# NAVAL POSTGRADUATE SCHOOL

**MONTEREY, CALIFORNIA**

# THESIS

**WHEN 9-1-1 IS NOT ENOUGH:**
**TRANSITIONING THE 9-1-1 CENTER INTO A MULTI-CHANNEL EMERGENCY COMMUNICATIONS CENTER**

by

Michelle R. Potts

June 2019

Thesis Advisor: Rodrigo Nieto-Gomez
Second Readers: Nicholas Dew
Bo Cheng, Altovista Technology

**Approved for public release. Distribution is unlimited.**

THIS PAGE INTENTIONALLY LEFT BLANK

| REPORT DOCUMENTATION PAGE | Form Approved OMB No. 0704-0188 |
|---|---|

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.

| 1. AGENCY USE ONLY *(Leave blank)* | 2. REPORT DATE June 2019 | 3. REPORT TYPE AND DATES COVERED Master's thesis |
|---|---|---|

| 4. TITLE AND SUBTITLE WHEN 9-1-1 IS NOT ENOUGH: TRANSITIONING THE 9-1-1 CENTER INTO A MULTI-CHANNEL EMERGENCY COMMUNICATIONS CENTER | 5. FUNDING NUMBERS |
|---|---|
| 6. AUTHOR(S) Michelle R. Potts | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000 | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A | 10. SPONSORING / MONITORING AGENCY REPORT NUMBER |

**11. SUPPLEMENTARY NOTES** The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

| 12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited. | 12b. DISTRIBUTION CODE A |
|---|---|

**13. ABSTRACT (maximum 200 words)**

Disasters, terrorist attacks, and network outages have demonstrated the limitations of the 9-1-1 system. Emergency communications centers that remain focused on 9-1-1 as the singular emergency reporting channel fall short of providing a comprehensive emergency response solution in their communities. A change is required to adapt to the modern means of communications, such as text and picture messaging, livestream video, crowdsourcing, apps, sensors, and social media. This thesis reports on the actions taken to transition an emergency communications center into a multi-channel environment capable of building resiliency, and provides supplemental reporting channels, creates situational awareness, and builds more efficient workflows. Using business model generation and lean strategy methodology, this thesis provides a model for implementation strategies and proposes a bottom-up approach to meet individual community needs. This thesis recommends a pathway to shift the culture and strategy in carrying out the mission of emergency communications and responding to requests for emergency services.

| 14. SUBJECT TERMS 9-1-1, emergency communications center, emergency reporting, multi-channel environment | 15. NUMBER OF PAGES 153 |
|---|---|
| | 16. PRICE CODE |

| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| Unclassified | Unclassified | Unclassified | UU |

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

**Approved for public release. Distribution is unlimited.**

# WHEN 9-1-1 IS NOT ENOUGH: TRANSITIONING THE 9-1-1 CENTER INTO A MULTI-CHANNEL EMERGENCY COMMUNICATIONS CENTER

Michelle R. Potts
Communications Manager, Chandler Police Department
Bachelor's degree, Arizona State University, 2011
Master's degree, Northern Arizona University, 2013

Submitted in partial fulfillment of the
requirements for the degree of

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

from the

**NAVAL POSTGRADUATE SCHOOL**
**June 2019**

Approved by: Rodrigo Nieto-Gomez
Advisor

Nicholas Dew
Second Reader

Bo Cheng
Second Reader

Erik J. Dahl
Associate Chair for Instruction
Department of National Security Affairs

THIS PAGE INTENTIONALLY LEFT BLANK

# ABSTRACT

Disasters, terrorist attacks, and network outages have demonstrated the limitations of the 9-1-1 system. Emergency communications centers that remain focused on 9-1-1 as the singular emergency reporting channel fall short of providing a comprehensive emergency response solution in their communities. A change is required to adapt to the modern means of communications, such as text and picture messaging, livestream video, crowdsourcing, apps, sensors, and social media. This thesis reports on the actions taken to transition an emergency communications center into a multi-channel environment capable of building resiliency, and provides supplemental reporting channels, creates situational awareness, and builds more efficient workflows. Using business model generation and lean strategy methodology, this thesis provides a model for implementation strategies and proposes a bottom-up approach to meet individual community needs. This thesis recommends a pathway to shift the culture and strategy in carrying out the mission of emergency communications and responding to requests for emergency services.

THIS PAGE INTENTIONALLY LEFT BLANK

# TABLE OF CONTENTS


I. INTRODUCTION....1
- A. RESEARCH QUESTION....1
- B. BACKGROUND....1
- C. OVERVIEW OF THE WORK....4
- D. RESEARCH DESIGN AND METHODOLOGY....7

II. LITERATURE REVIEW....9
- A. INTRODUCTION....9
- B. IMPROVING CUSTOMER RELATIONSHIPS....9
- C. MAKING EFFECTIVE DECISIONS....12
- D. DEVELOPING A COMPREHENSIVE STRATEGY....16
- E. ASSUMPTIONS AND DELIMITATIONS OF THE WORK....20

III. SITUATION ANALYSIS....23
- A. INTRODUCTION....23
- B. WIRELESS TECHNOLOGY....23
  - 1. Smartphones: Personal Computers in Disguise....23
  - 2. Non-service Initialized Phones: The Phones Not Counted, but with a Big Impact....25
- C. WIRELESS PHONE USE DURING LOCAL OR REGIONAL DISASTERS....27
  - 1. Orlando Pulse Nightclub....27
  - 2. Hurricane Harvey....28
  - 4. From Mass Regional Disruption to Local Frequent Disruptions....31
- D. WIRELESS PHONE USE FOR REPORTING TRAFFIC COLLISIONS....32
  - 1. Motor Vehicle Collision Notification Times....32
  - 2. Impact of Vehicle Collision Notification Time on Mortality Rate....33
  - 3. Automatic Traffic Collision Notification Time....34
- E. SUMMARY AND CONCLUSIONS....36

IV. COMPARATIVE ANALYSIS....37
- A. INTRODUCTION....37
  - 1. Managing Call Volume....37
  - 2. Regional Call Volume....38

3. Resource Allocation .....43
4. Industry Philosophy.....45
B. POTENTIAL NEW CHANNELS/INPUTS .....46
1. Social Media .....47
2. Crowdsourcing .....50
3. IoT and Advanced Sensors.....50
4. Video-to-911.....53
C. SUMMARY AND CONCLUSIONS .....55

V. BUSINESS MODEL GENERATION.....57
A. INTRODUCTION.....57
B. BACKGROUND .....57
C. PROJECT DESCRIPTION .....60
D. BUSINESS MODEL CONCEPT: MVP, FINDING YOUR WAZE .....62
E. BUSINESS MODEL CONCEPT: NINE BUILDING BLOCKS .....68
1. Customer Segments .....70
2. Value Proposition.....70
3. Channels.....72
4. Customer Relationships.....72
5. Goals/Revenue Stream.....73
6. Key Resources .....74
7. Key Activities.....76
8. Key Partnerships.....77
9. Costs .....80
F. BUSINESS MODEL CONCEPT: CUSTOMER DEVELOPMENT PROCESS.....81
1. Search Phase: Customer Discovery and Customer Validation.....81
2. Execution Phase: Customer Creation and Company Building.....82
G. REFLECTION .....82
1. Develop Your Network.....82
2. Be Flexible in Your Decision Making.....83
3. Play Nice With Your Peers.....83
4. Have a Communications Plan Ready.....84
5. Make Friends, You Will Need Them.....85

VI. THE MULTI-CHANNEL ENVIRONMENT .....87
A. NON-EMERGENCY TEXT MESSAGING .....87
B. AUTOMATED SECURE ALARM PROTOCOL TO PUBLIC SAFETY ANSWERING POINT .....89
C. TEXT-TO-911 .....90
D. PENDING NEW CHANNELS .....91
1. Video-to-911.....91
2. Acoustic Crash Sensors .....93
3. Twitter.....97
4. Highway Cameras, Wrong Way Sensors.....99
5. Noonlight.....101
6. Aggregating Platform .....103
E. SKILL EVALUATION .....106
F. NEXT STEPS .....107
1. Waze.....107
2. Video-to-9-1-1 .....107
3. Acoustic Crash Sensors .....107
4. Freeway Cameras.....108
5. Twitter.....108
6. Regional Working Group.....108
7. CommandCentral Aware .....108
8. Job Descriptions.....108
G. SUMMARY AND CONCLUSIONS .....109

VII. RESULTS AND CONCLUSIONS .....111
A. INTRODUCTION.....111
B. PROBLEM STATEMENT .....111
C. SIGNIFICANT CONCLUSIONS .....111
D. IMPLICATIONS OF THE WORK .....116
E. RECOMMENDATIONS FOR FUTURE STUDY .....118

LIST OF REFERENCES.....119

INITIAL DISTRIBUTION LIST .....129

THIS PAGE INTENTIONALLY LEFT BLANK

# LIST OF FIGURES

Figure 1. The City of Chandler, Located Southeast of Phoenix.....6

Figure 2. Multi-screen Dispatch Console.....15

Figure 3. East Valley of Phoenix Metropolitan Region. .....40

Figure 4. Future Data Possibilities Compared to Current 512 Byte Limitations. .....52

Figure 5. Chandler Police Emergency Communications Center.....60

Figure 6. An Overwhelming Amount of Data at the Regional View.....65

Figure 7. Waze Reports on Default Blue Background.....66

Figure 8. Waze Reporting in City of Chandler on ESRI Background .....67

Figure 9. Waze Mobile Application. .....68

Figure 10. Business Canvas Model: Implementation of Waze into an Emergency Communications Center .....69

THIS PAGE INTENTIONALLY LEFT BLANK

# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACLU | American Civil Liberties Union |
| ACN | automatic collision notification |
| ADOT | Arizona Department of Transportation |
| APCO | Association of Public Safety Communications Officials |
| ASAP | automated secure alarm protocol |
| BAPCO | British Association of Public Safety Communications |
| CHDS | Center for Homeland Defense and Security |
| CTIA | CTIA Wireless Foundation |
| DPS | Department of Public Safety |
| ECC | emergency communications center |
| EMS | emergency medical services |
| EU | European Union |
| FCC | Federal Communications Commission |
| GIS | geographic information system |
| IoT | Internet of things |
| ISIS | Islamic State of Iraq and Syria |
| IT | information technology |
| MIT | Massachusetts Institute of Technology |
| MR 9-1-1 | Maricopa Region 9-1-1 |
| MVP | minimum viable product |
| NENA | National Emergency Number Association |
| NSI | non-service initialized |
| OODA | observe-orient-decide-act |
| PSAP | public safety answering point |
| PTZ | pan, tilt, zoom |
| SOP | standard operating procedure |
| UK | United Kingdom |
| USCG | United States Coast Guard |
| VECC | Valley ECC |

THIS PAGE INTENTIONALLY LEFT BLANK

# EXECUTIVE SUMMARY

> That's how we rescued the 11,000 people, leaning in on how the public was self-selecting to use social media, because they couldn't get through on 9-1-1 calls.
>
> ~Vice Admiral Sandra Stosz, United States Coast Guard

The typical 9-1-1 emergency communications center (ECC) is operating with technology that does not reflect the modern means by which the public communicates in everyday life. At its core, the methods and procedures for emergency communications have not changed in more than 50 years: pick up a telephone and speak to a 9-1-1 operator.[1] ECCs have not kept pace with the last decade's emerging digital trends and transitioned from this 50-year old traditional voice environment into the new data environment. More specifically, they have not expanded beyond the traditional voice 9-1-1 system of communication.

