2017. "Turn Around Don't Drown PSA." Flood Safety. <http://www.nws.noaa.gov/os/water/tadd> (October 11, 2017).

²⁰³ HCOHSEM. "Harris County Basic Plan Annex I." 22.

²⁰⁴ HCOHSEM. "2016 Annual Report." 47.

²⁰⁵ HCOHSEM. "2016 Annual Report." 49.

Message Structure

HCOHSEM emergency messages are sent over a multitude of platforms. The primary platform that dictates how a message is built is the Common Alerting Protocol (CAP) which is the standard for the nation's Integrated Public Alert & Warning System (IPAWS).²⁰⁶ The CAP is designed to be compatible with many other platforms such as the Specific Area Message Encoding (SAME), the National Oceanic and Atmospheric Administration (NOAA) Weather Radio, and the Emergency Alert System (EAS). Annex A indicates that HCOHSEM does participate in IPAWS and EAS.

Decision-making and overcoming communication barriers

Building a better message is much like building a better mousetrap. Just as the trapper needs to understand what motivates the mouse, the emergency manager needs to understand the recipient, the risk, and the crisis communication process of emergency warnings and messages. Emergency managers become most effective when they understand their audience. It is important for HCOHSEM to understand that the people of Harris County “are a diverse group with different values, concerns, and filters which impact what they perceive.”²⁰⁷ HCOHSEM must also strive to understand the role of race and gender in the perception of the threat, how culture impacts response, and the issues associated with a particular community. Additionally, using all available information sources at their disposal, maintaining their credibility as an information source, and using persuasive language must all be of paramount concern to the public information officers in HCOHSEM.

²⁰⁶ U.S. Department of Homeland Security. Federal Emergency Management Agency. 2017. “Integrated Public Alert & Warnings.”

<https://www.fema.gov/integrated-public-alert-warning-system> (October 12, 2017).

²⁰⁷ NOAA. “Risk Communication and Behavior: Best Practices and Research Findings.” 12.

One key to HCOHSEM crafting effective messages comes from an understanding of how the people of Harris County receive the message and how they perceive the threat. A study conducted in Verona, MO found that the local Spanish-speaking population received emergency information from the Honduran priest at their church.²⁰⁸ Harris County has a wide and diverse population with 1,499,528 households in 2016. 43.1% of them speak a language other than English in the home.²⁰⁹ It is a matter of understanding, not just how people will react, but also the decision-making process used to rationalize their decisions.²¹⁰ There must be an understanding of “how race, gender, life circumstances, and communications” affect perspectives in disasters.²¹¹ The ReadyHarris.org website provides accessibility information as well. One such example is offering FEMA videos in American Sign Language (ASL), and instructions on how to schedule sign language interpreters for visits to the disaster recovery center.²¹² The HCOHSEM website provides links to information for people with access needs like deaf or hard of hearing and other disabilities.²¹³ Annex A of the HCOHSEM Basic Plan provides direction for warning the visually and hearing impaired, non-English speaking, and specialized facilities such as nursing and assisted living facilities.²¹⁴ HCOHSEM Annex I

²⁰⁸ Donner, *et al.* "Tornado Warnings in Three Southern States: A Qualitative Analysis of Public Response Patterns."

²⁰⁹ U.S. Census Bureau. "QuickFacts: Harris County, Texas."

²¹⁰ Vermeulen. "Understanding Your Audience: How Psychologists Can Help Emergency Managers Improve Disaster Warning Compliance." 309.

²¹¹ West and Orr. "Race, Gender, and Communications in Natural Disasters."

²¹² Harris County Office of Homeland Security and Emergency Management. 2017. "Accessible FEMA Videos and Sign Language Interpreters for DRC's." <http://www.readyharris.org/News-Information/Ready-Harris-News/Post/27187> (October 13, 2017).

²¹³ Harris County Office of Homeland Security and Emergency Management. 2017. "Prepare." <http://hcohsem.org> (October 13, 2017).

²¹⁴ HCOHSEM. "Harris County Basic Plan Annex A Warning." B-14.

discusses the platforms used to direct communication to the populations with visual, hearing, and language differences citing radio broadcasts, closed captioning, ASL translators present during press conferences, and maintaining a bilingual staff and PIO representatives, as well using Houston TranStar to provide “real-time translation of news conference audio feeds to Spanish language television stations.”²¹⁵

Feedback and Response

Near Real Time The proximity of Harris County to the Gulf of Mexico makes it vulnerable to tropical storms and hurricanes, though severe weather events like flash floods and winter storms occur more frequently. HCOHSEM has the challenging task of the planning, coordination, and implementation of all emergency management and homeland security-related activities for the more than 4.7 million residents that live in the county.²¹⁶ The ability to provide relevant geographic data in near real-time to citizens in the impacted areas of Harris County is hindered by the need for HCOHSEM to corroborate the data before its dissemination. These three competing interests of timeliness, relevance, and accuracy, must be satisfied if citizens are to trust and rely on an emergency notification system.²¹⁷ Delayed input, processing, and output of information amid the ever-changing landscape of emergencies may result in incidents or obstructions going unreported, or the continued reporting of obstacles that have been cleared.

On September 26, 2016, Harris County released ReadyHarris, a smartphone and tablet application used to provide up-to-date information to citizens of Harris County regarding threats

²¹⁵ HCOHSEM. “Harris County Basic Plan Annex I.” I-5.

²¹⁶ Harris County. *2016 Annual Report*. 9.

²¹⁷ Steen. “Emergency Management: There’s an App for That.”

posed by weather, flooding, or other related incidents.²¹⁸ The Texas Association of Municipal Information Officers (TAMIO) recognized ReadyHarris with an award for excellence last year; however, the application does have its limitations.²¹⁹ The first limitation of the application is the availability of access. This limitation exists for all computer applications, and is not unique to the ReadyHarris application. For Harris County citizens to benefit from the application, they must:

- Have access to a working smartphone or tablet that is compatible with the application,
- Have already downloaded the application,
- Be familiar with the language in which the application is formatted; and
- Maintain a continuous connection with the phone or tablet.

Of note, if storm winds compromise communication towers, or loss of electricity prevents people from charging their phones and tablets, or increased usage by citizens in the area exceeds the capabilities of communication infrastructure, the benefit of the ReadyHarris app may be minimized.

The ReadyHarris application is also limited by the one-way communication the application currently supports. It serves only as a tool used for disseminating information from HCOHSEM to residents, and does not allow individual users to submit information to Harris County about a disaster they are experiencing or one that has been resolved. As such, it relies on Harris County government officials to be the only source of information. This may allow for

²¹⁸ Phillips, David J. 2016. "Harris County Releases Emergency Preparedness App." Houston Chronicle, September 28.
<http://abc13.com/society/harris-county-releases-emergency-preparedness-app/1353174> (October 9, 2017).

²¹⁹ Harris County. 2017. "Harris County ReadyHarris App Receives Award of Excellence." The County Judge Report.
<http://www.judgeemmett.org/Newsletters/Newsletter.html> (October 9, 2017).

distribution of stale information as valuable time is being spent vetting and transmitting without the added capability of capturing of new information. Further, the application does not allow users to tailor their notifications to only a specific type or region. If flooding is occurring in southern communities of Harris County, and users in the northern communities of Harris County are notified of it, users may soon stop paying attention to all warnings- even the pertinent ones. The app runs the risk of being “the boy who cried wolf,” and illustrates the challenge of keeping residents informed without desensitizing them to new information. With the county comprising nearly 1,800 square miles, notifying the entire county of localized issues will likely have a diminishing return on the perceived importance of the messages.

A review of the application on the Google Play website further espouses this concern: “Too many alerts. Get these alerts fixed. I'm getting them every few minutes for the same storm. You'll have the ‘boy who cried wolf’ syndrome. I'm just ignoring alerts now.”²²⁰ Based on this review and others like it, the current broadcast functionality for disseminating information may be improved by allowing users to input their specific zip code. This would allow them to limit the alerts to only the ones relevant to them, and would limit the number of false alerts they receive. It would also provide recently-confirmed information about visible hazards, whether it be power-outages, flashing traffic lights, or flooding, in near real-time. A popular application for mobile devices may already provide this platform, and its utility to emergency management has yet to be thoroughly explored.

²²⁰ Google Play. *n.d.* “ReadyHarris App Reviews.” <https://play.google.com/store/apps/details?id=com.quickseries.Harris&hl=en> (October 9, 2017).

Waze is a mobile app owned and maintained by Google, which calls itself “the world’s largest community-based traffic and navigation app.”²²¹ Users of the app input their destination into the application, and its GPS software provides them the quickest route by factoring in traffic, detours, obstructions, and areas of restricted access. The application receives its information in two ways; first, it monitors the speeds of its users to confirm traffic conditions on various roads. If vehicle traffic begins to slow on a particular road, the Waze software algorithms record the slowed traffic and searches for additional routes that may be available. Secondly, the app allows for real-time submission of information from users. A motorist can report an accident on the roadway, debris slowing traffic, or the presence of police in the area, merely by pressing a button on the app. When a predefined number of minimum users report a particular issue, the map is updated with the report and notifies other drivers in the area. It then asks those drivers to confirm the hazard. When drivers cease to confirm the hazard, it is presumed to have been removed, and traffic is readjusted accordingly.²²² Apps like Waze set the foundation for future apps where citizens encountering flashing traffic-lights, downed trees, flooding, or other severe incidents could have a means of reporting them while others have a means of being notified of those hazards. Drivers would also be rerouted away from the hazards, to reduce congestion in a particular area, potentially accelerating response times for emergency vehicles on route to the scene.

In the past, Google has partnered with communities to aid first responders in their official capacities. Since October 2014, Waze has conducted its Connected Citizens Program,

²²¹ Waze. 2017. “Waze.” <https://www.waze.com> (August 1, 2017).

²²² Google. 2017. “How Does Waze Work?” <https://support.google.com/waze/answer/6078702?hl=en> (August 3, 2017).

an initiative providing state and local government's two-way data sharing.²²³ Partner governments receive input data about road conditions and hazards submitted to the app by users. The information is routed to traffic centers that respond with information regarding planned closures, and emergencies. Events like power outages, downpours, or flooding could impact traffic conditions, and the ability to submit such information via an app is certainly a reasonable course of action. Georgia Emergency Management & Homeland Security Agency, a Connected Citizens Program partner, may be a helpful resource for exploring the benefits of fostering such a partnership. The City of Fort Worth also participates in the program.²²⁴ These efforts demonstrate that the provision of accurate and relevant emergency information in real-time can save lives.

Communication decision making

Reviewing how people respond to information is dependent upon the method of messaging and the recipient's ability to understand, digest and take appropriate action. HCOHSEM has a robust, but outdated, Regional Joint Information Center (RJIC) Plan. It was last updated in 2014. With such a large market (the entire population of Harris County), the creation of a "one-stop shop" for information is critical given the number of competing media sources and outlets. Providing this service and functionality helps establish HCOHSEM as the expert source for timely and trusted emergency information. The RJIC operates using NIMS with well-defined organizational duties and responsibilities. The three major functions of the HCOHSEM RJIC are to gather information, analyze it for accuracy and relevance to the

²²³ Waze. 2017. "Connected Citizens Program." <https://www.waze.com/ccp> (August 2, 2017).

²²⁴ Waze. 2017. "Waze Connected Citizens Program | Existing Partners." https://wiki.waze.com/wiki/Connected_Citizens_Program (August 2, 2017).

situation, and to transmit it to the public through all available means.²²⁵ The RJIC must maintain the very highest standards to assure the message and information is always accurate and timely.

HCOHSEM maintains a very robust social media presence on Twitter, Facebook, and YouTube. By using these platforms, they can respond and send messages in near-real time with instantaneous messaging. The RJIC uses ReadyWarn, a web-based system that automatically populates alerts, warnings, and watches from various trusted sources, to post on the HCOHSEM Facebook page and Twitter account in real-time. The plan recognizes the PIO or the incident commander (IC) may not be available to promptly approve all social media messages. By having others briefed and trained in social media and setting boundaries on what can and cannot be disseminated helps to keep the organization streamlined, and allows for more near real-time messages during an emergency.²²⁶

During Hurricane Harvey, HCOHSEM had to expend resources to monitor social media for false emails and Facebook posts. In an effort to combat the misinformation, HCOHSEM commented on the post by placing a red “FALSE” banner over the article or post. The message at the beginning of the post read “Several false emails & FB posts are being circulated on Hurricane Harvey. Ignore the messages monitor the media for official news/warnings.”²²⁷ Social media can be a very beneficial tool to push out information from the RJIC, but it can also be a breeding ground for false or misleading information. The public must understand that any information posted on social media should be verified with local and state authorities.

²²⁵ HCOHSEM. *Regional Joint Information Center Plan*.

²²⁶ HCOHSEM. *Regional Joint Information Center Plan*.

²²⁷ Janusaitis, Bob. 2017. “Sample of ReadyHarris response to false emails and Facebook posts.”

HCOHSEM has a history of providing after-action plans to review how the operations of an event could be improved. A review of the Joint Information Center's After-Action Report (JICAAR) involving the Memorial Floods of 2015 and the spring floods of 2016 informed some of this study's recommendations. They identified the need for a Standard Operating Procedure to provide guidance for publicly displaying images of an emergency event. Further, this SOP also answered questions of "when should images be displayed" and "what type of images" would be appropriate. This also included guidelines to ensure that images do not display non-public information. Other discussion in the JICAAR focused on the operations of the phone bank. The report acknowledged the use of social media for getting the message out, but there was no mention of establishing a phone bank or point of contact to provide two-way communication with social media contacts. The 2016 JICAAR acknowledged that HCOHSEM has no countywide notification system for alerting residents to vital information. This fact is especially problematic considering that much of the severe weather occurs in the overnight hours where traditional methods such as TV, radio, and other forms of social media are not able to easily reach residents.²²⁸

Automation

The communication system through which information flows during a disaster can be characterized as a network of relationships between sources and recipients whom have a shared interest in the information communicated.²²⁹ HCOHSEM employs several digital communication mediums to disseminate information to the public, and has multiple layers of technological

²²⁸ HCOHSEM. *Regional Joint Information Center Plan*.

²²⁹ Steelman, *et al.* "What Information Do People Use, Trust, and Find Useful During a Disaster? Evidence from Five Large Fires."

automation integrated into its emergency management apparatus. This research project identified a few key areas where much of the information is sourced external to HCOHSEM. These sources include emergency sensors, internet-enabled technology (to include connected mobile devices), and social media. These technologies provide both one and two-way communication between the people of Harris County and government stakeholders. This communication enables a dialogue that minimizes the need for emergency management personnel to directly solicit localized information. By removing the human interaction for these devices, Harris County residents get the opportunity to seek out unfiltered, raw, and localized information. The challenge for most of these mediums is the measure of the public usage of this information. For many reasons, residents may not have the opportunity to monitor these information streams, and will likely rely on other legacy mass communication systems, such as newsprint, TV, and radio. Technology-based solutions that bridge the gap between legacy and modern communications systems are in the early stages of development. Until such technology is realized, legacy media information consumers and social media information consumers will need separate methodologies to guide the information dissemination process.

The Flood Warning System (FWS), a product of the Harris County Flood Control District (HCFCD), measures rainfall and monitors water levels within the waterways of Harris County.²³⁰ Data is sourced from a network of automated sensors strategically placed throughout Harris County. The near real-time information from these gauges is available to the public via website. FWS uses an interactive mapping system where users can input their address and layer the displayed map with several GIS features, including drainage channels, regional topography,

²³⁰ Harris County Flood Control District. 2017. "Harris County Flood Warning System." <https://www.harriscountyfws.org> (October 8, 2017).

water levels, and rainfall. This allows for the user to factor their proximity to sensors when making individual risk decisions. The technology is within an overarching definition of the “Internet of Things” (IoT) as these flood monitoring sensors use the internet to send sensor data to officials, supplanting the need for human inspections of water levels.²³¹ Further, the 154 sensors of the Flood Warning System operate autonomously, requiring no physical inspection until they present a fault. The data is continuously integrated into the Harris County Flood Warning System website and displayed in a user-friendly format, provided the user is accessing from a desktop platform. As the network of sensors are vital to HCOHSEM’s ability to advise the public on flood-related events, it is equally vital to maximize system resilience. Currently, each sensor transmits its data individually via radio signal. Data is relayed through two repeater towers to a base station.²³² Also, each sensor requires a wired power supply. This design stifles system resilience; if the repeater towers fail, or sensors lose power, the system is rendered unusable.

New “smart” IoT technology has the ability to significantly increase system resilience. This technology is designed around a low-power IEEE 802.15.4e wireless mesh network.²³³ This type of system allows integrated sensors to communicate data via Ethernet or cellular data connection, and also incorporates data routing capabilities into each sensor. Because of this, each sensor does not need a direct link to its end destination; sensors can receive information from other sensors to pass on, thus creating nearly innumerable pathways to transmit data between a

²³¹ Janusaitis, Bob. 2017. “Hurricane Harvey Observations.”

²³² Harris County Flood Control District. *n.d.* “About FWS.”

<https://www.harriscountyfws.org/About> (October 8, 2017).

²³³ B+B SmartWorx. 2014. “Smart IoT Technology for Flood and Water Level Monitoring.” <http://advantech-bb.com/smart-iot-technology-for-flood-and-water-level-monitoring> (October 8, 2017).

sensor and the end destination. Further, sensors using low power mesh network technology and do not require a direct AC power connection. Without the need to tap into an AC power source (such as the electrical grid or a portable generator), sensors can be placed nearly anywhere, requiring far less infrastructure support than the current sensor system in use by the HCFCFCD. A system that incorporates low power mesh network technology is substantially more resilient to adverse weather conditions and other hazards. In the case of localized cell network or power outages, data is automatically rerouted around the outage. Absent a long-term, regional wireless communication outage, these devices will continue to operate autonomously, feeding data to anyone who accesses the website.

The information from the Flood Warning System (FWS) appears to be well supported and only lacks socialization. The average citizen may not know this tool is available to help them monitor flooding in their area. Also, even though the interactive website is designed to be easy to use, some novice computer users may have difficulty navigating the website and understanding the information it provides. Additionally, citizens without a home computer will experience difficulty using the FWS website as it is not optimized for mobile devices. To the credit of emergency managers, the web portal to the FWS is socialized beyond the HCFCFCD website.²³⁴ The HCFCFCD uses Twitter and Facebook to broadcast information obtained from the FWS.^{235 236} While both social media feeds include frequent posts containing information from the FWS, HCFCFCD rarely mentions the FWS in their social media posts, or the web portal to the FWS

²³⁴ Harris County Flood Control District. 2017. "Interactive Mapping Tools." <https://www.hcfcfd.org/interactive-mapping-tools/harris-county-flood-warning-system> (October 5, 2017).

²³⁵ Twitter. 2017. "HCFCFCD." <http://www.twitter.com/hcfcfd> (October 8, 2017).

²³⁶ Facebook. 2017. "Harris County Flood Control District." <http://www.facebook.com/hcfcfd> (October 8, 2017).

interactive mapping tools. HCFCD has made progress in socializing these warning resources digitally, however it would not be a leap of the imagination to suggest that most citizens are not aware of these tools. In a county of an estimated 4.6 million people, HCFCD has a social media following of only 11,000 followers on Twitter and 6,340 followers on Facebook.^{237 238 239} This problem is made worse by the fact that HCOHSEM does not appear to spread information about these services via their dedicated digital communication vehicles. Additionally, this research team found no mention of the Flood Warning System on the HCOHSEM website, and the most recent social media post regarding the Flood Warning System was in 2015.²⁴⁰

Outside of Twitter and Facebook, additional social media platforms that saw extensive ad-hoc use by residents during Hurricane Harvey include Nextdoor and Zello.²⁴¹ Nextdoor is a free, private, and secured social networking service that connects users within a defined geographical area.²⁴² Zello is an application that functionally operates as a Push-To-Talk (PTT) communication system, using cellular and internet networks.²⁴³ Multiple users can simultaneously connect via computers, phones, tablets, or other connected devices in real time. Zello saw heavy use during Hurricane Harvey, as it became the preferred method for ad-hoc volunteers who engaged in rescue activities to directly communicate with impacted residents seeking rescue. Nextdoor and Zello added an additional layer of communication between the various users of the app and government stakeholders. While this is not necessarily a reliable

²³⁷ U.S. Census Bureau. "Harris County Quick Facts."

²³⁸ Twitter. "HCFCD."

²³⁹ Facebook. "Harris County Flood Control District."

²⁴⁰ Harris County Flood Control District. "Harris County Flood Control District."

²⁴¹ Janusaitis. "Hurricane Harvey Observations."

²⁴² Nextdoor. 2017. "About Us." https://nextdoor.com/about_us (October 5, 2017).

²⁴³ Zello. 2017. "Zello." <https://zellow.com> (October 8, 2017).

means of communicating, recent observations from Hurricane Harvey indicate that it did have some success in sharing information across the population. Notably, Nextdoor use in Houston saw an 800% increase in user traffic.²⁴⁴ Social media platforms such as Nextdoor and Zello are prime examples of communication vehicles that can augment the flow of information between the government and residents, but are not yet employed to their fullest potential.

Disseminating official notifications through social media was not a unique finding, but challenges do arise from using social media as an official method to communicate information during emergencies. Other sections discuss rumor control and the challenges that come from the usage of social media as a vehicle for information management, so it will not be discussed further here beyond the following: When the technological capacity of the 911 system is met, the public will reach out to whatever communication vehicle is available. This was demonstrably the case based on recent observations during Hurricane Harvey. Residents were quick to go beyond the 911 system and use social media to solicit assistance.²⁴⁵ While the use of social media in this manner would not normally be effective, it did help communicate general needs of individuals to emergency management personnel. In some instances, social media posts were successful in communicating the need for immediate aid when traditional systems (911) were unable to do so.²⁴⁶ Further reporting suggests that social media was reasonably effective, even if it was not by

²⁴⁴ Downen, Robert. 2017. "Volunteers, Neighbors Use Social Media as Lifelines During Harvey." Houston Chronicle, September 29.
<http://www.houstonchronicle.com/news/houston-texas/houston/article/Volunteers-neighbors-use-social-media-as-12241813.php&cmpid=twitter-premium> (October 9, 2017).

²⁴⁵ U.S. Fire Administration. Emergency Management and Response – Information Sharing and Analysis Center. 2017. "Social media vs. 9-1-1: make sure you and your community are ready." 2017. *The InfoGram* 17(37).
https://www.usfa.fema.gov/downloads/pdf/infograms/37_17.pdf (October 6, 2017).

²⁴⁶ Downen. "Volunteers, Neighbors Use Social Media as Lifelines During Harvey."

design.²⁴⁷ While social media did not effectively overcome the barriers of an overwhelmed 911 system, its use did enable spontaneous volunteers to directly assist citizens in immediate danger, thus providing needed response activities that ultimately saved lives. Several members of the research team were able to track the progress of friends and family who were affected by the disaster, including some who used Facebook as a primary means for coordinating a rescue.



Figures 7 and Figure 8. Facebook-Coordinated Rescue Efforts²⁴⁸

Harris County has invested in resources to overcome these challenges. One such resource is the Next Generation 911 (NG911). The State of Texas is actively working towards a statewide

²⁴⁷ O'Connor, Lydia. 2017. "How We Could Better Leverage Social Media During Disasters Like Harvey." *The Huffington Post*, September 5. http://www.huffingtonpost.com/entry/harvey-social-media_us_59a47f42e4b050afa90c1049 (October 6, 2017).