Disasters, such as Hurricane Harvey and Orlando Pulse, highlighted some of the capacity, technical, and operational limitations of the 9-1-1 system. They also demonstrated that the public will define and activate additional communication channels to report emergencies when 9-1-1 is not enough. This use should serve as a warning that even channels not previously designated as an emergency reporting platform will emerge during a crisis, even if it is not an official public safety-sanctioned platform.[2] Failing to address this usage proactively may force local leaders to face it for the first time during a disaster.

The focus of this thesis is to explore the contemporary, relevant communication channels of today, as well as the potential benefits they can provide to an ECC. To demonstrate this topic, one new channel (Waze) was implemented through a business

---

[1] "9-1-1 Origin & History," National Emergency Number Association, accessed July 2, 2018, https://www.nena.org/page/911overviewfacts?.

[2] Kristopher M. Thornburg, "Disruptive Emergent Systems in Disaster Response" (master's thesis, Naval Postgraduate School, 2019), 51–55

model generation and lean strategy methodology. This thesis reports on the actions of implementing Waze as a supplemental reporting channel into the Chandler Police ECC.

Waze is a Google mobile application that provides commuters with an interactive navigation tool. Waze was chosen because users have the ability to report traffic collisions, traffic hazards, road closures, and other types of traffic incidents. A 2018 study reported that U.S. drivers are reporting traffic collisions 40% of the time on Waze before 9-1-1 receives the reports. This reporting results in a five-minute faster response time for first responders.[3] This thesis begins with the implementation of Waze into the Chandler Police ECC as the first channel expansion into the multi-channel environment. Additional reporting channels, such as video-to-911, traffic cameras, acoustic crash sensors, and social media, are also evaluated for potential opportunities to move the ECC into a true multi-channel environment.

The limitation of coordinating live projects within the timeline of this thesis did not result in a full deployment of Waze; however, the lessons learned during the planning and implementation provide a model for continued channel expansion in the Chandler Police emergency communications environment. This thesis demonstrated that significant strides towards a multi-channel environment can be made in a relatively short amount of time, despite limitations to allocated time or funding. This new multi-channel ECC can provide a higher level of quality service to both the community and first responders through increased efficiencies, situational awareness, and better-informed decision-making using complementary channels and data aggregation.

This case study revealed the following lessons during the transition of the Chandler Police ECC from the single channel environment into a multi-channel environment:

- The Chandler Police ECC requires a rebranding of the philosophy and culture in order to better align with the mission of the ECC.

[3] CCP Partner Onboarding, *What is Waze?* (San Francisco: SFBay, Institute of Transportation Engineers, 2018), 32–33, http://www.sfbayite.org/wp-content/uploads/2018/05/9%20Google%20Waze%20Onboarding%20Deck%202018%20.pdf.

The mission of the ECC is to respond to requests for emergency services, with 9-1-1 as the principal way in which to do so. The technology should not drive the mission because the mission is not to simply answer 9-1-1. One first step is to change the name from the traditionally named 9-1-1 center to the Chandler ECC. This symbolic move is important for signaling changes are afoot to the technology menu of ECCs.

- Providing for the needs of the community is a priority in the decision-making and technology adoption, rather than relying on the development of nationwide best practices and recommendations by industry organizations.

Moving forward, channel expansion will be based on an assessment of community needs, and limitations of the region's 9-1-1 system or practices.

- It is necessary to actively pursue new channels that will mitigate current limitations, and increase decision-making effectiveness and situational awareness.

The majority of new channels are not currently designed for implementation into an ECC. The implementations discussed in this thesis required creativity, multiple iterations, and lean strategy thinking. Exploration and curiosity began the conversation, while key partnerships and experts helped move the project forward. The creation of a multi-channel environment for an ECC creates scalability and redundancy. Failure to do so could result in facing publicly driven channel emergence for the first time during a disaster.

- Collaboration with regional and state partners helps leverage shared resources and ensures regional consistency in services.

Meeting Chandler's individual community needs was considered in relationship to the regional and state partners. It was important to maintain a consistent level of service throughout the region, as citizens often do not understand jurisdictional boundaries. Sharing resources, such as software licensing, technical and operational expertise, and funding can reduce the redundant investment by each agency within a region. A regional

working group can facilitate the vetting and testing of new technology, create partnerships between agencies, and reduce the impact on individual agencies.

- An agile, aggregated platform designed to accommodate the needs of the multi-channel emergency communications environment is needed to accommodate the future number of inputs.

The agnostic platform should be able to connect new channels, aggregate them, and incorporate the multiple programs already required in the current emergency communications environment. Incorporating this platform is ideal in the early transition to the multi-channel environment to avoid the current retrofit issues of 9-1-1. The platform must be agile to accept new channels and decommission channels as needed.

- Human resource needs, such as evaluating any newly required skill sets, hiring practices, and training required for success in the new ECC should be critically evaluated.

The new or additional skill sets in the multi-channel environment creates a distinct evolution in job function. Job descriptions will be evaluated and adjusted as new channels are added to the ECC while simultaneously planning for the long term. Comprehensive training and proficiency monitoring will be ongoing as channels are added and new skills are required of professional staff.

# ACKNOWLEDGMENTS

This thesis is both a glimpse and culmination of a 19-month journey. I did not fully understand what I was undertaking at its outset. The Center for Homeland Defense and Security (CHDS) program has been the pinnacle thus far of my academic and professional experience. I have learned much about the world and myself. The faculty and staff have challenged me to think more critically, consider new perspectives, and venture into mental lanes never previously dared.

My advisors, Dr. Rodrigo Nieto-Gomez, Dr. Nicholas Dew, and Mr. Bo Cheng, were a trifecta of balanced brilliance. Bouncing ideas off Rodrigo is an invigorating experience. Unique ideas suddenly seem normal, and the unthinkable becomes possible with Rodrigo. Nick rescued me from my never-ending ideas and gave me an actionable channel through the business model. He kept me grounded and helped me remember the purpose of the work. Bo helped me connect in the real world, understood my public safety lens, and helped me understand the vast world of data, starting from the very beginning. I would also like to thank Dr. Lauren Fernandez for her encouragement starting in week one and consistently throughout the program; she is a pillar of the CHDS program. These minds, and the CHDS process, created an environment in which ideas are not just accepted; they are inspired, proliferated, and polished into action.

My sincerest thanks to Chief Sean Duggan of the Chandler Police Department for his encouragement and support in this pursuit, and to Chief Dale Walters, now of the Globe Police Department, for his support while I balanced our division and the program. Thank you to Liz Graeber, Maricopa Region 911 administrator, for your regional leadership and partnership on these projects. I am grateful to work with such an innovative and humble technical team. To our team: thank you for your patience and carrying the division while I was away; I could not have done it without you. To my circle: those who jumped in on these projects in different ways, those who took time to brainstorm, to sketch ideas on a white board, or pull up a chair under a virtual gazebo to listen along this rollercoaster journey, my heartfelt thanks.

To the members of Cohort 1705/1706, I am humbled to have spent time learning alongside the most intelligent and accomplished professionals in their disciplines. I have learned from the expertise each brought during class, and stories shared after hours. I am grateful for the friendships and look forward to when our paths will cross next.

I am eternally grateful to my parents, who set the tone early on for this education trajectory. Mom, thank you for always being there, for your encouraging words, and unending prayers. Dad, when I could not make sense of my own thoughts, you could. Thank you for patiently listening, for your wisdom and support. I still have a few more degrees to catch up.

Saving the best for last. To my husband and our A-Team, I owe you. Thank you for supporting me in my latest shiny thing. This was a big one. It is time for Hawaii, the marathon circuit, and hunting season again. I promise to pause before the next major shiny thing. Girls, I know many times I was merely a fixture with a laptop. I hope that a version of me remains in your memories that hard work is rewarded. Each of you has a special purpose in this world that is just as unique as you. Hard work is worth it. Go get ‘em. I love you all.

# DEDICATION

This thesis is dedicated to the memory of Cathy Coppes (1959–2018), who devoted her career to training the next generation of dispatchers and 9-1-1 emergency call takers. Ideas and projects, such as those discussed in this thesis, could not move forward without Cathy and other professionals in the emergency communications industry who are passionate about learning.

THIS PAGE INTENTIONALLY LEFT BLANK

# I. INTRODUCTION

## A. RESEARCH QUESTION

This thesis answers the following research question: How should ECCs transition from a single communication channel to a potentially infinite number of communication channels?

## B. BACKGROUND

The typical 9-1-1 ECC operates with technology that is a generation behind that in use by the general public. At its core, the methods and procedures for emergency communications have not changed in more than 50 years: Pick up a telephone and speak to a 9-1-1 operator.[1] ECCs have not made the transition from this half-century-old traditional voice communications environment. More specifically, few 9-1-1 ECCs have invested in channel capacity expansion beyond the traditional voice 9-1-1 system of communication.

The "universal number" of 9-1-1 was established to report emergencies and enable emergency services to easily determine the location of the caller. It was created prior to technology, such as cell phones and voice over internet protocol, and the 9-1-1 infrastructure required significant accommodations in order to accept the new technology. This retrofit style of adapting to the evolution of technology has created technical limitations on the current 9-1-1 system, but also philosophical constraints within the industry. To focus merely on the 9-1-1 technology loses sight of the true mission of the ECC, to respond to requests for emergency services.

Wireless devices are owned by approximately 95% of all Americans, according to early 2018 statistics.[2] These same reports reveal that 77% of Americans own

---

[1] "9-1-1 Origin & History," National Emergency Number Association, accessed July 2, 2018, https://www.nena.org/page/911overviewfacts?.

[2] "Mobile Fact Sheet," Pew Research Center: Internet, Science & Tech, February 5, 2018, http://www.pewinternet.org/fact-sheet/mobile/.

smartphones.[3] Smartphone ownership provides a transition to the data environment with channel options, such as text, picture and video messaging, apps, social media, sensors, and the internet of things (IoT). The public communicates using these data-driven communication channels in everyday life. One study found that 71% of the average American's online time is spent using a smartphone.[4] Of the 240 million 9-1-1 calls placed in the United States annually, the National Emergency Number Association (NENA) found that up to 80% of those calls originate from cell phones.[5] Thus, a large technology gap exists between the services provided by the typical ECC and the communication habits and desires of users of emergency services.

The permeation of data-driven communication exemplified by smartphones demonstrates the new normal in the standard for day-to-day communications by the public. Modern society relies heavily on digital communication technology for all forms of communications, such as voice, social media, text, and email messaging. Within a typical ECC, the frequency of each channel's usage further provides an indication of communication channel preferences. 9-1-1 ECCs should consider evaluating such channels and their usage as potential additional emergency reporting channels to supplement the single, fixed means of technology of the past.

When the primary communication channel of 9-1-1 is not enough, the public has demonstrated during recent disasters that they will define and activate additional communication channels.[6] This history provides a starting point for identifying the channels to which community members default when in crisis. It also serves as a warning that even a channel not previously designated as such, will emerge during a crisis even if it is not an official public safety-sanctioned or designated platform in which to report an emergency. The response then defaults to the local ECC to make the decision to be

---

[3] Pew Research Center: Internet, Science & Tech.