²⁴⁸ Upright, Rory. 2017. "Facebook news-feed rescue efforts."

upgrade of the 911 system.²⁴⁹ However, there was little evidence to confirm Harris County has completed or made substantial progress in the transition to NG911. While NG911 is unlikely to have prevented the sheer volume of Hurricane Harvey-related 911 calls from overloading public safety answering points and call centers, its implementation may have led to a stronger communication infrastructure. This may have helped mitigate system overload from the anticipated rapid increase in call volume associated with a major emergency event.²⁵⁰ Regardless of the source of information, the technological advancement of information management throughout the response architecture is progressing in the way it receives information about specific issues or general needs of the public. By way of automated sensors, developing technology around emergency management is not only being used by Harris County, it is also being used by the public in an increasing measure.²⁵¹

Harris County has also employed modern approaches to integrating messaging into the emergency management process. HCOHSEM uses the ReadyHarris app to provide users of connectable devices a direct line of communication to receive critical information.²⁵² It employs a basic location service to assist users in identifying local life safety facilities, including fire stations, hospitals, and shelters. It also has a map to identify flooding and emergency evacuation zones. This one-way communication of vetted information between HCOHSEM and the public

²⁴⁹ Hanson, Wayne. 2009. "Texas Issues Next Generation 911 Master Plan." *Government Technology: State & Local Government News Articles*.
<http://www.govtech.com/em/safety/Texas-Issues-Next-Generation.html> (October 6, 2017).

²⁵⁰ Janusaitis. "Hurricane Harvey Observations."

²⁵¹ Harris County. 2017. "Central Technology Services."
<https://cts.harriscountytexas.gov/Pages/psts.aspx> (October 6, 2017).

²⁵² Harris County Office of Homeland Security and Emergency Management. 2016. "Be prepared for a disaster."
<http://readydl.com/landing/eoc48201/index.html> (October 6, 2017).

allows for the clarity in communication necessary for swift and appropriate action during an emergency. Through an adjustable subscription, these alerts can be received via the app, text, or email. The explicit value in this form of technology is the users of the app are able to receive pertinent information directly from HCOHSEM, and take the appropriate action based on the information provided. Direct communication pathways from the official source to the receiver significantly decrease the opportunities for misinformation to spread and affect citizen action, thus increasing the likelihood citizens will engage in protective actions that maximize life safety.²⁵³ However, device applications are limited by the willingness or ability of citizens to use them. Complete data on the usage of the ReadyHarris app, including total number of downloads and user interaction with the app were not available for analysis. Publicly available data on the ReadyHarris app strongly suggests that the ReadyHarris app is substantially underutilized by the residents of Harris County. The ReadyHarris app is available for download on devices that use Apple iOS or Google Android.²⁵⁴ While Apple does not publicly release application download statistics, Google Android does so in predetermined ranges. Using this range, the ReadyHarris app has been installed on 5,000 to 10,000 devices.²⁵⁵ There are a number of possible explanations for the low number of downloads compared to the population of Harris County. Possibilities include poor marketing of the app to citizens, lack of availability in languages other than English and Spanish, and populations within Harris County not possessing app-compatible devices. If a goal for HCOHSEM is to use the ReadyHarris app as a primary communication

²⁵³ Steelman, *et al.* “What Information Do People Use, Trust, and Find Useful During a Disaster? Evidence from Five Large Fires.”

²⁵⁴ HCOHSEM. “Be prepared for a disaster.”

²⁵⁵ Google. 2017. “Ready Harris.”

<https://play.google.com/store/apps/details?id=com.quickseries.Harris&hl=en> (October 8, 2017).

vehicle with the public, then further study and analysis is warranted, beyond the scope of this paper, to determine how to increase market saturation of the ReadyHarris app.

HCOHSEM maintains an active presence on social media, notably Twitter and Facebook to disseminate information. Similar value is found in using these direct communication platforms, as they allow emergency managers to communicate directly, absent a filter, to the public for awareness and action. During Hurricane Harvey, HCOHSEM sent dozens of updates to their Facebook page.²⁵⁶ Twitter was updated at about the same rate.²⁵⁷ The use of social media is directly limited by the user, and how the user interacts with a particular social media platform. Some users may receive notifications through shared or retweeted posts that originate from registered and visible followers, or directly from HCOHSEM on Twitter or Facebook. Twitter and Facebook are the most popular social media platforms for HCOHSEM to interact with the public, with 33,500 people following the HCOHSEM @ReadyHarris Twitter feed and 14,630 following the @ReadyHarris Facebook page.^{258 259} HCOHSEM also automatically shares or retweets posts from “trusted sources” on its social media feeds. Current trusted sources for HCOHSEM include agencies that have a vested interest in the emergency management process, and most often hold a position in the county Emergency Operations Center (EOC).²⁶⁰ Notable trusted sources are the Harris County Sheriff's Office, Texas Department of Public Safety, United States Coast Guard, as well as various other local, state, and federal agencies.²⁶¹ Analysis

²⁵⁶ Facebook. 2017. “Ready Harris.” <https://www.facebook.com/ReadyHarris> (October 6, 2017).

²⁵⁷ Twitter. 2017. “Harris County OHSEM (@ReadyHarris).” <https://twitter.com/ReadyHarris> (October 6, 2017).

²⁵⁸ Twitter. “Harris County OHSEM.”

²⁵⁹ Facebook. “Harris County Office of Homeland Security and Emergency Management.”

²⁶⁰ Janusaitis. “Hurricane Harvey Observations.”

²⁶¹ Janusaitis. “Hurricane Harvey Observations.”

of HCOHSEM’s social media feeds identify relatively few posts of original content; most of the post on the feeds are shares/retweets from trusted sources. Although this methodology is in line with HCOHSEM’s *Social Media Standard Operating Guideline*, it also presents certain challenges.²⁶² Based on the information provided by HCOHSEM, there is not a mechanism within the information pipeline to review information from trusted sources. Because of this, there is potential to inadvertently disseminate misinformation or information that is not congruent with HCOHSEM’s message. Examples of vulnerabilities in the information management system are described in other areas of this analysis. The literature also suggests automatically sharing information from other organizations can jeopardize user trust and contribute to disaster fatigue. While citizens are more likely to trust information from official sources, there are a gamut of “official” sources of information, and the citizenry is unlikely able to identify all of the local, state, and federal agencies and their respective “official” roles in the emergency management process.²⁶³ Because of this, citizen trust in the HCOHSEM social media feeds can be negatively affected, even though the shared information is on a citizen-trusted feed. Alternatively, the citizenry is more likely to trust other agency information—thereby engaging in the desired action or sharing the social media post on their feeds - if it is prefaced with HCOHSEM original content.

However, it is nearly impossible to ascertain the demographics of users that have seen a HCOHSEM social media post; whether it be a Harris County resident, social media connection of a Harris County resident, or an unaffiliated interested party. Also, individual organizations

²⁶² Harris County Office of Homeland Security and Emergency Management. *n.d.* “*Social Media Standard Operating Guideline.*”

²⁶³ Steelman, *et al.* “What Information Do People Use, Trust, and Find Useful During a Disaster? Evidence from Five Large Fires.”

throughout the area have individual accounts that have variable usage. For example, the Houston Office of Emergency Management (OEM) has 33,600 Twitter followers and 12,165 Facebook followers.^{264 265} By comparison, other peer organizations have a comparable number of followers on their respective presences on social media; New York City OEM has 44,400 Twitter followers and 40,805 Facebook followers, Miami- Dade OEM has 11,100 Twitter followers and 6,951 Facebook followers.^{266 267 268 269} This data suggests the low saturation of local emergency management agencies in the social media market is systemic within the emergency management community and not limited to HCOHSEM.

Nevertheless, HCOHSEM has a vacuum in the impact that social media has on residents. While it is fundamentally impossible to determine the taxonomy of the users of either service, all of the available data would suggest many users are not seeking out information via social media from HCOHSEM. The value of social media may be better realized as a tool for the citizens for the foreseeable future until official government sites take a greater hold. This user-driven information sharing was evident in the response phase of Hurricane Harvey.²⁷⁰ By local users reaching out to each other via social media, evidenced by the previously-discussed use of

²⁶⁴ Twitter. 2017. "Houston Office of Emergency Management."

<https://twitter.com/HoustonOEM> (October 5, 2017).

²⁶⁵ Facebook. 2017. "Houston Office of Emergency Management."

<https://www.facebook.com/HoustonOEM> (October 5, 2017).

²⁶⁶ Twitter. 2017. "New York City Office of Emergency Management."

<https://twitter.com/nycoem> (October 5, 2017).

²⁶⁷ Facebook. 2017. "New York City Office of Emergency Management."

<https://www.facebook.com/NYCEmergencymanagement> (October 5, 2017).

²⁶⁸ Twitter. 2017. "Miami-Dade Emergency Management." <https://twitter.com/MiamiDadeEM> (October 5, 2017).

²⁶⁹ Facebook. 2017. "Miami-Dade Emergency Management."

<https://www.facebook.com/MiamiDadeCountyEM> (October 5, 2017).

²⁷⁰ Downen. "Volunteers, Neighbors use Social Media as Lifelines During Harvey."

Nextdoor and Zello, citizens were able to mobilize neighbors, spontaneous volunteers, and local responders to support rescue efforts. This became a more aggressive method of communication as the public became more aware that the use of social media was working to help connect victims of flooding with the rescue teams, both official and unofficial.

Although technological developments in communication mediums have extreme potential to create a paradigm shift in how information is distributed and shared during an emergency, there are some inherent limitations. Connected mobile devices are similar to their legacy media counterparts (television and radio) in that mobile devices need electrical power to work (to charge the battery) and a broadcasted network to receive information (cellular or data). If there is insufficient infrastructure to maintain these methods of communication and keep the devices powered, the ability to send and receive information via connected devices is drastically reduced.

Integration and Information Management

An essential part of any disaster response is the effective integration and analysis of information collected. This information management function has been identified as a critical capability across the nation.²⁷¹ To conduct this effectively, research has indicated there are best practices and opportunities for emergency management agencies to consider. Analysis provides details on current research as applied to Harris County's operations in addition to considerations founded in observations from the response to Hurricane Harvey.

Plans, Policies, and Procedures

There are many guidance documents that provide details on methods for analyzing information. Some provide overarching principles while others are established as requirements

²⁷¹ Department of Homeland Security. *National Incident Management System*.

by executive action. An understanding of these levels of guidance provides a foundation for the integration of items identified via the team's research. The following establishes what plans, policies, and procedures related to information management are currently in place across the entire community of Harris County. Recommendations for additions and deletions are included in a later portion of this report.

State. The State of Texas operates a 24/7 Watch Office to monitor threats and incidents across the State. Information is fed to this office by regionally placed personnel that liaise with other state and local officials. The HCOHSEM EOC provides and receives information via the Disaster District Committee.²⁷² Each Disaster District Committee liaises with County officials on behalf of the State Operations Center.²⁷³ Plans and procedures for this function exists, but were not available at the time of this report. Continued research will be needed to determine the extent to which State guidance supports effective integration of disaster response information.

Local. Harris County's warning operations are predicated on the County's Emergency Management Plan, specifically Annex I Public Information. The plan itself does not have significant information regarding the collection of information, rather it focuses on information dissemination, which is addressed later in this paper.²⁷⁴ Research found the HCOHSEM Regional Joint Information Center Plan was far more detailed in its description of public information operations. The plan guides the effective operations of the Harris County Regional

²⁷² State of Texas. 2017. "Texas Emergency Management Executive Guide: FY 2017 Edition." Austin, TX: Texas Dept. of Public Safety.

<http://www.dps.texas.gov/dem/GrantsResources/execGuide.pdf> (October 10, 2017).

²⁷³ State of Texas. "Texas Emergency Management Executive Guide: FY 2017 Edition."

²⁷⁴ HCOHSEM. "Annex I: Emergency Public Information."

Joint Information Center (RJIC).²⁷⁵ The plan is scalable and describes the functions necessary to fulfill the JIC mission for Harris County regardless of the incident size or available staff.²⁷⁶

The plan focuses on information dissemination, but also incorporates guidance on gathering and analyzing information. Personnel assigned to gather information during an incident “review reports from HCOHSEM partners, the news media, and the public,” to determine the applicability of the information for public dissemination.²⁷⁷ Social media is identified as a source of valuable intelligence for disaster operations. Staff in the RJIC use SnapTrends and TweetDeck, social media analysis platforms, to sift through the vast amount of social media related to an incident and forward it to other individuals in the RJIC and EOC.²⁷⁸ These products are mentioned in plans, but thus far there are limited details on the capabilities of the products’ implementation by HCOHSEM, other than its ability to maintain situational awareness across various social media platforms.²⁷⁹ This information can be valuable to the operation and its integration throughout the enterprise is essential to the effectiveness.

The plan’s appendices further provide the roles and responsibilities of the PIO and Assistant PIOs.²⁸⁰ Each Assistant PIO is given a functional area to supervise: RJIC Manager, Information Gathering & Document Production, Information Dissemination, and Social Media Management.²⁸¹ The integration of information gathered within the RJIC is managed by the

²⁷⁵ HCOHSEM. “Regional Joint Information Center Plan.”

²⁷⁶ HCOHSEM. “Regional Joint Information Center Plan.”

²⁷⁷ HCOHSEM. “Regional Joint Information Center Plan.” 4.

²⁷⁸ HCOHSEM. “Annex I: Emergency Public Information.”

²⁷⁹ Harris County Office of Homeland Security and Emergency Management. 2014. “Social Media Standard Operating Guidelines.” Houston, TX: Harris County Government.

²⁸⁰ HCOHSEM. “Regional Joint Information Center Plan.”

²⁸¹ HCOHSEM. “Regional Joint Information Center Plan.”

APIO over Information Gathering & Document Production.²⁸² This split of duties between information collection and document production leaves little room for information analysis.

Information Sources and Analysis

Any effective warning program must include relationships with various response partners.²⁸³ There are two aspects of information sources: source and type. Sources can be either internal or external, and types can be either format of information.²⁸⁴ In each of these categories, there are trusted sources. Emergency Management organizations must cultivate relationships within each of these categories before a disaster.²⁸⁵ Informal relationships are very effective at confirming information through unofficial channels.²⁸⁶ This can be due to the congestion of official channels during disaster operations.

Information can also be gathered through sensors placed throughout the community. During hurricane events, flood gauges provide valuable information regarding the status of swelling creeks and streams. These readings can serve to either confirm information from the public or lead RJIC staff to seek out information related to the status of a particular area. When combined with geospatial information systems, information gathered through sensors placed throughout the community can provide detailed information on the current situation as well as provide realistic forecasts when compared to historical data.²⁸⁷ Very similar to the use of amateur

²⁸² HCOHSEM. *Regional Joint Information Center Plan*.

²⁸³ EMI. *G272 Warning Coordination*.

²⁸⁴ Emergency Management Institute. *n.d. Situational Awareness and Common Operating Picture Course*. Emmitsburg, MD: Federal Emergency Management Agency.

²⁸⁵ EMI. *G272 Warning Coordination*.

²⁸⁶ Huder. *Disaster Operations and Decision Making*.

²⁸⁷ Alamdar, *et al.* "Towards multi-agency sensor information integration for disaster management." 68-85.

radio operators during severe weather, sensors can provide ground-truth information to confirm forecasts and expected events along the incident timeline.²⁸⁸

When HCOHSEM gathers information, staff must place a level of trust in the source of that information.²⁸⁹ In the information age, there is far more information available than there are resources to properly analyze it. Data mining programs are useful tools to sift through large amounts of data and identify vital information for operational purposes.²⁹⁰ However, in order for these programs to be effective, organizations must establish criteria well in advance to set a firm foundation for any data-mining operations.

Social Media

Social media has been one of the most innovative and disruptive technologies in modern human history.²⁹¹ Social media has created a new method for communication between public agencies and the public at large. The control of information, once the domain of the traditional media, has been put into the hands of the public. “Compared to traditional media, web-based social media technologies are characterized by greater capacity, dependability, and interactivity, each of which may be advantageous for disaster communications.”²⁹² The amount of information available to any person has expanded beyond comprehension. The information is far richer and

²⁸⁸ EMI. *G272 Warning Coordination*.

²⁸⁹ HCOHSEM. *Regional Joint Information Center Plan*.

²⁹⁰ Zheng, L., C. Shen, L. Tang, C. Zeng, T. Li, S. Luis, and S. Chen. 2013. “Data Mining Meets the Needs of Disaster Information Management.” *IEEE Transactions on Human-Machine Systems* 43(5).

²⁹¹ Hiltz and Plotnik. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

²⁹² Houston, J.B., J. Hawthorne, M.F. Perreault, E.H. Park, M.G. Hode, M.R. Halliwell, S.E.T. McGowen, R. David, S. Vaid, J.A. McElderry, & S.A. Griffith. 2014. “Social media and disasters: a functional framework for social media use in disaster planning, response, and research.” *Disasters* 39(1). 4.

creates a far more dynamic user experience than previously available.²⁹³ This has led to unprecedented opportunities for government and business. Emergency managers can utilize this disruption to their advantage. Most notably, it has created a means for collective intelligence that can be exploited for operational use.²⁹⁴

One of the greatest challenges related to effectively using social media is incorporating it into the overall operation. Social media has long been employed, with great success, by organizations seeking to push information to their customers.²⁹⁵ Social media also has a tremendous capacity for operational intelligence gathering. Integrating this type of information into the overall EOC response is critical to modern, effective disaster response. Harris County conducts information collection from social media within the RJIC.²⁹⁶ This information is then forwarded to the Operations Section of the EOC for consideration.²⁹⁷ The tactical hub of the operation, the EOC Operations Section is charged with making decisions about evacuations. The key capability necessary for a successful operation is to quickly sift and identify critical information.²⁹⁸

Research has indicated there are tools available to emergency managers to assist with the analysis of social media data. These tools consist of volunteer teams as well as information

²⁹³ Houston *et al.* “Social media and disasters: a functional framework for social media use in disaster planning, response, and research.”

²⁹⁴ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

²⁹⁵ NDPTC. 2016. *Social Media for Natural Disaster Response and Recovery*. Honolulu, HI: University of Hawaii.

²⁹⁶ HCOHSEM. “Annex I: Emergency Public Information.”

²⁹⁷ Department of Homeland Security. *National Incident Management System*.

²⁹⁸ Hiltz and Plotnick. “Dealing with Information Overload When Using Social Media for Emergency Management: Emerging Solutions.”

technology.²⁹⁹ Utilizing a disruptive technology requires an innovative and disruptive approach, due to the evolving nature of these types of technologies.³⁰⁰ Virtual Operations Support Teams (VOSTs) have been established across the world to augment emergency management personnel in the social media space.³⁰¹ The virtual nature of social media allows for virtual volunteers to support information collection and analysis efforts.³⁰² While not currently used by HCOHSEM, this innovative approach to incorporating social media into emergency management operations serves as a force multiplier to EOC staff already taxed with data collection and analysis.

The other set of tools available to emergency managers involves the use of information technology platforms. There are many tools, used by various industries, to perform data-mining of the wealth of information found on social media.³⁰³ Research indicates practitioners should continually evaluate their needs against the market of available technology tools.³⁰⁴ The significance of these tools is evident in the policies provided by Harris County. The use of SnapTrends and other applications show the importance of social media in the HCOHSEM emergency management process. As technology continues to evolve, HCOHSEM should continue to evaluate available tools against their information needs.

²⁹⁹ Stern, E. 2017. “Unpacking and Exploring the Relationship between Crisis Management and Social Media in the Era of ‘Smart Devices.’” *Homeland Security Affairs*, 13(4).

³⁰⁰ Houston *et al.* “Social media and disasters: a functional framework for social media use in disaster planning, response, and research.”

³⁰¹ NDPTC. *Social Media for Natural Disaster Response and Recovery*.

³⁰² Cobb, C., T. McCarthy, A. Perkins, A. Bharadwaj, J. Comis, B. Do, and K. Starbird. 2014. “Designing for the Deluge: Understanding & Supporting the Distributed, Collaborative Work of Crisis Volunteers.” *CSCW ’14 Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*: 888-899.

³⁰³ NDPTC. *Social Media Tools and Tactics*.

³⁰⁴ Stern. “Unpacking and Exploring the Relationship between Crisis Management and Social Media in the Era of ‘Smart Devices.’”

Information Management

During an emergency or disaster event, communication is crucial. It comes in many forms and from multiple agencies, first responders, citizens, etc. One thing all these sources have in common is they provide both useful information needed by decision makers, as well as not-so-useful noise which may be a barrier to effective communication. One might think to have so much information coming in was a great thing, but in fact, sometimes the number of incoming reports and volume of data can be overwhelming.³⁰⁵ This deluge of data must be addressed as a lack of information, but in a different manner.

Information management is defined, according to the Association for Information and Image Management (AIIM), as “the collection and management of information from one or more sources and the distribution of that information to one or more audiences.”³⁰⁶ HCOHSEM manages information both through the RJIC and the EOC. During Hurricane Harvey, for the purposes of warnings and public information, the interface between the HCOHSEM EOC and other City EOCs was made through the RJIC.³⁰⁷ While other touch-points between staff at affected EOCs are likely to have existed, the RJIC’s interface ensured public messaging across local and state agencies were synchronized.³⁰⁸

To help manage the information, many companies are developing technologies to make it easier for decision-makers to make informed decisions. While not perfect, much of the technology has been helpful and improvements will likely make the applications more available

³⁰⁵ Wheeler, Bill. 2017. Personal Interview. June 28. College Station: Texas A&M University.

³⁰⁶ Association for Information and Image Management. 2017. “What Does That Mean?”
<http://www.aiim.org/Resources/Glossary/Information-Management> (October 10, 2017).

³⁰⁷ Janusaitis. “Hurricane Harvey Observations.”

³⁰⁸ Janusaitis. “Hurricane Harvey Observations.”

and better at what they do. For instance, research indicated the use of information management software was found to positively affect decision making during an event.³⁰⁹ This is a single example, but it shows the potential of software to impact information management during emergencies and disaster events. The State of Texas has endorsed the utilization of WebEOC, a disaster information management tool, and makes it available to local jurisdictions.³¹⁰ Harris County uses this tool to facilitate formal information and resource requests to and from the State of Texas.³¹¹ The tool has additional capabilities for managing information during disaster response, but HCOHSEM has chosen to limit its implementation to the Texas Division of Emergency Management formal information and resource request processes.³¹² Documentation provided to the research team makes brief references to PIER, which supports the collaboration of public information professionals.³¹³ The research team, however, has been informed this product is in the process of being discontinued by Harris County.³¹⁴

One of the primary functions of an EOC is to manage information.³¹⁵ To function properly, information must flow in and out of an EOC in a manner that is both expedient and authorized by management or policy.³¹⁶ “The EOC is ultimately a center for information management and decision making.”³¹⁷ This decision making has to occur with a level of

³⁰⁹ Ntuen *et al.* "Designing an Information Visualization Tool for Sensemaking."

³¹⁰ State of Texas. "Texas Emergency Management Executive Guide: FY 2017 Edition."

³¹¹ Janusaitis. "Hurricane Harvey Observations."

³¹² Janusaitis. "Hurricane Harvey Observations."

³¹³ Janusaitis. "Hurricane Harvey Observations."

³¹⁴ Janusaitis. "Hurricane Harvey Observations."

³¹⁵ NERRTC. 2016. *Emergency Operations Center (EOC) Operations and Planning for All-Hazards Events*. College Station, TX: Texas A&M University.