[4] CTIA, *Wireless Snapshot 2017* (Washington, DC: CTIA, n.d.), 4, accessed May 27, 2018, https://api.ctia.org/docs/default-source/default-document-library/ctia-wireless-snapshot.pdf.

[5] "9-1-1 Statistics," National Emergency Number Association, accessed July 29, 2018, https://www.nena.org/page/911Statistics.

[6] Kristopher M. Thornburg, "Disruptive Emergent Systems in Disaster Response" (master's thesis, Naval Postgraduate School, 2019), 51–55

proactive or reactive with respect to customer requests for emergency services. These community expectations evidently exist and new channels, such as multimedia and social media, have been shown to develop organically within the community, with or without public safety involvement or guidance.

Emergency reporting channels that emerge during disasters give ECCs direction about customer preferences and guide ECCs into developing a more responsive emergency reporting system. For example, sensor networks, such as acoustic traffic crash sensors, can "listen" for traffic collisions and quickly activate nearby cameras. The cameras can be automatically viewed within the ECC to determine if a traffic collision occurred prior to receiving a 9-1-1 call. Vehicle sensors, similar to the technology used by OnStar, can activate a specific type of notification of a crash to the ECC within seconds of impact. The notification can automatically relay the location of impact to the ECC and real-time video can quickly reveal the severity of the crash, be it a fender-bender or a more serious head-on collision with potential injuries. OnStar can also send airbag deployment information, the speed at the time of impact, the number of occupants, and other pertinent information to the ECC. The detailed and timely notifications provided by these sensors would enable the ECC to become more efficient, accurate, and reliable in its communications with the public. The real-time data-driven information is provided immediately and the ECC can respond proactively, rather than reactively when it relies on delayed reporting from witnesses, often in an emotional state due to the immediate crisis. Instantaneous, data-driven information also allows the ECC to match more closely and deploy the type and number of lifesaving resources required to the scene of the crisis.

The new data generation should be virtually automatic yet monitored by trained employees to make the best possible informed decisions, and witnesses are not required to notify 9-1-1. The ability to expand these communication channels creates opportunities for earlier reporting, and therefore, provides customers with faster response times. These expanded channels can provide additional situational awareness for an ECC to validate incidents for resource allocation and mitigate further risk to public safety. Data-driven decision making based on high-quality data inputs may ultimately lead to a more efficient emergency response.

The mission of the 9-1-1 ECC is to respond to requests for emergency services, with 9-1-1 as the principal channel with which to do so. The technology should not drive the mission because the mission is not to simply answer 9-1-1 phone calls. Nevertheless, ECC expansions are commonly based on the selection of a specific communications technology. The unintended result is the creation of an ECC that always lags behind modern technology, a common governmental agency problem.

A shift in philosophy is required to avoid the current plight of technology to handle text-to-9-1-1. Text messaging was deployed in the mobile phone marketplace 25 years ago.[7] Yet, as of 2018, only approximately 25% of 9-1-1 centers nationwide have implemented text-to-9-1-1 technology.[8]

This thesis explores the contemporary, relevant channels of communication available in 2018 and the potential benefits they provide the ECC. The work begins with a description of the process of implementation of one supplemental reporting channel, Waze. It discusses in depth the implementation process and the requirements for addressing the public safety issue of traffic incidents. Potential supporting channels are then reviewed to look for opportunities to aggregate data and assist ECCs in developing data-driven, effective decision-making processes. Business model generation and lean strategy provide a guideline and developmental structure for ECCs looking to expand from their current single 9-1-1 communication channel to potentially an infinite number of communication channels. This multi-channel environment will become a model for the next generation of ECCs, a more efficient, data-driven environment designed for situational awareness and better-informed decision making using the relevant communication channels of today.

## C. OVERVIEW OF THE WORK

Emerging technology creates both opportunities and challenges for a modern ECC. Many contemporary technology tools in the marketplace have the potential to become an

---

[7] Alan Stewart, "Text Messaging," *Encyclopædia Britannica*, February 24, 2017, https://www.britannica.com/technology/text-messaging.

[8] "Text 911 Master PSAP Registry.xlsx," Federal Communications Commission, accessed July 2, 2018, https://www.fcc.gov/files/text-911-master-psap-registryxlsx.

emergency reporting communication channel, such as social media, cell phone apps, and multimedia messaging. The aggregation of data provided by these tools can provide ECCs with a more enhanced, as well as a comprehensive level of situational awareness, and thereby, produce a more efficient and safe response.

This thesis reports on the process of transitioning a typical ECC into a modern multi-channel environment based on Waze. Waze is a crowdsourcing navigation app used to report traffic incidents. It is able to report traffic incidents in real time, potentially sooner than the current 9-1-1 calls report traffic incidents. A 2018 study reported that U.S. drivers are reporting traffic collisions 40% of the time on Waze before 9-1-1 receives the reports.[9] This early reporting results in a five-minute faster response time for first responders in some locations.

The implementation strategies employed will include the business model generation and lean strategy methodology.[10] The minimum viable product (MVP) for this project is the implementation of Waze data onto the 9-1-1 map of the City of Chandler Police Department (Chandler) ECC. The goal is for data to be aggregated with traditional 9-1-1 call data for more informed decision-making. Further, Waze is evaluated for use as a bi-directional communication tool. The ability for the ECC to notify community members using this app of incidents that may affect their commute provides an additional community engagement tool. See Figure 1 for the location of Chandler in the Phoenix, Arizona metropolitan area.

---

[9] CCP Partner Onboarding, *What is Waze?* (San Francisco: SFBay, Institute of Transportation Engineers, 2018), 32–33, http://www.sfbayite.org/wp-content/uploads/2018/05/9%20Google%20Waze%20Onboarding%20Deck%202018%20.pdf.

[10] Alexander Osterwalder, Yves Pigneur, and Tim Clark, Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers, 1st ed. (Hoboken, NJ: Wiley, 2010); Eric Ries, The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses, 1st ed. (New York: Crown Business, 2011).

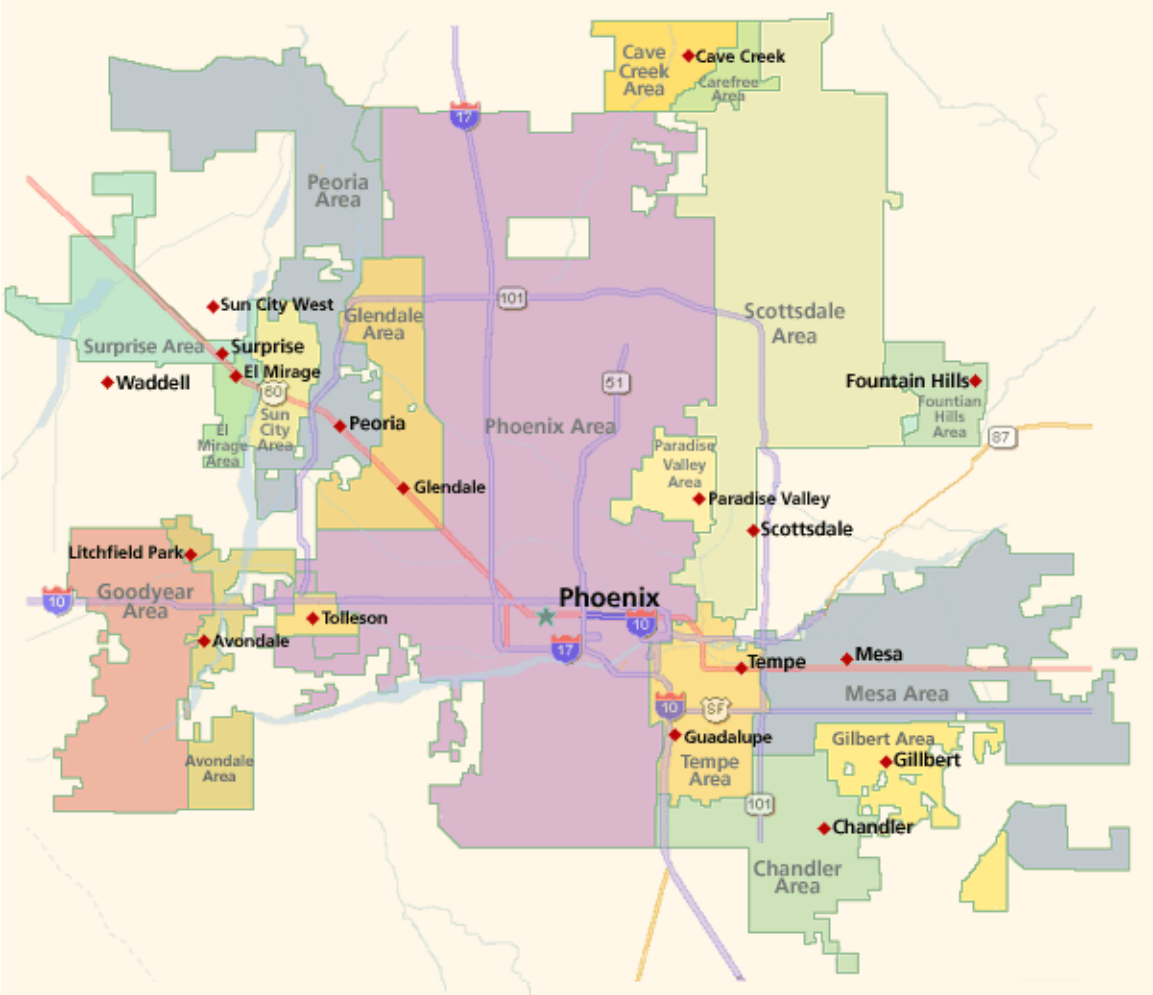


Figure 1. The City of Chandler, Located Southeast of Phoenix.[11]

The City of Chandler is a suburban city with a population of approximately 256,000 located in the Phoenix metropolitan area. Chandler consists of both residential and commercial areas over a 65 square miles incorporated area. Chandler is known for attracting technology employers, such as Intel, Orbital, Microchip, Freescale Semiconductor, and Avnet.[12] Separating Phoenix and Chandler is a major commuter highway that provides access to downtown Phoenix. It is also the major route to travel

[11] Source: "Painting in Phoenix Area Neighborhoods," accessed March 17, 2018, MTS Painting, https://mtspaint ing.com/about-mts-painting/painting-service-area/painting-in-phoenix-area-neighborhoods/.

[12] "Leading Employers," City of Chandler, Arizona, January 2018, http://chandleraz.gov/default.aspx?pageid=305.

outside the metropolitan area to the south. During 2018, Chandler responded to 25,577 reports of traffic collisions.[13] This number demonstrates that traffic collisions provide a high level of frequency and impact the quality of life of commuters and community members.

Following the successful implementation of Waze, this thesis explores additional complementary channels for potential implementation. If phases in the Waze implementation cannot move forward, additional channel capacity expansion projects that can work in tandem with this project will be explored.

This thesis provides a model for transitioning to the new multi-channel environment using the lean strategy business process model. Topics in the lean strategy model that will be evaluated include: MVP, value proposition, key partners, key activities, key resources, customer development process, customer segments and relationships, and cost. Recommendations based on an analysis of the implementation experience, in conjunction with the literature and business model, are proposed for decision makers interested in moving from a single-channel ECC into a multi-channel emergency communications ecosystem.