³¹⁶ Huder. *Disaster Operations and Decision Making*.

³¹⁷ NERRTC. *Emergency Operations Center (EOC) Operations and Planning for All-Hazards Events*. 2-11.

confidence that is difficult to attain in the ever-changing environment of disasters.³¹⁸ Many times, decision makers are expected to make decisions with less than optimal knowledge of the situation on the ground.³¹⁹ NERRTC provides a unique method for effectively managing the information in an incident:

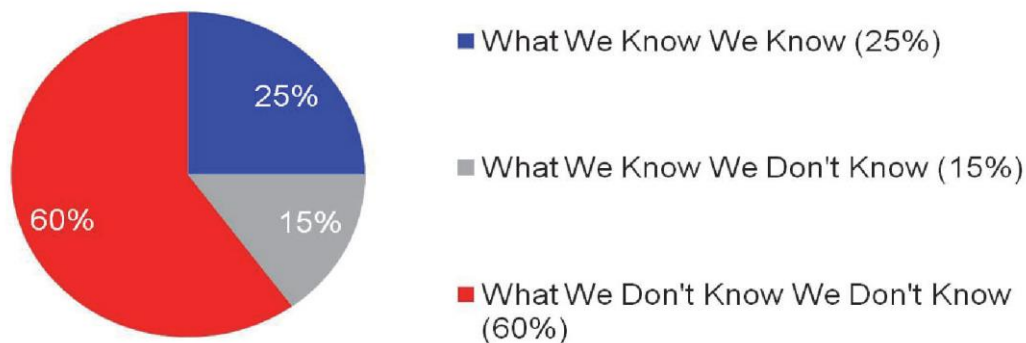


Figure 9. Managing Information in an Incident³²⁰

The “Red Slice,” or the unknown unknowns, is attributed to many of the failures in disaster operations.³²¹ Therefore, EOC’s must stand ready to limit the “Red Slice” as much as possible. This can be accomplished through the use of policies, procedures, and technology supporting information management.³²² While there may be policies in place within the Harris County EOC or RJIC to address this issue, research did not reveal any specific plans, policies, or procedures to address this aspect of information management.

³¹⁸ Carver and Turoff. “Human-computer interaction.”

³¹⁹ Carver and Turoff. “Human-computer interaction.”

³²⁰ NERRTC. *Emergency Operations Center (EOC) Operations and Planning for All-Hazards Events*. 4-8.

³²¹ NERRTC. *Emergency Operations Center (EOC) Operations and Planning for All-Hazards Events*.

³²² Bharosa *et al.* “Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises.” 49-65.

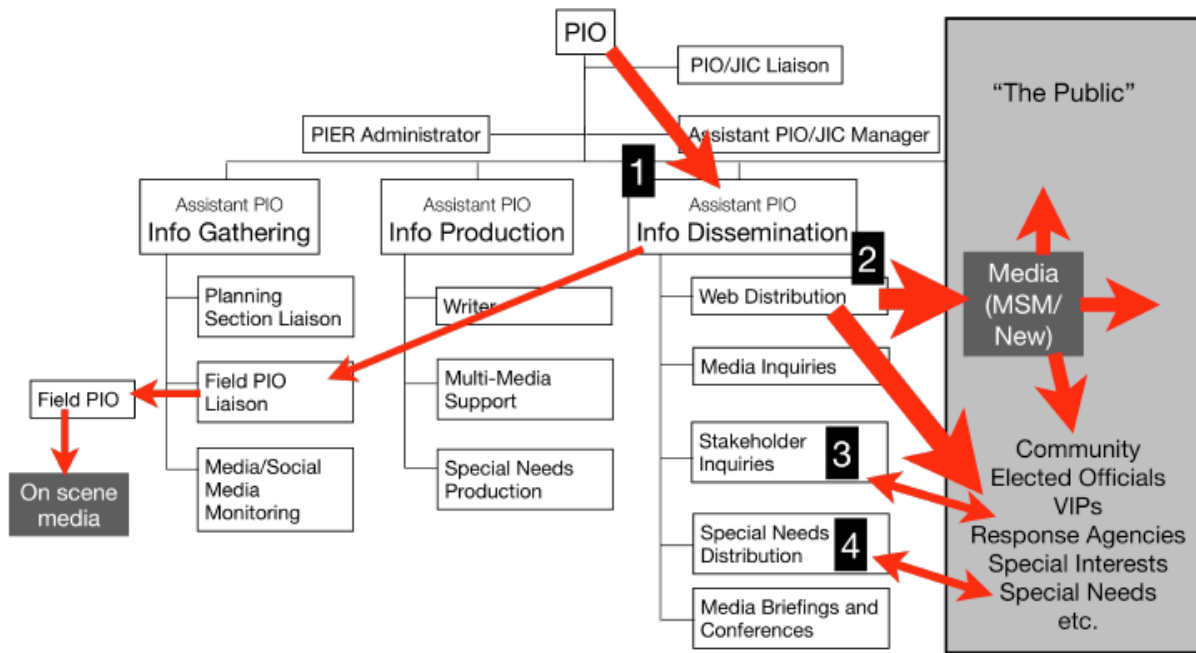


Figure 10. Information Dissemination³²³

Information within the HCOHSEM RJIC is shared through the Information Dissemination component.³²⁴ The Assistant PIO over this area controls what information is provided to the various entities and stakeholders supported via the RJIC.³²⁵ At this point, the Assistant PIO over Information Dissemination manages the processes involved in sending that information to applicable destinations; e.g., a website, social media, stakeholders, special needs populations, and field PIOs.³²⁶ The sharing of information beyond the RJIC must be explicitly approved by the PIO and IC.³²⁷ In a fast-moving incident, this process must happen very quickly

³²³ Harris County Office of Homeland Security and Emergency Management. *n.d.* “JIC Communication Workflow.” Houston, TX: Harris County Government. 2.

³²⁴ HCOHSEM. “JIC Communication Workflow.”

³²⁵ HCOHSEM. “JIC Communication Workflow.”

³²⁶ HCOHSEM. “JIC Communication Workflow.”

³²⁷ HCOHSEM. “Regional Joint Information Center Plan.”

and may need to be augmented with standing orders to facilitate the timely sharing of information to the appropriate destination.

Situational Awareness and Common Operating Picture

Information gathered within the confines of a disaster is collected, in part, to inform responder situational awareness. In this context, situational awareness is defined as “the result of comprehensive information collection, analysis, and dissemination in a context relevant to the authorities and responsibilities of a particular organization level.”³²⁸ There are three essential elements to proper situational awareness: perception, comprehension, and projection.³²⁹ The information integration aspects of situation focus on the latter two: comprehension and projection. As information is analyzed, staff members must share critical information to appropriate stakeholders. Currently, the HCOHSEM RJIC Plan provides that a Stakeholder Inquiry group will manage these relationships.³³⁰ These requests are tracked via a Status Board and incorporated into any future news releases and press conferences.³³¹ This was essential to managing rumors that were rampant throughout the incident through collaborative relationships with HCOHSEM’s stakeholders.³³²

Choosing the appropriate information to share is a difficult task.³³³ This process is informed by the established Essential Elements of Information (EEl)s.³³⁴ Essential elements of

³²⁸ Federal Emergency Management Agency. 2011. *National Incident Support Manual*. Washington, D.C.: Dept. of Homeland Security. 20.

³²⁹ EMI. *Situational Awareness Common Operating Picture Course*.

³³⁰ HCOHSEM. “Regional Joint Information Center Plan.”

³³¹ HCOHSEM. “Regional Joint Information Center Plan.”

³³² Janusaitis. “Hurricane Harvey Observations.”

³³³ Huder. *Disaster Operations and Decision Making*.

³³⁴ EMI. *Situational Awareness and Common Operating Picture*.

information are predetermined pieces of information necessary for decision making.³³⁵ In this context, EEs inform what situational awareness is important to share across multiple entities. This concept of shared situational awareness facilitates what is known as the Common Operating Picture.³³⁶ Having a Common Operating Picture among emergency management and response personnel ensures for standardized information across the entire response enterprise.³³⁷

The HCOHSEM common operating picture is currently maintained by the Emergency Operations Center.³³⁸ There are several tools available to manage the COP throughout the operation. The RJIC provides information to the EOC's COP via interfaces with both the Planning and Operations Sections.³³⁹ Operational and tactical information typically remains in the EOC, with selected information forwarded to JIC typically in situations public safety officials determine a need for warning and evacuations.³⁴⁰

The integration of sensors via geographic information systems has proven valuable in increasing the timeliness and effectiveness of warnings by local officials.³⁴¹ Sensors, such as flood gauges, can provide excellent information to either confirm or deny reports from the field. Combined with social media reports and citizen reporting, a geographic view of intelligence received along with other data sets, such as floodplain and storm surge maps for flooding incidents, reveal additional insight beyond what is initially apparent.³⁴² HCOHSEM uses the

³³⁵ EMI. *Situational Awareness and Common Operating Picture*.

³³⁶ EMI. *Situational Awareness and Common Operating Picture*.

³³⁷ FEMA. *National Incident Support Manual*.

³³⁸ Janusaitis. "Hurricane Harvey Observations."

³³⁹ HCOHSEM. "JIC Communication Workflow."

³⁴⁰ Janusaitis. "Hurricane Harvey Observations."

³⁴¹ Foresti *et al.* "Situational awareness in smart environments: socio-mobile and sensor data fusion for emergency response to disasters."

³⁴² Foresti *et al.* "Situational awareness in smart environments: socio-mobile and sensor data fusion for emergency response to disasters."

sensor data from the Harris County Flood Control District to assist in warning process.³⁴³ This information results in far more granular warnings than what are provided by either the Emergency Alert System (EAS) or the National Weather Service (NWS).³⁴⁴ This insight, when used in the context of warning decisions, sets the stage for effective, timely, and targeted public warnings.

³⁴³ Janusaitis. “Hurricane Harvey Observations.”

³⁴⁴ Janusaitis. “Hurricane Harvey Observations.”

Conclusion

In emergency management, effective citizen response to messaging is dependent upon effective information management and communication. This point was made clear by the client's request for research and the subsequent meeting with the research team to finalize the desired research focus. Throughout the course of our research, the client was updated regarding the research progress. This included periodic status updates by the research team providing the needed inputs to ensure the best possible product to address their information management situation. These updates proved to be an invaluable source of scoping, updates on current processes, and recent lessons learned, especially in the immediate response to Hurricane Harvey. These periodic updates provided much needed clarification to the research team throughout the course of the project as new information became available and research priorities shifted or became more focused.

In addition to the periodic inputs from the client, a comprehensive literature review enabled the research team to develop the baseline level of knowledge required to conduct a thorough study on emergency management-specific information flow. This entailed reviewing the relevant federal doctrine, to include precursor products on which the current federal guidelines for emergency administration were built. This was important to ensure that HCOHSEM is foundationally sound in its structure and that it operates in accordance with federal guidelines. In addition to analyzing the relevant doctrinal information, a wide breadth of academic as well as observational sources were studied by the research team in order to provide a well-rounded approach to analyze the components that comprise the information cycle. These academic sources, as well as the published case studies, contained a vast amount of applicable information on how emergency management is applied in real-world scenarios. This aspect of

the literature review became especially important in the short-term response to Hurricane Harvey, when all the team had to rely on news reports, first-hand accounts, and real-time observations for information relating to the hurricane.