## D. RESEARCH DESIGN AND METHODOLOGY

The following research approach and methodology is used in this thesis to answer the research question satisfactorily. The principal methodologies used are a comprehensive literature review, a comparative analysis of a typical ECC, and an advanced ECC that leverages new channels of digital communications and development of a business case study that demonstrates the value proposition of adopting a multi-channel ECC development strategy.

Chapter II examines the academic and ECC industry literature related to the benefits of employing a multi-channel ECC environment. Specifically, the means and methods of improving ECC customer service are reviewed, as is the literature related to

[13] "Chandler Police Department Versaterm Records Management System," Chandler Police, accessed January 7, 2018, http://www.chandlerpd.com/data/.

making intelligent decisions in a data-driven organization. This chapter concludes with an exploration of the literature related to developing a comprehensive strategy related to ECCs.

Chapter III explores the current challenges and opportunities for modern ECCs, specifically in relation to wireless technologies and their impact on ECCs. The move from "hard-wired" phones to "wireless" cellular phones is of great importance to the future evolution of ECCs.

Chapter IV begins the comparative analysis portion of the work with an examination of the limitations now experienced by a typical ECC with respect to call volume and resource allocation and the impact of "new" media, such as social media, crowdsourcing, and the IoT.

Chapter V provides a stepwise description of the development of an ECC business model designed to evaluate new media technologies based on the value of adopting Waze at a specific police agency, as described in Section C of this chapter.

Chapter VI evaluates a variety of other potential digital communication technologies currently available or may be available in the future to progressive ECCs and an evaluation of their efficacy for emergency communications.

Chapter VII provides a summary of significant conclusions reached during the course of this study. The last two sections examine the implications of the work to modern ECCs and recommendations for future research.

# II. LITERATURE REVIEW

## A. INTRODUCTION

The multi-channel environment is used in various business environments but a survey of business associates and associations failed to identify a single business model in the emergency communications industry. The following literature review explores the benefits available in the multi-channel environment and analyzes their applicability for emergency communications.

This literature review is presented in three parts. The first section discusses how the multi-channel environment provides opportunities for organizations to increase customer satisfaction, loyalty, and quality of service. Augmenting the environment with channels used by the public in everyday communications provides channel choice and ease of use. In turn, customer satisfaction with 9-1-1 services may increase. Section two explores information capacity expansion to make better decisions. Additional information leads to more informed decisions, which has life safety implications in the emergency communications environment. Section three concludes with the review of the literature that recommends the creation of a comprehensive implementation strategy that integrates complementary channels into a multi-channel environment.

## B. IMPROVING CUSTOMER RELATIONSHIPS

The multi-channel environment provides opportunities for organizations to increase customer satisfaction, loyalty, and quality of service. Neslin et al. supports this view and adds the customer learning process to the conversation.[17] As the number of channel experiences increases, the customers formulate and refine their opinions on the individual channels, which, in turn, drive the preferred channel choice for the next opportunity. ECCs

[17] Scott A. Neslin et al., "Challenges and Opportunities in Multichannel Customer Management," *Journal of Service Research* 9, no. 2 (November 1, 2006): 95–112, https://doi.org/10.1177/1094670506293559; Wolfgang E. Ebbers et al., "Facts and Feelings: The Role of Rational and Irrational Factors in Citizens' Channel Choices," *Government Information Quarterly* 33, no. 3 (July 2016): 506–15, https://doi.org/10.1016/j.giq.2016.06.001; Willem Pieterson, "Citizens and Service Channels: Channel Choice and Channel Management Implications," *International Journal of Electronic Government Research* 6, no. 2 (April 2010): 37–53. https://doi.org/10.4018/jegr.2010040103.

that provide a multi-channel environment that accommodates for these preferences and perceptions create a system likely to increase customer satisfaction.

The research produced by Reddick and Turner offers that a customer's personal view of public service predicts channel choice.[18] Specifically, the more value a citizen places on the quality of public services, the stronger the influence. Reddick and Turner contend that the relationship between the government and the citizen helps shape channel choice. These researchers found that in the Canadian public service organizations, regardless of the citizen's ultimate channel choice, if the citizen is satisfied with the experience, the satisfaction level increases for all channels. Ebbers et al. agree with Reddick and Turner and suggest that trust and emotion are the driving factors in determining how a citizen views public services.[19] This research indicates that any multi-channel implementation should be done with sensitivity to other organizational and cultural considerations. The right channel added to the right environment has the opportunity to increase satisfaction across all channels. As such, finding the appropriate channel that best meets the needs of the citizens and assists in providing services can have a synergistic effect.

Pieterson's research adds a more pragmatic understanding of these considerations.[20] Pieterson found that customers choose channels based on speed and ease of use. He also states that habits and experiences created throughout the decision-making process influence channel choice. His research indicates that habits influence the customer channel choice, and new channels may not be immediately embraced. It also suggests that experiences can influence a customer to remain with or change channels.

Different researchers break down decision-making strategies into various categories. Pieterson uses four categories: "task characteristics, channel characteristics,

---

[18] Christopher G. Reddick and Michael Turner, "Channel Choice and Public Service Delivery in Canada: Comparing e-Government to Traditional Service Delivery," *Government Information Quarterly* 29, no. 1 (January 2012): 1, https://doi.org/10.1016/j.giq.2011.03.005.

[19] Ebbers et al., "Facts and Feelings."

[20] Pieterson, "Citizens and Service Channels."

personal characteristics, and situational characteristics."[21] Ebbers breaks down the channel choice categories very similarly: "task-related factors, channel related factors, habit characteristics, and personal characteristics."[22] Neslin elects to expand the category options when he finds six categories that describe how customers choose channels: "firm marketing efforts, channel attributes, channel integration, social influence (or social norms), situational variables, and individual differences."[23] These listed categories indicate a bi-directional influential relationship, not simply a customer-driven influence. Reddick and Turner claim citizens base their channel choice contact with their government on four factors: "the digital divide, the nature of the interaction, the value placed on public services, and citizens' overall satisfactory experience with government service delivery."[24] Regardless of which strategy an ECC determines is most appropriate, each of these models provides a multi-faceted approach to accommodate for the possible variables an organization may encounter.

The function of the ECC is to receive and respond to emergency requests. Pieterson's findings that channel choice is determined by speed and ease of use have particularly useful application in the ECC situational context. Pieterson's research suggests that customers are highly influenced by habits and previous experiences. For 50 years, the nationally recognized message is to dial 9-1-1 in an emergency. A shift in that entrenched mindset during an emergency may not immediately occur for a community member to move to a different channel. However, Pieterson and Neslin agree that experiences influence a customer to remain with or change channels. A positive experience with the new channel could reinforce use in the new channel.

Ebbers et al. and Reddick and Turner agree that trust and emotion are contributing factors to how citizens view public services. The ECC often offers the first point of contact between community members and the police department. The quality of service provided

---

[21] Pieterson.

[22] Ebbers et al., "Facts and Feelings."

[23] Neslin et al., "Challenges and Opportunities in Multichannel Customer Management."

[24] Reddick and Turner, "Channel Choice and Public Service Delivery in Canada."

at the time of this initial contact can set the tone for the emotions felt throughout the rest of their contact with the police department. How citizens feel about the police department can also set the tone for their perception and trust of the introduction of any new channels. One community member could perceive a new channel as positive, efficient, and progressive. The same channel could be seen as negative and an opportunity to collect data on its citizens, for example. These divergent responses could be based on trust and emotion.

Decision-making models outlining influences that drive channel choice vary between researchers. However, all the aforementioned research unanimously agrees that organizations can benefit from providing multiple channels. The increased channel choice increases customer satisfaction, loyalty, and the quality of service in public service organizations.

## C. MAKING EFFECTIVE DECISIONS

Moving to a multi-channel communication environment allows organizations to expand their information capacity and availability to make more effective decisions. Data-driven decision-making has emerged in various disciplines as a tool used in organizational development to increase the quality of the decision-making process. Penn and Dent "define data-driven decision-making as a single phenomenon that can be described as input, throughput, and output where technology and people come together."[25] Žliobaitė provides a modeling description wherein, "data-driven decision making refers to using predictive models learned on historical data for decision support."[26] New technology, such as Twitter and Waze, have revealed ways in which emergencies are being reported much quicker than 9-1-1 calls, essentially "predicting" that 9-1-1 calls are about to arrive by hard-wired telephone lines to the ECC. This early notification, by way of data-driven technology, provides an ECC additional information from different sources to make better decisions.

---

[25] Stephen P. Penn and Eric B. Dent, "Attaining Data-Driven Decision-Making through Social Discourse," *The Journal of Applied Management and Entrepreneurship* 21, no. 2 (April 1, 2016): 26–44, https://doi.org/10.9774/GLEAF.3709.2016.ap.00004.

[26] Indrė Žliobaitė, "Measuring Discrimination in Algorithmic Decision Making," *Data Mining and Knowledge Discovery* 31, no. 4 (July 2017): 1060–89, https://doi.org/10.1007/s10618-017-0506-1.

A review of the research reflects a variety of processes used to apply data-driven decision-making. According to Elgendy and Elragal, the principal benefit of data-driven decision-making is to "enhance the quality of the decision-making process, and potentially the quality of the decision as a byproduct."[27] To Gray, the use of data, metrics, and analytics increase the speed of the observe-orient-decide-act (OODA) loop and make it more effective.[28]

The OODA loop research was compared to the National Institute of Standards and Technology risk management process, which is a similar process of monitor-frame-assess-respond when managing information security issues, specifically in the cybersecurity industry. The authors recommend these two processes at a greater speed rather than the Shewhart cycle, which offers an often-extended planning stage, followed by the do-check-act stages.[29]

Elgendy and Elragal created a "design science methodology called Big-Data, Analytics and Decisions."[30] This methodology integrates big data tools, architectures, and analytics into a four-phase decision-making process: intelligence-design-choice-implementation. This process removes complexity but includes all the necessary tools and inputs at the front end. Sivarajah et al. add to the big data discussion, but focus on methods to analyze the data.[31] Their findings resulted in five analytical methods: descriptive, inquisitive, predictive, prescriptive, and pre-emptive. Each of these methods provides useful models for improved decision-making in various situations. The authors suggest that by quantifying data, locating inconsistencies, and finding trends that may be labeled concerns or opportunities, organizations can achieve increased organizational output.

---

[27] Nada Elgendy and Ahmed Elragal, "Big Data Analytics in Support of the Decision Making Process," *Procedia Computer Science* 100 (2016): 1071–84, https://doi.org/10.1016/j.procs.2016.09.251.

[28] Douglas Gray, *Improving Cybersecurity Governance Through Data-Driven Decision-Making and Execution* (Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2014), 3, http://www.dtic.mil/dtic/tr/fulltext/u2/a610301.pdf.

[29] Gray, 4–6.

[30] Elgendy and Elragal, "Big Data Analytics in Support of the Decision Making Process."

[31] Uthayasankar Sivarajah et al., "Critical Analysis of Big Data Challenges and Analytical Methods," *Journal of Business Research* 70 (January 2017): 263–86, https://doi.org/10.1016/ j.jbusres.2016.08.001.

Research by Brynjolfsson and McElheran supports this anecdotally, finding higher productivity and improved performance when combined with a management response.[32] They state that overall, better decisions are attributable to better data.

Sharma, Mithas, and Kankanhalli suggest incorporating business analytics (specifically using the patterns and trends of data and understanding the causes of them) in order to make decisions that add value.[33] They state that humans must then make a conscious choice to follow the recommendations provided by machine learning. Decision makers must then take the insights gained from the recommendations produced by the data and transform them into strategic and operational decisions to generate value. This suggested process includes the sociotechnical considerations of data-driven decision-making.

Penn and Dent propose an even more socially weighted perspective than Sharma et al., which underscores the importance of discourse and culture within an organization.[34] They state that these two characteristics measurably affect the effectiveness of data-driven decision-making through the power of social influence. Considerations within these two characteristics of discourse and culture include concepts such as the motivation behind decisions, environmental factors, and the company's cultural nuances. Penn and Dent further suggest that decisions focused solely on the IT perspective can enhance decision-making, but only to a limited degree. The ability to interweave the analytical tools with the environmental connections of people, culture, and behaviors create the most effective decisions. This research is noteworthy for the emergency communications environment. The standard amount of technology found in the single channel emergency communications environment includes five to seven computer monitors and the associated

---

[32] Erik Brynjolfsson and Kristina McElheran, "The Rapid Adoption of Data-Driven Decision-Making," *American Economic Review* 106, no. 5 (May 2016): 133–39, https://doi.org/ 10.1257/ aer.p20161016.

[33] Rajeev Sharma, Sunil Mithas, and Atreyi Kankanhalli, "Transforming Decision-Making Processes: A Research Agenda for Understanding the Impact of Business Analytics on Organisations," *European Journal of Information Systems* 23, no. 4 (July 2014): 433–41, https://doi.org/10.1057/ ejis.2014.17.

[34] Penn and Dent, "Attaining Data-Driven Decision-Making through Social Discourse."

software and monitoring requirements. The sociotechnical design becomes essential for the user to be able to manage the functions in a limited space (Figure 2).

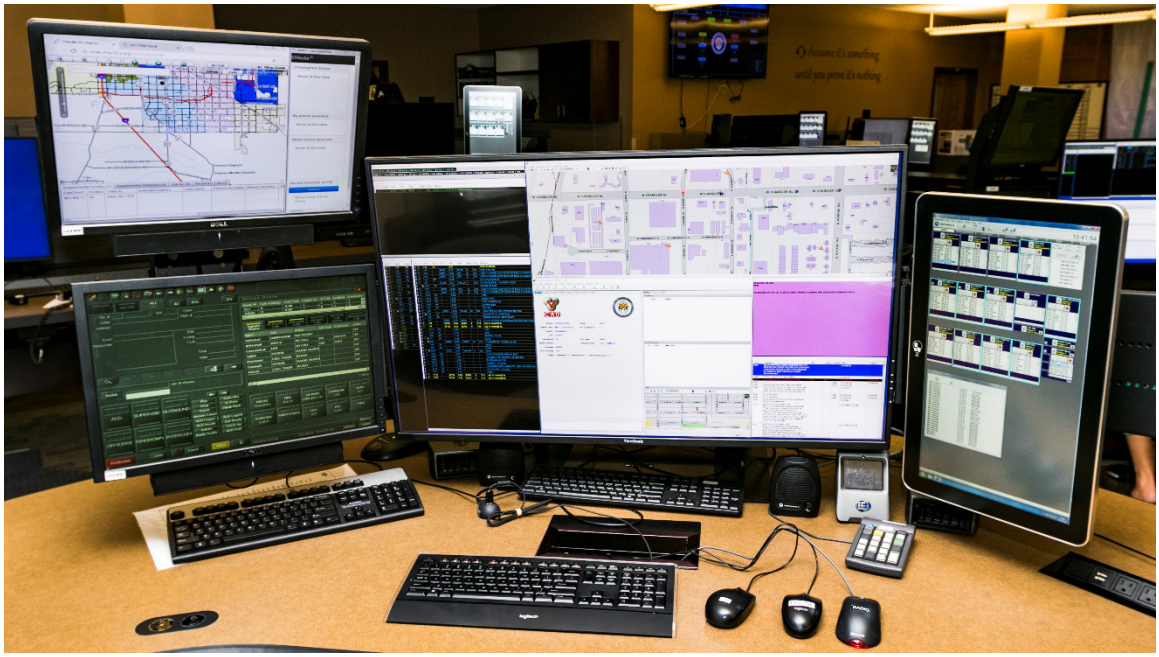

Figure 2. Multi-screen Dispatch Console

The literature provided noted gaps and concerns associated with data-driven decision-making as well. Penn and Dent suggest the need for further research in the area of culture and information technology, and its ability to drive organizational capabilities fully at the higher levels.[35] Similarly, Brous et al. imply that trust and acceptance barriers need to be researched, as some managers struggle to trust the data, and therefore, have not fully embraced the capabilities of data-driven decision-making.[36] Žliobaitė cautions readers regarding the drawbacks of data-driven decision-making and its potential use for indirect discrimination.[37] She further warns that machine learning and algorithms that

[35] Penn and Dent, "Attaining Data-Driven Decision-Making through Social Discourse."

[36] Paul Brous et al., "Factors Influencing Adoption of IoT for Data-Driven Decision Making in Asset Management Organizations," in *Proceedings of the 2nd International Conference on Internet of Things, Big Data and Security* (Porto, Portugal: SCITEPRESS—Science and Technology Publications, 2017), 70–79, https://doi.org/10.5220/0006296300700079.

[37] Žliobaitė, "Measuring Discrimination in Algorithmic Decision Making."

direct virtually every scenario, rather than a currently case-by-case scenario, effectively can discriminate systematically and on a grand scale. Public safety agencies take active steps to avoid any type of discrimination, bias, perceived bias, or disproportionate treatment towards specific groups or demographics.

The research provides a glimpse of the various processes in which data-driven decision-making can improve the quality and efficiency of decisions in organizations. Strong support also exists for addressing the sociotechnical component in the process. Researchers also recommend that organizations not limit the scope to only the technical or economic benefits of the organization. The social and cultural components have the ability to provide additional context to provide the most comprehensive approach to data-driven decision-making.

## D. DEVELOPING A COMPREHENSIVE STRATEGY

Creating a comprehensive and efficient multi-channel environment requires a strategic integration of individual yet complementary channels. The literature reflects multiple ways in which organizations can approach the multi-channel environment. Neslin and Shankar provide a linear, somewhat traditional, framework identifying five tasks for managers: "analyze customers, develop multi-channel strategy, design channels, implement, and evaluate."[38] The authors discuss the differentiation between channels in this process. They suggest considering the multi-channel management strategy in terms of efficiency (cost reduction), segmentation (based on customer usage), and customer satisfaction (enhancement). They further contend that any segmentation between channels should be, "measurable, accessible, differentially responsive, actionable, and substantial."[39] These factors ensure that the multi-channel environment is not a simple addition of channels that creates redundancy. Rather, it is a way in which the channels can efficiently work together to avoid redundancies and work intelligently.

---

[38] Scott A. Neslin and Venkatesh Shankar, "Key Issues in Multichannel Customer Management: Current Knowledge and Future Directions," *Journal of Interactive Marketing* 23, no. 1 (February 2009): 71, https://doi.org/10.1016/j.intmar.2008.10.005.

[39] Neslin and Shankar, 71.

Stone, Hobbs, and Khaleeli explore the multi-channel environment and focus on technology, organizational issues, measurements, and economics.[40] The authors highlight the need for the customer experience to be the starting point. They provide recommendations related to the complexity of technology, managing internal organizational issues, ongoing measurements and adjustments of processes, and assessing the economics. They provide two detailed roadmaps for implementing a multi-channel strategy. Both roadmaps suggest starting with a quick success, and then build off that success into a rapid return on investment, redesign and move into another quick success. This thesis builds off these suggestions by providing case studies and a template for the implementation of a multi-channel environment using the lean strategy business model.

Payne and Frow illustrate a more structured approach in the creation and design of an integrated multi-channel strategy.[41] Their research also focuses on customer relationship management, with multi-channel integration as a cross-functional process in which to do so. Payne and Frow categorize their findings into six types of strategies for organizations: "mono-channel provider strategy, customer segment channel strategy, graduated account management strategy, channel migratory strategy, activity-based channel strategy, and an integrated multi-channel strategy."[42] Each of these strategies covers a different type of channel purpose, business environment, or technical environment. This research provides considerations when planning for the type of future multi-channel environment. The categories can further present a starting point for developing a strategic plan.

---

[40] Merlin Stone, Matt Hobbs, and Mahnaz Khaleeli, "Multichannel Customer Management: The Benefits and Challenges," *Journal of Database Marketing & Customer Strategy Management* 10, no. 1 (September 2002): 39–52, https://doi.org/10.1057/palgrave.jdm.3240093.

[41] Adrian Payne and Pennie Frow, "The Role of Multichannel Integration in Customer Relationship Management," *Industrial Marketing Management* 33, no. 6 (August 2004): 527–38, https://doi.org/10.1016/j.indmarman.2004.02.002

[42] Payne and Frow, 531.

Kabadayi et al. highlight the benefits of complementarity and synergy in multi-channel systems.[43] These benefits are accomplished through the quality of service delivered by individual channels and through the quality of the integration of channels. The researchers summarize their findings for managers into two sections, stakeholder-focused implications and channel-focused implications.[44] When addressed concurrently and with the other in mind, they complement one another and provide the ability to create a quality multi-channel strategy. As ECCs transition to the multi-channel environment, this research notes that it is not a linear transition. A key component will include the coordination of both stakeholder and channel considerations.

Goersch similarly discusses multi-channel integration in terms of synergy, first as a benefit to customers, which ultimately benefits the organization.[45] Although the context of this article's research is in terms of retail websites, the focus of the discussion has merit in its consideration of the customer interface and the design and functionality of any multi-channel integration. His findings propose six criteria to manage a successful multi-channel integration: "branding, channel cross-promotions, consistency, integrating logistics, channel-specific capabilities, and information management."[46] While Goersch adds the retail perspective such as channel cross-promotions, his study overlaps with the research of Kabadayi, Loureiro and Arnevale in describing the value of individual channels and the synergy created through integration.

Wilson and Daniel introduce the topic of dynamic capability into multi-channel management strategy.[47] The authors cite the definition of dynamic capability provided by

---

[43] Sertan Kabadayi, Yuliya Komarova Loureiro, and Marina Carnevale, "Customer Value Creation in Multichannel Systems: The Interactive Effect of Integration Quality and Multichannel Complexity," *Journal of Creating Value* 3, no. 1 (May 2017): 1–18, https://doi.org/10.1177/2394964317697608.

[44] Kabadayi, Loureiro, and Carnevale, 14.

[45] Daniel Goersch, *Multi-Channel Integration and Its Implications for Retail websites* (Gdansk, Poland: ECIS 2002, 2002), 11, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.107.8423&rep=rep1&type=pdf.

[46] Goersch, 753.

[47] Hugh Wilson and Elizabeth Daniel, "The Multi-Channel Challenge: A Dynamic Capability Approach," *Industrial Marketing Management* 36, no. 1 (January 2007): 10–20, https://doi.org/10.1016/j.indmarman.2006.06.015.