In a similar vein, the methodology used for this study was an essential element to its overall success. The Action Research model using a Purposeful Design contributed to the immediate incorporation of new data and allowed for a flexible response to the client's requests. By effectively employing this methodology and using the basis of knowledge gained in a comprehensive literature review, this research team examined nearly all aspects of the HCOHSEM information management structure. The information cycle was analyzed in great depth to identify potential sources of friction which could act as a barrier to effective information flow. Some examples of such potential barriers were the physical layout of the RJIC, the hierarchy involved with releasing a public message, and the standard operating procedures guiding the organization. These individual elements were examined to further understand and solve the information flow problem. The research team discovered that there is no singular, simple solution for improving HCOHSEM operations during an emergency event. The challenge of continuous improvement is complicated by the understanding that there is little tolerance for error by HCOHSEM. As one official said, "I have to communicate, and I can't make a mistake." This fact, along with the increasing burden of rumor control and citizen interaction/reaction to an emergency notification or event, implies that the information management challenge will only continue to grow as more information is passed back-and-forth between Harris County officials and the citizens they serve.

This project found no significant structural or organizational changes are necessary in order to improve the challenging information management environment. HCOHSEM conforms

to the doctrinal guidelines established by federal sources and is a leader in state and local response plans. The culture of the organization, as well as its structure, facilitates information sharing and management. However, there are some organizational processes that may facilitate the flow of information during an emergency event, such as reviewing workflow processes on a yearly basis to incorporate new technologies as they emerge. There are some recommendations tied to the human factors involved with responding to official communication, as well as more effective message crafting practices that may lead to more citizen protective action following notification. Some of these recommendations can be implemented at little or no cost by HCOHSEM; however, some of them may require a more in-depth shift in paradigm regarding how the organization communicates with its followers.

Some of the recommendations focus on a more robust ReadyHarris application, which may require an additional amount of capital investment by HCOHSEM. The most investment-heavy recommendations involve establishing communications committees, increasing staffing, and implementing a more robust information network for emergency response. The research team also notes that a complex problem will necessitate a complex solution, and while these recommendations may be implemented singularly, they are intended to provide a holistic course of action to solving the information management challenge.

It is evident that HCOHSEM is a recognized industry leader in the field of emergency management. As such, the willingness to share the knowledge and findings presented in this project may be of great benefit to emergency leaders across the nation. These recommendations presented by this team are based on the most current and modern practices in emergency management with the inclusion of several first-hand lessons learned and observations of the response to Hurricane Harvey. While the response efforts are still ongoing, there is an enormous

potential for future research to determine what best practices outside of the established doctrine were effective in responding to the largest hurricane to strike Texas since 1961.

The following recommendations will provide HCOHSEM with actionable efforts to change their information management process. Some of these recommendations will require significant procedural modifications to the operational routine, while others can be more easily implemented. This team strongly supports the full consideration of these recommendations, and their implementation to the greatest extent practical to facilitate HCOHSEM's goals, which this research has been conducted to support. Each recommendation is presented with the intent of improving processes and effectiveness at HCOHSEM, ultimately resulting in improvements within the organization and in a safer Harris County.

Recommendations

Recommendation 1: Improve the ability to communicate warnings across all platforms to non-English speaking residents of Harris County. Improvements can be made to the ReadyHarris.org website, the ReadyHarris app, as well as HCOHSEM’s Facebook and Twitter accounts.

Harris County is the most ethnically diverse large metropolitan area in the country. The wide range of cultures and languages represented across the county necessitates HCOHSEM adopt a variety of approaches in order to ensure emergency message notifications are received, understood, and have the desired impact. Understanding this principle, ReadyHarris.org is currently available in five languages English, Chinese, French, Spanish, and Vietnamese.³⁴⁵ The website’s visitors are able to change language with a “Select Language” drop down menu:



Figure 11. ReadyHarris.org “Select Language” function³⁴⁶

HCOHSEM should consider including multiple language options on ReadyHarris.org directly on the page rather than through a drop-down menu. Those visiting the website who are unable to read the English language may not recognize the “Select Language” option and leave ReadyHarris.org to seek information from other sources. Alternate language options can be made available through links on the main page and written in the

³⁴⁵ HCOHSEM. “ReadyHarris.org.”

³⁴⁶ HCOHSEM. “ReadyHarris.org.”

language of the user to assist non-English reading visitors. The New York State Homeland Security and Emergency Services website provides an example of this:



Figure 12. NY Homeland Security and Emergency Services Language Assistance³⁴⁷

HCOHSEM should create separate ReadyHarris Facebook and Twitter pages in Spanish in order to increase engagement with the Spanish-speaking population of Harris County. The Hispanic population in Harris County increased by 15% from 2010 to 2016, and Latinos accounts for 42% of the total population for the county.^{348 349} With the growth of the Hispanic population in Texas, it is important for HCOHSEM to increase its engagement with the Latino community. New Facebook and Twitter pages using Spanish as their primary language are simple, yet highly effective methods of engaging this growing component of Harris County.

³⁴⁷ New York State Homeland Security and Emergency Services. *n.d.* "Homeland Security and Emergency Services." <http://www.dhSES.ny.gov> (October 26, 2017).

³⁴⁸ Loeb, Vernon. 2017. "Harris County's Hispanic population growth leads the U.S." Houston Chronicle, June 22. <http://www.houstonchronicle.com/local/gray-matters/article/Harris-County-s-Hispanic-population-growth-leads-11239038.php> (October 26, 2017).

³⁴⁹ U.S. Census Bureau. "QuickFacts."

Recommendation 2: Increase the advertisement and outreach of the State of Texas Emergency Assistance Registry (STEAR) program to better assist those with functional and access needs during an emergency.

The State of Texas Emergency Assistance Registry (STEAR) “is a free registry that provides local emergency planners and emergency responders with additional information on the needs in their community.”³⁵⁰ The system is designed to collect information for local jurisdictions regarding those with disabilities, functional, or access needs. This may include issues such as limited mobility, communication barriers, those in need of transportation, or personal care.³⁵¹ STEAR is a free and voluntary service provided by the Texas Division of Emergency Management (TDEM). Registration on this program is not a guarantee that local emergency responders will provide a specific service, but can provide the region or jurisdiction with actionable information about needs of the some of the most at-risk populations during an emergency. STEAR also aids HCOHSEM with “their planning, response, and recovery effort.”³⁵²

HCOHSEM should undertake a public awareness campaign to increase awareness for groups that require extra assistance in an emergency. The vision and mission of HCOHSEM is to “Develop and assist in the delivery of effective public outreach programs” and “collect, provide, and disseminate information” in order to protect the residents of Harris County

³⁵⁰ Texas Department of Public Safety. Texas Department of Emergency Management. 2017. “State of Texas Emergency Assistance Registry (STEAR) – Public.” <https://www.dps.texas.gov/dem/stear/public.htm> (November 19, 2017).

³⁵¹ TxDPS. TDEM. “STEAR.”

³⁵² TxDPS. TDEM. “STEAR.”

during an emergency.³⁵³ The data collected through STEAR can provide vital intelligence to first responders as well providing targeted messages to specific populations in the community.

There was only one mention of STEAR in the 2016 Annual Report stating United Way registers residents for the STEAR program.³⁵⁴ The HCOHSEM website provides a link for 2-1-1 and United Way, and should also provide a link to easily access STEAR.

HCOHSEM should have a direct link to the STEAR database on the ReadyHarris website to generate more participation in the STEAR program. An information database is only as good as the data entered into it, and if the residents of Harris County are not aware of the system, they cannot use it. The intelligence gathered through system could prove vital in an emergency.

Recommendation 3: Improve the interactive data exchange on the ReadyHarris application.

HCOHSEM should integrate technology that allows for two-way communication via the ReadyHarris application. Harris County and its citizens would benefit from the ability to send and receive information to and from one-another. One such example is Waze, a mobile app owned and maintained by Google, which calls itself “the world’s largest community-based traffic and navigation app.”³⁵⁵ By incorporating Waze-like features into the ReadyHarris app, HCOHSEM would not only provide a more useful tool for Harris County residents to use, but it would open another conduit of communication. In an emergency event, this may prove to be an

³⁵³ Harris County Office of Homeland Security and Emergency Management. 2017. “Vision and Mission.” <http://hcohsem.org> (October 13, 2017).

³⁵⁴ HCOHSEM. “2016 Annual Report.”

³⁵⁵ Waze. 2017. “Waze.” <https://www.waze.com> (August 1, 2017).

extremely important asset for emergency managers, especially if the app gains the same popularity as Waze has achieved.

Google has formed partnerships with communities through programs like Waze to assist first responders' organizations. In October, 2014, Waze has conducted its Connected Citizens Program, an initiative providing two-way data sharing between state and local governments.³⁵⁶

Partner governments receive input data about road conditions and hazards submitted by users via the app. **HCOHSEM should explore the potential partnerships available with Google and other technology companies in order to modernize the technical tools they employ.**

Exploring these partnerships will ensure that HCOHSEM remains on the cutting edge of technical advances, and remains at the forefront of the emergency management industry.

Recommendation 4: Improve the rate of download and performance of the ReadyHarris app across multiple software platforms (iOS, Android, etc.).

In September 2016, HCOHSEM released the ReadyHarris App for use on smartphones, tablets, and other mobile devices. The application provides near real-time notifications and instructions to individuals facing a wide range of emergencies. With their release of the application, Harris County intended to provide information for some sort of citizen protective action in response to the emergency. With a population of 4.5 million residents and an ever-increasing instance of emergency events, it is critical that Harris County officials have a credible means to inform and instruct the public in a timely manner.

Though Harris County saw initial success with its release of the ReadyHarris application, the number of citizens who have downloaded the application seems minimal in

³⁵⁶ Waze. 2017. "Connected Citizens Program." <https://www.waze.com/ccp> (August 2, 2017).

light of the county's total population. As of the end of June, nine months after the application's release and a month into Harris County's hurricane season, only 12,300 downloads have been recorded across both platforms.³⁵⁷ This figure indicates less than one percent of Harris County citizens have downloaded and are using the application. A review of publicly available sources explains the possible reason for the limited downloads: the application tends to fail.³⁵⁸ Multiple reviews of the application on the Android platform state the application frequently fails to open, crashes unexpectedly, and otherwise fails to perform as expected. As a result, the application has received fairly low reviews, which may further discourage citizens from downloading it.

Harris County should increase the allotment of funding to improve the ReadyHarris application and to increase its use among citizens. Software designers must improve the ReadyHarris application to ensure it operates at peak performance and does not crash or otherwise malfunction during normal use. Additionally, **Harris County should implement a campaign to increase the public's awareness of the application, and to inform current users of the added features and stability of the improved application.** This will increase the number of downloads for the ReadyHarris app, and will also encourage individuals who may have previously tried the application to download it again.

Recommendation 5: Establish a standing communications committee.

³⁵⁷ Harris County. 2017. "Award-Winning Emergency Preparedness App Available to the Public" July 17. Harris County Commissioners Court.
<http://www.hcp4.net/newsroom/articleid/155/award-winning-emergency-preparedness-app-available-to-the-public> (October 22, 2017).

³⁵⁸ Google Android. 2017. "ReadyHarris Reviews." Google Play.
<https://play.google.com/store/apps/details?id=com.quickseries.Harris&hl=en> (October 22, 2017).

Communication is the backbone of any successful operation. Messaging begins with a strong understanding of the community to be serviced. From the literature review, it is evident “standard all-hazards emergency preparedness risk and response communications efforts do not always reach people with barriers relating to literacy, language, culture, or disability.”³⁵⁹ For example, dealing with the hard of hearing community is challenging during an emergency. With this in mind, **HCOHSEM should establish a standing Community Communications Committee. The makeup of the committee should include members from various groups or organizations who can represent the larger diverse populations of the community.** The committee would act as a sounding board for messages created by HCOHSEM. This will help authorities to understand the best way to communicate a message to various communities.

Recommendation 6: Review the Harris County JIC Communication Workflow for opportunities to incorporate emerging communications trends.

Our research indicates that social media, like technology, is changing at an ever-increasing rate. The ability to stay abreast of the latest trends is an essential component of communicating with an increasingly tech-savvy public. The incorporation of new trends in social media must include the ability to integrate across multiple social media platforms. This capability needs to address both the information collection and dissemination aspects of public information, as social media’s two-way communication capability blurs the lines between a single threaded public information processes.

HCOHSEM should review the JIC Communications Workflow and consider revising the document. The revision should consider updating the “Notifications” section to

³⁵⁹ Engelman, Alina Anna. *Addressing Disparities in Emergency Communication with the Deaf and Hard-of- Hearing: Cultural Competence and Preparedness for First Responders*. 1.

review the latest forms of social media communications. Social media has expanded beyond the “Text, phone, and email distributions,” listed in the workflow notifications section.³⁶⁰

Reviewing the document on an annual basis will allow for new and emerging communications mediums to be incorporated quickly. These new mediums of communication can have an impact on the required personnel and tools required for an effective response. Additional resources related to these new communications mediums/methods must be allocated and planned for before an event occurs.

Recommendation 7: Incorporate routine analysis of new and emerging information technologies for use the RJIC.

The analysis of public information, specifically social media, is a critical component to any modern disaster response, as evidenced by the prominent role it played in the response to Hurricane Harvey. Tools and processes are available to assist emergency managers in analyzing the vast sea of social media data, however, tools are of little use without the staff to employ them. **HCOHSEM should add a role for the Web Distribution Specialist to monitor and manage changing social media trends** specific to new and emerging communication technologies as they relate to their role in the RJIC’s response. **Harris County should also provide for the needed personnel and equipment to carry out the receipt and redistribution of vetted information from these new sources in a timely manner.** The specialist can be trained, but also needs standard orders to address questions as they arise. **HCOHSEM should create standard orders and give trained personnel the authority to act on questions/comments to facilitate information flow and interaction with the community.**

³⁶⁰ HCOHSEM. “JIC Communication Workflow.”

Even a simple acknowledgement from an official source, something as generic as “I don’t have the answer to that right now, but will find out and get back to you shortly.” Once acknowledged, this information request can be placed on the RJIC status board for prompt resolution. This can go a long way to maintaining public trust and confidence in HCOHSEM.

Recommendation 8: Increase the functionality of the ReadyHarris App or seek a more robust alternative application.

HCOHSEM should use the EOCTReady platform to its fullest capacity or seek out another platform. EOCTReady is the base system that supports ReadyHarris app on both Apple and Google mobile platforms. It offers features like near real-time weather alerts, which are not being utilized by ReadyHarris.³⁶¹ There appears to be no evidence of “geo-fenced” alerts employed by HCOHSEM (i.e. alerts targeted to a specific location) which is another feature that EOCTReady offers. These alerts would enable HCOHSEM to push tailored alerts to users, based on location. Integration between the app and social media, another feature in the software suite, is key to fully engaging the public throughout an emergency event. Finally, incident reporting could also be enabled in the baseline software. This would allow for a series of unique alerts to come from citizens and it would allow for HCOHSEM to minimize duplication of notification and potentially increase the value in the responses from the public.

Most of these features appear to be included in the EOCTReady baseline package. Whether it is due to a lack of financial investment in the app development competency, or the time investment that is typically required to fully develop an app based communication system, the

³⁶¹ QuickSeries Publishing. *n.d.* “Emergency Management Communication System Features.” EOCT-Ready. <http://eocready.com/features> (October 22, 2017).

underutilization of the official application is leaving vital communications capability unused. In either case, full investment in ReadyHarris and EOCHReady or seeking out a new application will benefit both HCOHSEM, and the users of the software. **Harris County and HCOHSEM should commit to building a complete, robust application, and using it to its fullest potential.** Either option will require some investment, but the benefits of improving the system far outweighs the costs of improvement.

While integration with the Harris County Flood Warning System would be a great addition to the functionality of the ReadyHarris application, there is little evidence to suggest it could be done in a fully automated system without significant system integration investments. If there were sufficient resources to pair a GIS engineer with someone who can draft geographic-specific alerts in the support of the app and its users, it would be the perfect marriage of the information and the need to distribute it. By employing information that is both robust and targeted, HCOHSEM can minimize on the problem of overloading its users with non-pertinent notifications.

Recommendation 9: Develop and implement an awareness campaign to increase social media presence and ReadyHarris App downloads.

HCOHSEM's social media presence and number of app downloads is limited when compared to the population of Harris County. To be successful, **HCOHSEM should substantially increase its social media presence by undertaking a social media awareness campaign.** A comprehensive awareness campaign should include the following elements:

- HCOHSEM should consider using other popular social media platforms outside of Facebook and Twitter, including Snapchat, LinkedIn, Pinterest, and YouTube. Social media management resources (such as Hootsuite) can be used to coordinate HCOHSEM posts across all used social media platforms simultaneously.

- HCOHSEM should partner with local organizations and media outlets to promote social media presence.

On Twitter, HCOHSEM has 33,500 followers. For comparison, the Twitter followings of several local organizations are:

- | | |
|---------------------|--------------|
| • Houston Texans | 1.7 Million |
| • Houston Astros | 1.04 Million |
| • Houston Chronicle | 559,243 |
| • KHOU 11 News | 645,400 |
| • KPRC 2 News | 582,500 |
| • ABC 13 News | 666,400 |
| • Fox 26 News | 266,500 |
| • Visit Houston | 80,300 |

Re-Tweets from these organizations, through established partnerships, could serve as a force multiplier and boost any notification issued by HCOHSEM. Partnerships with local organizations that enjoy significant social media presences and using multiple social media platforms substantially increases and broadens HCOHSEM social media exposure.

- HCOHSEM should develop and disseminate original content. Original, non-emergency related content keeps followers engaged and deters notification fatigue. Examples include promotional giveaways, contests, and polls.
- HCOHSEM should purchase social media advertising to market the organization and the ReadyHarris app.

Facebook, Twitter, Snapchat, LinkedIn, Pinterest, and YouTube sell advertising space. Further, each named social media platform provides significant analytic support to track advertising effectiveness, including ad views, user demographics, redirects, and other statistics. Purchased ads allow HCOHSEM to focus ReadyHarris app and HCOHSEM social media presence marketing efforts directly to likely users.

Recommendation 10: Implementation of Virtual Operations Support Team (VOST) capabilities within the RJIC.

The increased amount of intelligence from social media is a distinct problem for emergency managers. As discussed previously, VOSTs have the capability to assist emergency managers by virtually sifting through the massive amounts of information on social media.³⁶²

HCOHSEM should implement a VOST to assist in the analysis and filtration of potentially actionable intelligence found in the vast amount of social media data. The RJIC has a limited capacity to gather information from social media and incorporate it into its operations. VOSTs would provide a force multiplier to Harris County without the need to expand its operational footprint at the Harris County Emergency Operations Center. As with partnering with any volunteer organization, there is significant ground work needed to facilitate a smooth inclusion into HCOHSEM's operations.

There are many VOSTs available to support social media operations. The Virtual Operations Support Group coordinates VOSTs from around the world.³⁶³ Additionally, there is a large amount of publicly-available information on the international coordination of VOSTs. Implementation of VOSTs in local Emergency Operations Centers requires foundational steps to support such an effort:

1. Volunteer with an existing VOST.
2. Get active in social media within the local community.
 - a. Locally, organize with existing disaster volunteer organizations to prepare for social media operations.
 - b. Non-locally, participate on a VOST that is outside the area.
3. While forming the team, practice skills by live-tweeting events, such as conferences, special events, or festivals.
4. Offer to assist other areas during real disaster activations.
5. Link up with other VOSTs to provide mutual support in disasters.
6. Continue to build connections with others in the social media effort.³⁶⁴

³⁶² NDPTC. *Social Media for Natural Disaster Response and Recovery*.

³⁶³ Virtual Operations Support Group. 2017. "VOSG History."
<https://vosg.us/history> (November 19, 2017).

³⁶⁴ Reuter, S. 2012. "How to Plan & Build a VOST for your Community or Organization."

This program would be similar to other disaster volunteer organizations, such as Community Emergency Response Teams (CERT). As a result, management of this program would share similarity in other volunteer organizations ubiquitous to emergency management agencies across the United States.

HCOHSEM should adhere to best practices to ensure the efficient and effective implementation of VOST within the RJIC:

1. Create clear policies, structures and goals ahead of the actual emergency
2. Practice and training help improve important skills
3. Ensure effective team composition and skills
4. Understand your platforms and community
5. Know the parameters and the scope of your mission
6. Take time to debrief and reflect³⁶⁵

As this program matures, HCOHSEM may find additional best practices are necessary to address future concerns. **As a leader in the emergency management community, HCOHSEM should take a leadership role in this new concept in disaster management.**

Recommendation 11: Implement an Information Management System across the entire Harris County EOC apparatus.

Many emergency management agencies use an information management system to facilitate the effective flow of information during responses. In order to help solve the

think disaster, March 14.

<https://thinkdisaster.com/2012/03/14/how-to-plan-build-a-vost-for-your-community-or-organization> (November 19, 2017).

³⁶⁵ Alley, A., M. Mori, A. Vitullo, and J. Wallace. 2015. Social media monitoring for emergency managers. Syracuse, NY: Maxwell School of Citizenship and Public Affairs. http://sotetech.syr.edu/wpcontent/uploads/2015/07/PAGES_EM_SocialMedia_7.13.pdf (November 19, 2017)

information management problem, **HCOHSEM should implement an Information Management System to encompass all Harris County emergency operations.** Any information management system implemented by HCOHSEM must be capable of “assembling, maintaining, and distributing a common operating picture.”³⁶⁶ As the primary hub of public information, the RJIC should also be capable of this. While most emergency management agencies use computer-based information management systems, the process can be conducted as a manual process.³⁶⁷ Regardless of the mechanism employed to facilitate information management, there are six capabilities that any effective information management system must provide:

1. Collect, update, and process data;
2. Disseminate the right information to the right people at the right time;
3. Track resources;
4. Display readiness status;
5. Track Tasking; and
6. Assist in event documentation.³⁶⁸

These characteristics must be fully addressed throughout the RJIC, in addition to the EOC.

Our research has indicated computer-based information management systems offer the added benefit of integrated visualizations. The visualization of information offers decision-makers context to base their decisions in a timely fashion.³⁶⁹ Using a computer-based system offers the unique capability of incorporating visualization as part of the system instead of

³⁶⁶ NERRTC. *Emergency Operations Center (EOC) Operations and Planning for All-Hazards Events*, 4-6.

³⁶⁷ NERRTC. *Emergency Operations Center (EOC) Operations and Planning for All-Hazards Events*, 4-6.

³⁶⁸ NERRTC. *Emergency Operations Center (EOC) Operations and Planning for All-Hazards Events*, 4-21.

³⁶⁹ Ntuen, Park, and Gwang-Myung. “Designing an Information Visualization Tool for Sensemaking.”

requiring personnel to manually create a representation of data from the operation. This frees up personnel to focus on data collection and analysis. As the current organization combines information analysis with document production, this capability maximizes the distribution of work within the RJIC. Additionally, a computer-based system would seamlessly link the information gathering processes within the RJIC and the Harris County EOC. This would further reduce the personnel needed to maintain the information management processes necessary for HCOHSEM to respond to disasters.

Recommendation 12: Provide dedicated staff to the analysis function within the RJIC.

One of the most critical roles in any information management process is the analysis and synthesis of gathered information.³⁷⁰ Research indicates properly analyzing the wealth of information during a disaster response is difficult at best. Information Management Systems can help facilitate effective analysis, but staff is still needed to conduct the analysis. During a large-scale response, such as Hurricane Harvey, the analysis needs are expected to far exceed the limited staff currently dedicated by HCOHSEM to the analysis of public information. The value provided by a properly staffed analysis function in the RJIC would be realized through the information that could be provided to others in the RJIC as well as the Harris County EOC.