Eisenhardt and Martin: "An organization's processes that integrate, reconfigure, gain and release resources to match and even create market change."[48] Wilson and Daniel apply this dynamic capability approach to the multi-channel strategy to develop innovation and determine appropriate resource allocation.[49] The authors recommend the organization focus on the ability to operationalize mainstream activities with new activities. Their findings create a model that comprises seven components: "vision and strategy, harnessing the competence base; organizational intelligence; creativity and idea management; organizational structure and systems; culture and climate; and the management of technology."[50] Further, their model promotes a methodology similar to Stone, Hobbs, and Khaleeli in that experimentation and hands-on learning leads to flexibility and agility.

This dynamic capability is the principal concept behind a platform that can accept the contemporary communication channels of the day and retire the channels no longer relevant. This change requires the flexibility to reconfigure technology when needed or to run mainstream activities alongside new activities. It also requires organizational intelligence to know when new technology should replace mainstream technology or when new ideas should be operationalized. Wilson and Daniel provide supporting research for the lean strategy business model in the multi-channel environment that has application potential in the ECC.

This literature review reveals that other business environments have transitioned to the multi-channel environment and increased customer satisfaction, loyalty, and quality of service. The quality of service in life safety circumstances is critical. Finding ways to improve the current quality of service should be ongoing. The ECC is the first contact with the public. Providing customer satisfaction on that first contact builds trust between the public safety agency and the community, the trust that they will be heard and their needs appropriately handled. Adding channels can provide new ways for customer satisfaction

---

[48] Kathleen M. Eisenhardt and Jeffrey A. Martin, "Dynamic Capabilities: What Are They?" *Strategic Management Journal* 21 (2000): 1107, http://mail.tku.edu.tw/myday/teaching/992/SEC/S/992SEC_T3_Paper_20100415_Eisenhardt%20Martin%20(2000)%20-%20Dynamic%20capabilities%20what%20are%20they.pdf.

[49] Wilson and Daniel, "The Multi-Channel Challenge," 1–4.

[50] Wilson and Daniel, 11.

by accommodating preferences and channel choice. A multi-channel environment creates opportunities for this added layer of benefits to the existing single channel system.

The research surveyed also demonstrates that multi-channel environments create the ability for organizations to expand their information capacity and make more optimal decisions. This information can be given to first responders for situational awareness and officer safety. The increased information availability in an ECC allows for a more efficient and timely response to emergencies. This increased availability indicates that the multi-channel environment in an ECC can positively influence the life safety emergency response.

The final section of the literature review supports implementation strategies that integrate complementary channels. The research includes various models to consider in the planning process to include both customers and channels. Most notably is the lean strategy business model used in the multi-channel environment that has application possibilities in the ECC.

## E. ASSUMPTIONS AND DELIMITATIONS OF THE WORK

Every research project must have boundaries so that the research may be focused and productive. This work is no different. This work makes the following assumptions:

- The specific data used within this writing is limited to the City of Chandler and the Department of Public Safety (DPS).
- Agency-specific data used is from 2018 and prior. Data that required a manual review was collected for October 2018, or January 2018–October 2018.
- The circumscribed timeline for this thesis does not allow for the full implementation of any of the new channels explored. Rather, the thesis reports on the transition to those new channels within that limited amount of time.

- The Chandler Police ECC is responsible for dispatching law enforcement for a single municipal jurisdiction. Many ECCs are consolidated and may dispatch for multiple jurisdictions or disciplines, such as police, fire or emergency medical services (EMS).

THIS PAGE INTENTIONALLY LEFT BLANK

# III. SITUATION ANALYSIS

## A. INTRODUCTION

Emerging communications technology creates both opportunities and challenges for the modern ECC. Many contemporary technology tools in the marketplace have the potential to become an emergency reporting communication channel, such as social media, apps, and multimedia messaging. The aggregation of data provided by these tools can provide ECCs with a more comprehensive level of situational awareness, and thereby drive a more efficient and safe response. This chapter explores the impact of burgeoning wireless communications on the typical ECC.

## B. WIRELESS TECHNOLOGY

Wireless technology created an unanticipated and overwhelming impact on 9-1-1 systems and processes within the ECC. Wireless device ownership provides immediate access to 9-1-1, and the community is using it. Varying studies cite that as of 2018, between 70% and 80% of the 240 million annual 9-1-1 calls originate from cell phones.[51] Maricopa County, Arizona cites their 2018 cell phone 9-1-1 statistics higher than this national average, at 85%.[52]

### 1. Smartphones: Personal Computers in Disguise

The rapid increase in smartphone ownership has replaced traditional analog voice technology with wireless data traffic for primary communication channel usage. The CTIA Wireless Foundation (CTIA) is a nonprofit trade association comprised of wireless industry stakeholders, such as AT&T, Sprint, Intel, Verizon, Apple, and Samsung.[53] Their mission is to coordinate best practices and industry initiatives, as well as advocate for legislative and regulatory issues. In a May 2017 report, CTIA released 2016 statistics that the United

---

[51] National Emergency Number Association, "9-1-1 Statistics"; "Consumer Help Center," Federal Communications Commission, accessed July 2, 2018, https://www.fcc.gov/consumers/guides/911-wireless-services.

[52] Liz Graeber, "911 Totals 2018," accessed March 29, 2018.

[53] "Our Mission," CTIA, accessed July 2, 2018, https://www.ctia.org/about-ctia/our-mission.

States had 395.9 million wireless subscribers, a 4.8% increase from the reported 377.9 million subscribers in 2015.[54] These total wireless subscriber statistics represent a U.S. market penetration of 120.6%, or that the average American has just over 1.2 wireless devices.[55]

The Pew Research Center, known for its public opinion polls and other social science data gathering, released updated statistics in February 2018.[56] Their findings supported the increase in cell phone ownership cited by CTIA and Ericsson but provided a slightly different statistic, that is, 95% of Americans owned cell phones. This percentage indicates that not all adults in America have cell phones and that some adults have multiple devices. Of most interest in this report is the increase in American smartphone ownership to 77% in 2018 from the 35% reported in 2011.[57] In the 2016 CTIA report, of the 395.9 million subscribers, 261.9 million were reported to be smartphones.[58]

Residential landline ownership is no longer maintained at the same rate as wireless subscribers.[59] The National Center for Health Statistics conducted a survey to determine the number of homes that maintain a landline. The survey used data from July–December 2016 and reported that 50.8% of homes no longer had a landline phone, but maintained only a wireless phone, which continued a downward spiral that began several years earlier.[60]

---

[54] "Americans' Wireless Data Usage Continues to Skyrocket," CTIA, accessed July 2, 2018, https://www.ctia.org/news/americans-wireless-data-usage-continues-to-skyrocket.

[55] CTIA, "Our Mission."

[56] Pew Research Center: Internet, Science & Tech, "Mobile Fact Sheet."

[57] Pew Research Center: Internet, Science & Tech.

[58] CTIA, *CTIA 2016 Annual Wireless Industry Survey Snapshot* (Washington, DC: CTI, 2017), 2, https://api.ctia.org/docs/default-source/default-document-library/ctia-wireless-snapshot.pdf.

[59] Stephen J. Blumberg and Julian V. Luke, *Wireless Substitution: Early Release of Estimates from the National Health Interview Survey, July–December 2016* (Washington, DC: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics, 2017), 2, https://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201705.pdf.

[60] Blumberg and Luke, 1.

Smartphones provide mobility and immediate access to data. Consumers spent twice as many minutes on mobile as desktop in April 2016.[61] The time spent on smartphones doubled in 2016 to an average of 2 hours 32 minutes per day per user spent on mobile applications and web. Of total online time, 71% is reported to be on a smartphone.

These industry experts project that data traffic growth will continue at a staggering rate.[62] In its June 2017 report, Ericsson released projections that monthly mobile data traffic per user is anticipated to be 26GB per month by 2022. Also predicted in this report is that mobile data traffic would grow at a rate of 42%. This growth rate matches the 2017 statistics to date reported by CTIA.[63]

### 2. Non-service Initialized Phones: The Phones Not Counted, but with a Big Impact

Non-service initialized (NSI) phones are cell phones without a wireless carrier plan and are not activated.[64] These phones are not included in the statistics of the nearly 396 million wireless subscribers in the United States. This creates additional volume to the already increased wireless impact. It also does not provide the 9-1-1 operator with reliable location information of the caller.

The ability for NSI phones to call 9-1-1 was originally made available to provide the elderly, victims of domestic violence, and low-income residents access to emergency services. It also allows wireless users who experience temporary financial hardships or have their wireless accounts suspended for any number of reasons, the ability to retain

---

[61] CTIA, *Wireless Snapshot 2017*, 4.

[62] Ericsson, *Ericsson Mobility Report* (Stockholm, Sweden: Ericsson, 2017), 14–34, https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf.

[63] CTIA, "Americans' Wireless Data Usage Continues to Skyrocket."

[64] "Cell Phones and 9-1-1," National Emergency Number Association, accessed July 2, 2018, https://www.nena.org/default.aspx?page=911Cellphones.

uninterrupted access to emergency services.[65] The National Association of State 9-1-1 Administrators and other public safety groups have requested that the Federal Communications Commission (FCC) sunset the mandate that these phones retain the ability to dial 9-1-1 when not activated.

NSI phones create unnecessary call volume, which can delay valid 9-1-1 calls. A review of the 6,812 non-service-initialized calls received by the Chandler Police ECC in 2018 demonstrated that 5,490 (81%) of them were unintentional.[66] Of the remaining 1,322 calls, 454 generated a call for service in which police or fire was dispatched (6.7%). Of the 454 calls for service, 143 were finalized with some type of police action (2%).

The two most common problematic scenarios include a child using the phone as a toy, and the purposeful abuse of 9-1-1. Non-service-initialized phones are often the cell phone replaced by the newest version of the smartphone and given to the child as a toy. Many people are unaware that these phones are able to call 9-1-1 when the battery is charged. The most extreme criminal case documented was experienced by the Oahu Police Department.[67] A suspect dialed 9-1-1 from an untraceable non-service-initialized phone 200–300 times per day for nine consecutive months. The Houston Emergency Center reported in March 2017 that at least 10% of their daily 9-1-1 call volume was attributed to non-service-initialized phones, equal to between 1,000 to 1,500 calls daily.[68] Houston further added its concerns about the increase in frequency with trends of smartphone phone upgrades becoming more frequent. A portion of the Houston calls was reviewed individually, and no actual emergencies were found in its review.

---

[65] "Harmful Consumer Wireless Behavior and Practices," Federal Communications Commission, October 14, 2014, https://www.fcc.gov/news-events/blog/2014/10/14/harmful-consumer-wireless-behavior-and-practices.

[66] Chandler Police, "Chandler Police Department Versaterm Records Management System."

[67] "Comments of the National Association of State 911 Administrators," Google Docs, accessed July 2, 2018, https://drive.google.com/file/d/0B_rtue3opT_JMFhNOW9peHJoZ0E/view.

[68] Paul Kirby, "Texas 911 Agency Cites NSI Call Nuisance," *National Public Safety Telecommunications Council* (blog), March 22, 2017, https://blog.npstc.org/2017/03/22/texas-911-agency-cites-nsi-call-nuisance/.

## C. WIRELESS PHONE USE DURING LOCAL OR REGIONAL DISASTERS

Recent disasters have revealed limitations in the current capabilities of 9-1-1 systems. These limitations result in citizens using alternatives, such as social media, to contact emergency services during crisis events when they are unable to reach 9-1-1. These same disasters have further demonstrated that public safety agencies are not prepared to use alternative channels, such as social media, as a supplemental function of the 9-1-1 system. The following case studies illustrate the modern evolution of communication technologies used during a localized disaster.