HCOHSEM should dedicate staff solely for the purpose of analysis within the RJIC structure and workflow. The current structure does not provide readily available staff dedicated to the task of analyzing data. Traditional public information sources, such as traditional media and stakeholders, are easily analyzed by the current RJIC structure, but they are limited in number and scope in providing information. The advent of social media necessitates dedicated

³⁷⁰ NERRTC. *Emergency Operations Center (EOC) Operations and Planning for All-Hazards Events*.

staff to analyze the massive amount of information available on various platforms. Many of the tools necessary for information analysis, specifically social media, are already used by HCOHSEM (i.e. HootSuite, TweetDeck, etc.). This analysis function can be augmented by VOST resources recommended above to limit the necessary investment in on-site people and space.

Recommendation 13: Officially endorse the shortened organizational title from Harris County Office of Homeland Security and Emergency Management to an easy-to-communicate acronym, HCOHSEM.

The Harris County Office of Homeland Security and Emergency Management should implement the use of a concise, pronounceable acronym to more easily communicate organizational identity. This is especially important during times of emergency where time spent saying “Harris County Office of Homeland Security and Emergency Management” could be more effectively used coordinating response efforts. **The pronunciation of this acronym should be standardized.** The research team has consistently referred to the organization as HCOHSEM, pronounced “Hic-KOH-Sem,” throughout the project. Employing this method of communication has demonstrably increased efficiency when referring to the principal emergency management organization in Harris County. Implementing this recommendation will likely necessitate some sort of awareness campaign internal to HCOHSEM to ensure that all members are standardized with the change.

Appendix A

Vignettes for Consideration Regarding Technologies Associated with Homeland Security and Emergency Management, and the Risk Surrounding Their Use

Definition of IoT as it relates to HS/EM

Internet of Things (IoT) is a network of interconnected services that link service capable devices to each other and the internet at large.³⁷¹ In the networks around Homeland Security and Emergency Management (HS/EM) hardware, these can be found in devices like flood sensors, Chemical, Biological, Radiological, and Nuclear (CBRN) devices, and emergency devices like smoke and fire detectors. These connections are essential to expanding the understanding of an emergency and anticipating its growth, and, with any optimism, preventing further damage from it. Significant opportunities to expand this footprint of technology as a layer in HS/EM exist. By investing in technologies that enable preventative actions to disaster responses, it stands to reason those investments will be better served than in recovery efforts from the eventual issue. Pay for it now or, pay for it later. Developing research is continuing to add value to the overall approach that emergency responders can improve their methods of investment and technological integration. Yang (2013) is conducting research to provide a taxonomy of related technology that may enable emergency responders to integrate new or developing technologies to their arsenal of tools.³⁷² Use of these technologies in HS/EM is the way forward. The ability to spread

³⁷¹ Estefanell, Marc Valls. 2017. "IoT: Connected Emergency Services." LinkedIn. <https://www.linkedin.com/pulse/iot-connected-emergency-services-marc-valls-estefanell> (November 1, 2017).

³⁷² Yang, Lili, and Shuang-Hua Ling. "How the internet of things technology enhances emergency response operations."

technological sensors across a larger footprint will enable managers to understand and respond more effectively. Forward, this application will save lives and reduce response times by removing the human element from the response process. If a building owner was reliant on a night watchman to monitor for security and fire incidents before, they may not be able to use a network of sensors to overcome the drowsy watchmen, but also reduce the likelihood of false alarms. If an alarm is triggered, that watchman would now be able to confirm the existence of the incident and being first response to it. If there wasn't one at all, precious resources at local rescue organizations can be salvaged.

Examples of IoT in HS/EM

Breaking down IoT technology into its component sections may assist in the understanding of how to approach implementation at an emergency response agency. The following is a selection of components of an integrated IoT system.

- ***Device***: An IoT device allows identification, remote sensing, actuating and remote monitoring capabilities.
- ***Resource***: Resources are software components on the IoT device for accessing, processing, and storing sensor information, or controlling actuators connected to the device. Resources also include the software components that enable network access for the device.
- ***Controller Service***: Controller service is a native service that runs on the device and interacts with the web services. Controller service sends data from the device to the web service and receives commands from the application (via web services) for controlling the device.
- ***Database***: Cloud-based database stores the data generated by the IoT device.
- ***Web Service***: Web service can be either implemented using REST principles (REST service with HTTP or CoAP web service) or using Web Socket protocol (Web Socket service).
- ***Centralized Controller***: The centralized controller is aware of the status of all the end-nodes and sends control commands to the nodes. The centralized controller serves as a link between the IoT device, application, database and analysis components.

- **Analysis Component:** Analysis component is responsible for analyzing the IoT data and generating results in a form which are easy for the user to understand.
- **Application:** IoT applications provide an interface that the users can use to control and monitor various aspects of the IoT system. Applications also allow users to view the system status and view the processed data.³⁷³

Further consideration is necessary for understanding the goals of these components. They should have specific missions that they look to support, allowing for a categorization that permits organization development of resource acquisition and application.³⁷⁴ Public Information and Warning systems allow for tools like traffic information from sensors to be integrated into stoplights or traffic routing to ensure the smooth flow of traffic. Evacuations could be enabled by adding sensors to roads or ethically sourcing information from mobile providers to assess the gauge of response to an evacuation order. Mass Casualty Response could benefit from a sensor that tracks patients or allow for support to triage operations, sending previously categorized patients to staging areas that might be better supported to contribute to their eventual medical needs. Example: if you need a band aid and an ice pack, go to location A, if you're in cardiac arrest, take the patient to location B. That routing could be assisted during initial triage and allow managers to track the flow of patients through the emergency process. Public Event Security allows for an opportunity to add and integrate IoT into events like stadiums, malls, rallies,

³⁷³ Bahga, Arshdeep. 2015. "Internet of Things (IoT) Systems for Emergency Management." LinkedIn. <https://www.linkedin.com/pulse/internet-things-iot-systems-emergency-management-arshdeep-bahga> (November 1, 2017).

³⁷⁴ Coffey, Andrew. 2015. "Thinking Forward: An Internet of Things Primer for Emergency Managers." Homeland Security Today: Thinking Forward: An Internet of Things Primer for Emergency Managers. <http://www.hstoday.us/columns/best-practices/blog/thinking-forward-an-internet-of-things-primer-for-emergency-managers/3d7e0f8e1606db790d4e515154960d0e.html> (November 1, 2017).

concerts, etc. By measuring the flow of personnel through certain gates or choke points, changes can be made to the emergency response by deploying emergency resources to areas of concentration that are receiving the majority of the support.

Risk and Threats

A common challenge of any organization that operates today is the threat of cyber adversaries. Be it a retail store or a government organization, their presence in the electronic domain creates a target for adversaries to exploit and subvert their operation. Organizations like HCOHSEM are not immune. HCOHSEM exists in a domain where they stand to be threatened as a government entity and as one who stands to maintain and develop emergency plans. While National Security entities may be targeted for adversarial gain, HCOHSEM could be targeted for subversion of operations or exploitation of best practices. While little direct threat has been substantiated, the model in which they operate is well within the general matrix of those that stand to be targeted. Those that operate Mass Communication Systems, civilian or government, are at risk.³⁷⁵ Organizations that are failing to invest in cyber defense are likely to be targeted and violated. Skipping the investment in defense creates costs in the eventual cost of repair and recovery. Substantiated attacks to these systems include targeting of Web-Based management systems, CBRN defense, and disaster recovery assets. The risk of losing these critical systems creates a vacuum in support available to the citizens of Harris County. Without the ability to communicate, HCOHSEM loses the ability to coordinate. That absence in the capability to communicate threats would cripple an organization serving the millions in Harris County. Dallas

³⁷⁵ AlertMedia. 2017. "Cyber Threats and Mass Communications Systems | AlertMedia." <https://www.alertmedia.com/cyber-threats-and-mass-communications-systems> (November 4, 2017).

recently was victim of a similar attack that inhibited their ability to communicate and while it wasn't directly destructive, the risk of compromise of the system and the trust associated with it is difficult to measure.³⁷⁶ By impacting the alert warning systems of any area, the trust is compromised. That trust is vital.

Localities have the opportunity to lean on federal and state resources for additional support in both warning against attacks and awareness of threats. The following are list of sources that will allow for HCOHSEM to find resources at the State and Federal level that can allow for awareness and alert of these threats that may provide resources for prevention of attack and degradation of the services.

INFRAGARD- <https://www.infragard.org>

FBI managed system that allows for integration of National Data Sources with local management officials.

DHS National Protection and Programs Directorate, Office of Cybersecurity and Communications- <https://www.dhs.gov/topic/cybersecurity>

Department of Homeland Security centralized resource for information on National resources that pertain to cybersecurity and the management of assets that support it.

Texas Department of Information Resources- <http://dir.texas.gov/View-About-DIR/Pages/Content.aspx?id=23>

Texas' coordinated State effort to reduce cyber threats and the response to them.

National Security Agency/Information Assurance Directorate-

³⁷⁶ Rosenberg, Eli, and Maya Salam. 2017. "Hacking Attack Woke Up Dallas With Emergency Sirens, Officials Say." *The New York Times*.
<https://www.nytimes.com/2017/04/08/us/dallas-emergency-sirens-hacking.html?mcubz=3> (November 4, 2017).

<https://www.iad.gov/iad/index.cfm>

DOD's source of computer security standards and support.

National IA Education & Training Programs (NIETP)-

<https://www.iad.gov/NIETP>

IAD's training program that provides free/cheap educational resources for development of Information Assurance capability.

Committee for National Security Standards-

<https://www.cnss.gov/cnss>

Resource for viewing the standardizations being used at the national level, may be beneficial when developing security protocol on regional/local systems.

National Information Assurance Partnership-

<https://www.niap-ccevs.org/index.cfm>

Amplifying information beyond the DOD standard that is presented by NSA/IAD

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Glossary

Ad hoc networks: A network configured with limited planning, available resources, and without any pre-existing infrastructure.

Action research: The use of techniques of social and psychological research to identify social problems in a group or community couples with active participation of the investigators in group efforts to solve these problems.

After-action report: A report that evaluates the actions and performance during an emergency or other event.

All-hazards approach: Planning for any type of disaster or emergency likely to occur in a specific area, region, or jurisdiction and the necessary response to each.

Common operating picture: A common understanding of what is happening at any given point, during an emergency, between decision-makers, on-scene personnel, and other leaders, created by sharing of information and data available.

Confirmation bias: A situation where decision-makers seek out evidence or information that supports a particular scenario they believe is transpiring even if contradictory indications present.

Crowd-source information: Information from citizens via cell phones, online applications, phone calls, etc., useful in decision-making, during an emergency.

Cycle of denial: A situation where decision-makers deny that events are happening contrary to the scenario they want to be unfolding, during an emergency. See also confirmation bias.

Doctrinal agreements: Formal agreements outlining the duties, responsibilities, responses and engagement of all levels of government, during an emergency or disaster.

Heuristic-systematic model: Method of decision-making using cues and events, along with an evaluation of information and data, to determine the best response to a given situation.

Internet of Everything: The connection of "smart" devices to the internet, including TVs, refrigerators, and others, as well as cell phones and computers, etc. for the purpose of sharing information and communication. See also Internet of Things.

Internet of Things: The connection of devices, to each other and the internet, for the purpose of sharing information, communication, or any other purpose.

Machine logic: Decision-making software or systems designed to filter incoming information, prioritize it, then forward important information to appropriate personnel.

Normalcy bias: When people, faced with an emergency, minimize or dismiss the situation causing a failure to prepare for the disaster they believe will never happen.

Public Information Officer: A person whose job it is to communicate with the public, news media, or other organizations on behalf of an organization, government agency, or other group.

Purposive sampling: A nonprobability sampling method in which elements are selected for a purpose, usually because of their unique position.

Qualitative data analysis: Techniques used to search and code textual, aural, and pictorial data and to explore relationships among the resulting categories.

Quantitative data analysis: Statistical techniques use to describe and analyze variation in quantitative measures.

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