### 1. Orlando Pulse Nightclub

Case study 1 describes the events that occurred on June 12, 2016, which marks the deadliest domestic extremist killing in U.S. history since the 1995 Oklahoma City bombing.[69] An armed gunman who pledged allegiance to Islamic State of Iraq and Syria (ISIS) took hostages in Orlando, Florida's Pulse Nightclub that ultimately killed over 50 people and injured many others. Emergency calls flooded into the Orlando Police Department's 9-1-1 ECC.[70] Information reported by victims and witnesses was relayed to police officers at the scene, and medical calls were transferred to the Orlando Fire Department. The volume of emergency calls exceeded the capacity of the 9-1-1 system and ECC staff. The result was an extended 9-1-1 call wait time, and overflow calls routed to the Orange County 9-1-1 ECC. Hostages began to send text messages and post on social media to communicate with friends and family what was happening during the incident to describe their injuries and share their location within the scene.[71] Many who saw the social

---

[69] Anti-Defamation League, *Murder and Extremism in the United States in 2016* (New York: Anti-Defamation League, 2017), 1–2, https://www.adl.org/sites/default/files/documents/MurderAndExtremismInUS2016.pdf.

[70] "Orlando Nightclub Shooting 911 Calls Released," ABC News, YouTube, video, 8:33, August 31, 2016, https://www.youtube.com/watch?v=HLzG_IsW_3E&t=224s.

[71] FDNY Center for Terrorism and Disaster Preparedness, *Orlando Terror Attack* (New York: FDNY Center for Terrorism and Disaster Preparedness, 2016), 16–17, https://info.publicintelligence.net/FDNY-OrlandoAttack.pdf.

media posts or received the texts called 9-1-1 on their behalf, also adding to the 9-1-1 center's call volume.[72]

The Orlando Police Department did not have text-to-9-1-1 or any other communication channels available.[73] Calling 9-1-1 was the agency's only formal channel available, yet the public used other channels like text messaging, Facebook, and Twitter to contact friends and family as channels of communication to report their emergencies. These newly created data-driven communication channels resulted in second-hand duplicate 9-1-1 calls, which further overwhelmed the 9-1-1 ECC.

### 2. Hurricane Harvey

The setting for Case Study 2 is Hurricane Harvey that brought five days of devastation to South Texas as a Category 4 hurricane on August 24, 2017.[74] Storm winds exceeded 130 miles per hour, heavy rain reached 50 inches in some places, and rivers crested to approximately 30 feet from flooding. The resulting damage was catastrophic, with a death toll reaching a tragic 82.[75]

Harris County is located in southern Texas and encompasses the city of Houston, one of the areas inundated with the effects of Hurricane Harvey. Forty 9-1-1 centers are located in the Greater Harris County 9-1-1 Emergency Network, one of the largest 9-1-1 networks in the nation, and the largest network in Texas.[76] These 9-1-1 centers faced record high call volume that received approximately 80,000 calls compared to the 8,000

---

[72] ABC News, "Orlando Nightclub Shooting 911 Calls Released."

[73] Federal Communications Commission, "Text 911 Master PSAP Registry.xlsx."

[74] "Major Hurricane Harvey–August 25–29, 2017," National Weather Service, June 18, 2018, https://www.weather.gov/crp/hurricane_harvey.

[75] Eva Ruth Moravec, "Texas Officials: Hurricane Harvey Death Toll at 82, 'Mass Casualties Have Absolutely Not Happened,'" *Washington Post*, September 14, 2017, https://www.washingtonpost.com/national/texas-officials-hurricane-harvey-death-toll-at-82-mass-casualties-have-absolutely-not-happened/2017/09/14/bff3ffea-9975-11e7-87fc-c3f7ee4035c9_story.html.

[76] "Greater Harris County 9-1-1 Emergency Network (GHC 9-1-1)," Greater Harris County 9-1-1 Emergency Network, 2017, http://www.911.org/.

calls in an average 24-hour period.[77] About a dozen of these 9-1-1 centers were incapacitated from the storm.[78] Houston had another option to the traditional voice call to 9-1-1; text-to-9-1-1 had been implemented a few years prior, but very few used it.[79] Members of the public turned to social media for emergency requests for rescue during the storm. Rescue requests were posted on various social media platforms, such as Facebook, Twitter, and Next Door. Family, friends, neighbors, and strangers responded to assist. Many of these data-driven communication channels emerged and operated independently of official government public safety communications channels.

The United States Coast Guard (USCG) tweeted specifically not to request rescue needs on social media during Hurricane Harvey and provided multiple contact options for those needing an emergency response.[80] A consultant for the Coast Guard publicly explained the difficulty of extracting actionable data from the quantity of information posted on Twitter. Less than one month later, after responding to three major hurricanes in three weeks, the Coast Guard had changed its mind. Vice Admiral Sandra Stosz spoke out asking for national guidelines and protocols. "That's how we rescued the 11,000 people, leaning in on how the public was self-selecting to use social media, because they couldn't get through on 911 calls."[81]

---

[77] Heather Kelly, "Harvey Highlights Issues of Aging 911 Tech," CNN Money, September 1, 2017, http://money.cnn.com/2017/09/01/technology/future/911-tech-harvey/index.html.

[78] Lauren Silverman, "Facebook, Twitter Replace 911 Calls For Stranded In Houston," NPR, August 28, 2017, https://www.npr.org/sections/alltechconsidered/2017/08/28/546831780/texas-police-and-residents-turn-to-social-media-to-communicate-amid-harvey.

[79] Ben Johnson and Jana Kasperkevic, "Barely Anyone Used Text-to-911 during Hurricane Harvey," Marketplace, August 30, 2017, http://www.marketplace.org/2017/08/30/tech/barely-anyone-used-text-911-during-hurricane-harvey.

[80] Marcus Gilmer, "During Harvey, Social Media Rose to the Challenge as a Force for Good," Mashable, August 29, 2017, https://mashable.com/2017/08/29/social-media-harvey-rescues-force-for-good/.

[81] "Recent Hurricanes Have the Coast Guard Rethinking Social Media's Role in Rescue and Response," Federal News Radio, September 21, 2017, https://federalnewsradio.com/management/2017/09/recent-hurricanes-have-the-coast-guard-rethinking-social-medias-role-in-rescue-and-response/.

### 3. 9-1-1 Outages

The first two disasters provide examples in which more 9-1-1 calls were made than technology and staff had the capacity to answer. However, many catastrophes have another sound: silence. In Case Study 3, over a six-hour period on April 9, 2014, 6,600 people across the country dialed 9-1-1 and could not reach emergency services.[82] Most callers received a fast busy signal and the few emergency calls that did go through were routed to the wrong location. No large-scale disaster or terrorist attack had occurred. CenturyLink reported the cause was a software coding glitch in their network that affected a total population of 11 million people in seven states (California, Florida, Minnesota, North Carolina, Pennsylvania, South Carolina, Washington). Of the total 60 counties impacted, Washington State felt the greatest impact with all 39 counties in the state affected. Effectively, all continuity of operations plans at all ECCs in the state of Washington were rendered useless. Exacerbating the problem, ECCs were not properly notified by CenturyLink, delaying the execution of public safety contingency plans that could be put in place. Century Link was fined $20.25 million.

T-Mobile agreed to a $17.5 million settlement in July 2015 following two 9-1-1 outages in August 2014.[83] A planned upgrade that went awry resulted in 50 million T-Mobile customers nationwide from connecting outgoing calls to 9-1-1 for a total of three hours. Alerts of the outage to emergency communications centers did not occur for another three hours, again resulting in a delay of contingency plans.

AT&T experienced a five-hour 9-1-1 outage on March 8, 2017, and another 47-minute outage on May 1, 2017.[84] The two outages produced a total of 15,200 attempted 9-1-1 calls that could not reach their local ECC in 49 states, the District of Columbia, Puerto

---

[82] Public Safety and Homeland Security Bureau, *April 2014 Multistate 911 Outage Report* (Washington, DC: Federal Communications Commission, 2015), 1–5, https://www.fcc.gov/document/april-2014-multistate-911-outage-report.

[83] "T-Mobile to Pay $17.5 Million to Resolve 911 Outage Investigation," Federal Communications Commission, December 8, 2015, https://www.fcc.gov/document/t-mobile-pay-175-million-resolve-911-outage-investigation-0.

[84] Federal Communications Commission, *AT&T Mobility, LLC, No. EB-SED-17-00024532* (Washington, DC: Federal Communications Commission, 2018), 1.

Rico and the Virgin Islands, across thousands of ECCs. This outage occurred during a planned network upgrade. The FCC fined AT&T $5.25 million.

FCC Chairman Ajit Pai directed the Public Safety and Homeland Security Bureau to investigate a nationwide 9-1-1 outage involving CenturyLink beginning on December 27, 2018.[85] States experiencing outages included Washington, Oregon, Missouri, Montana, Massachusetts, Idaho, Arizona, and Utah. Preliminary reports from CenturyLink state the cause was a network card in their operations center in Colorado. Many of the same affected centers in the 2014 outage were again affected in the 2018 outage.

### 4. From Mass Regional Disruption to Local Frequent Disruptions

The Orlando Pulse Nightclub shooting and Hurricane Harvey provide examples of distinctly different types of public safety emergencies. Orlando's shooting was a local, isolated terrorist attack with regional impact. Hurricane Harvey was a regional, natural disaster. Both incidents overwhelmed 9-1-1 ECCs and resulted in a data-driven, multi-channel emergence from the public to request emergency services, albeit not always requesting the emergency services from 9-1-1 or public safety agencies. These listed 9-1-1 outages are not exhaustive and these fines demonstrate that despite the legal requirements of telecommunication companies, the oversight and enforcement by the FCC, the outages continue at an alarming rate and at times, have a larger footprint than disasters. Most disturbingly, these partners that support the 9-1-1 infrastructure are arguably impacting a greater number of emergency calls than the disasters.

The three case studies presented describe catastrophes that disrupted emergency communications on a regional scale. In the next section, localized events can also disrupt communications for one or more local emergency service agencies, such as traffic collisions.

---

[85] "Chairman Pai Announces Investigation into CenturyLink 911 Outage," Federal Communications Commission, December 28, 2018, https://www.fcc.gov/document/chairman-pai-announces-investigation-centurylink-911-outage.

## D. WIRELESS PHONE USE FOR REPORTING TRAFFIC COLLISIONS

Regional catastrophes are a rarity that typically occur over a period of days or weeks, which leave residual effects affecting many people, and solutions are often expensive and time-consuming. Other localized emergencies emergency communication challenges routinely occur, usually multiple times a day, impact few, and have a lower societal cost.

### 1. Motor Vehicle Collision Notification Times

Motor vehicle traffic collisions are an international public safety concern. They impact every community, rural and urban, from the smallest township to the largest metropolitan area. The first fatality is reported to have occurred in London in late 1896.[86] Following this first fatality, conservative estimations over the next 100 years report a cumulative 25 million fatalities by 1997. By 2002, the World Health Organization reported road traffic injuries as the leading cause of global injury mortalities, at 22.8%.

The Center for Disease Control and Prevention more recently reported motor vehicle crashes as the leading cause of death in 2015 for ages 10 and 16–23.[87] The National Highway Traffic Safety Administration reported that in 2016, almost 7.3 million motor vehicle crashes were reported to police departments across the United States. Fatalities accounted for 37,461 of these crashes, 2,177,000 resulted in injuries, and 5,065,000 were classified as property-damage-only.[88] Nationwide projections for 2017 are estimated to be a slight decrease of 0.8% for a total of 37,150 fatalities. Early estimates for Region 9, which

---

[86] Margie M. Peden and World Health Organization, eds., *World Report on Road Traffic Injury Prevention* (Geneva: World Health Organization, 2004), 58, https://www.researchgate.net/profile/Margaret_Peden/publication/260288299_World_Report_on_Road_Traffic_Injury_Prevention/links/00b4953bd0f0d23cf0000000/World-Report-on-Road-Traffic-Injury-Prevention.pdf?origin=publication_detail.

[87] National Center for Statistics and Analysis, *NHTSA 2016 Quick Fact* (Washington, DC: United States Department of Transportation, National Highway Traffic Safety Administration, 2018), 1–6, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812451.

[88] National Center for Statistics and Analysis, *Police-Reported Motor Vehicle Traffic Crashes in 2016* (Washington, DC: United States Department of Transportation, National Highway Traffic Safety Administration, 2018), 1–2, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812501.

includes California, Arizona, and Hawaii, reflects a decrease of 4%.[89] The City of Chandler experienced a 56.25% decrease in fatalities from 16 in 2016 to nine in 2017, but increased 33% in 2018 to 12.[90]

These overall statistics reflect both an impact on public safety and the communities in which they serve. They also provide an opportunity for ECCs to evaluate their processes and determine what changes or adjustments can be made that could decrease the mortality rates of these fatalities, or improve the quality of service provided when motor vehicle traffic crashes occur. This section evaluates topics that directly impact the ECC and the role of 9-1-1 operators.

### 2. Impact of Vehicle Collision Notification Time on Mortality Rate

In a 2013 study conducted by Wu et al., two groups were divided based on notification time.[91] One minute or less was considered the earlier group; over one minute was considered the late group. This study determined that the earlier group had a cumulative survival rate of 52.14%, which was 1.47% higher than the latter group. This 1.47% was estimated to represent up to 290 lives per year from 2005 to 2009. The same researchers conducted a study using 2009–2012 data but made slight adjustments in the method. The results demonstrated a 4% increase in fatality hazards with a notification of more than two minutes.

Plevin et al., evaluated the different variables that could influence the likelihood of a motor vehicle crash becoming a fatality in a 2017 study.[92] The researchers used crash information from 1996–2012 and divided prehospital time into intervals. Their research

---

[89] National Center for Statistics and Analysis, *Early Estimate of Motor Vehicle Traffic Fatalities in 2017* (Washington, DC: United States Department of Transportation, National Highway Traffic Safety Administration, May 2018), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812542.

[90] Chandler Police, "Chandler Police Department Versaterm Records Management System."

[91] Jingshu Wu et al., "The Effect of Earlier or Automatic Collision Notification on Traffic Mortality by Survival Analysis," *Traffic Injury Prevention* 14, no. sup1 (January 1, 2013): S50–57, https://doi.org/10.10
80/15389588.2013.799279.

[92] Rebecca E. Plevin et al., "Evaluating the Potential Benefits of Advanced Automatic Crash Notification," *Prehospital and Disaster Medicine* 32, no. 2 (April 2017): 156–64, https://doi.org/10.1017/S1049023X16001473.

found that the longer the initial notification interval resulted in more invasive medical procedures in the first three hours. It was also found that the patient was more likely to be transferred to a trauma center for a higher level of care. What is different in this study from the other studies is the delineation of time is 30 minutes. Plevin et al. found that crash to notification times less than 30 minutes were statistically insignificant. However, each minute after the 30 minutes led to a significant increase in fatality odds. This 30-minute delineation is important when considering rural versus urban environments reporting traffic crashes.

### 3. Automatic Traffic Collision Notification Time

Much of the research found was related to notification time of motor vehicle crashes and technology-driven notification, specifically the benefits of automatic collision notifications (ACN). These systems are designed to provide an automatic emergency notification of a crash, either directly to an emergency services center, or through a third party call center that can, in turn, notify emergency services. The automatic notification includes the vehicle's location information and can often begin the notification process prior to the occupants' ability to notify emergency services themselves. The first ACN systems were installed in vehicles in the late 1990s.[93]

In a 2001 study conducted by Kanianthra et al. EMS received crash notifications within two minutes on all ACN-equipped vehicles.[94] Vehicles not equipped with ACN technology exceeded a five-minute notification time on 20% of their vehicles. Applying these findings to the time distribution of fatalities in the Fatality Analysis Reporting System, the researchers estimated between 240 and 765 lives could be saved using this technology based on its direct link to early notifications.

---

[93] Wu et al., "The Effect of Earlier or Automatic Collision Notification on Traffic Mortality by Survival Analysis,"

[94] Jean Yoder, "Fatality Analysis Reporting System (FARS)," NHTSA, November 14, 2016, https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars.

Clark and Cushing evaluated 30,875 incapacitating or fatal crashes in a 2002 study.[95] The researchers compared actual outcomes to probabilities with notification times set to one minute to simulate the use of an ACN system. Two different models were used, one focused on total annual fatalities, and the other included incapacitating injuries. The first model predicted 421 lives could be saved (1.5%), and the second model predicted a decrease of 1,674 fatalities (6%).

An international study supports these findings in both the rural and urban environments and estimated that 11% of passenger vehicle fatalities could be saved with the full implementation of ACN.[96] In this 2008 Australian study, the existing notification times were six minutes in the rural environment and three minutes in urban areas. The ACN implementation adjustment to one-minute notification estimated 41 urban and 63 rural lives saved.

The majority of the aforementioned literature reflects that the earlier the notification of the crash, the more likely the positive outcome. These outcomes are defined differently in the literature, the times are measured differently, and they use different criteria. However, the overwhelming common theme is early crash notifications are beneficial. To ensure the earliest possible notification, it requires immediate access through technology to notify emergency officials.

A 2017 study by Stickles et al. of the Dell Medical School at the University of Texas-Austin reviewed a 10-year span of increased usage of mobile phones and its correlation with motor vehicle fatalities.[97] The purpose of the study was to determine if the proliferation of phones resulted in lower fatality rates and decreased notification times. The study found some associations between reduced notification times and improved

---

[95] David E. Clark and Brad M. Cushing, "Predicted Effect of Automatic Crash Notification on Traffic Mortality," *Accident Analysis & Prevention* 34, no. 4 (July 2002): 507–13, https://doi.org/10.1016/S0001-4575(01)00048-3.

[96] Wu et al., "The Effect of Earlier or Automatic Collision Notification on Traffic Mortality by Survival Analysis."

[97] Jimmy L. Stickles, James M. Kempema, and Lawrence H. Brown, "Effect of Mobile Phone Proliferation on Crash Notification Times and Fatality Rates," *The American Journal of Emergency Medicine* 36, no. 1 (January 1, 2018): 24–26, https://doi.org/10.1016/j.ajem.2017.06.047.

outcomes in some subgroups, but the overall median notification times did not decrease. These researchers conclude that caution is warranted when building mobile communication networks and to avoid using motor vehicle crash notifications as a platform for supporting the need for these networks. This further supports the benefits of automated notifications and supplementing the current dependency on human interaction currently required under most conditions to report a traffic collision.

## E. SUMMARY AND CONCLUSIONS

It can be concluded from the data in this chapter that trends in wireless phone usage will continue to increase. The increase in smartphone ownership has significantly increased 9-1-1 call volume into ECCs. Recent local and regional disasters have created new considerations for leaders when the capacity of an ECC is exceeded and the community creates alternative reporting channels. Similarly, the reliability of the infrastructure with the ongoing 9-1-1 outages should be considered in terms of impact. Traffic collisions provide opportunities for leaders to explore wireless phone usage, redundancy, and alternative reporting in the everyday emergency response.

The following chapter examines the major limitations in the existing 9-1-1 systems, the limitations of a typical ECC workflow, and the philosophical approaches of the emergency communications industry.

# IV. COMPARATIVE ANALYSIS

## A. INTRODUCTION

Three major limitations are present in the 9-1-1 emergency communications environment. First, there are a limited number of incoming simultaneous calls possible in a typical ECC. Second, all ECCs are challenged with properly allocating its limited resources. Finally, many, sometimes conflicting, sometimes inefficient, philosophical approaches are available to manage incoming calls. Each of these limitations are now addressed, in turn.

### 1. Managing Call Volume

Managing call volume first begins in the design of the 9-1-1 infrastructure. Industry standards guide the system design, and NENA provides recommendations to assist ECCs with determining what is required to bring 9-1-1 calls into the center.[98] The industry standards are based on the Poisson distribution method, a probability distribution method that assesses the historical number and length of calls during the busiest hour and expresses future probability. The Poisson distribution method is specifically designed for assessing randomly occurring data, as 9-1-1 calls can be classified. The national association has set a minimum grade of service to ensure that no more than one out of 100 calls during the average busy hour is blocked due to call congestion.[99] Applying this method to 9-1-1 calls during the busiest hour results in a recommendation of the appropriate number of pathways to deliver 9-1-1 calls to ensure the capacity is not exceeded. Capacity studies are often done annually.

Maricopa County, Arizona, for example, far exceeds the minimum standards provided by the national association. The 9-1-1 load capacity is monitored on a call-by-

---

[98] National Emergency Number Association, *E9-1-1 Voice Circuit Requirements: Providing a P.01 Grade of Service, Technical Information Document 03–506* (Alexandria, VA: National Emergency Number Association, 2007), 8–10, https://c.ymcdn.com/sites/www.nena.org/resource/resmgr/Standards/NENA_03-50
6_v1.1_E9-1-1_Voic.pdf.

[99] National Emergency Number Association, 5.

call basis, rather than monthly or annually. It is also not based on the busiest hour, but on call volume at any given time. Technical staff is alarmed when the capacity is exceeded and a call is not routed according to the preferred routing, called priority one routing, at any of the 26 ECCs in the region. Call surges are expected, which push the occasional calls into non-priority one routes, but additional trunk lines are added when it occurs more frequently. Annual capacity studies are also conducted to ensure no overall degradation in service. Additional trunks can be added, or adjustments between the number of wireless and landline trunks can be made based on system monitoring and data review. The national standard addresses call congestion but does not address the proper routing during call congestion. The exceptional programming measures by the Maricopa Region technical team also monitor for efficiencies to the caller by ensuring the system delivers the 9-1-1 call to the intended ECC.

### 2. Regional Call Volume

Each region has its own system and workflow design. ECCs are classified into one of two different types: a primary Public Safety Answering Point (PSAP) or a secondary PSAP. An agency considered a primary answering point receives the original 9-1-1 call, which are often law enforcement, such as a city police department or county sheriff's office, when the caller places it. An answering point agency only able to receive 9-1-1 calls transferred from another agency, such as a fire department, highway patrol, or campus police department, is considered a secondary answering point. A secondary answering point agency never receives the initial 9-1-1 call. An agency's primary or secondary classification is determined within the region or state, and therefore can vary across the United States.

In Maricopa County, local law enforcement agencies are the primary answering points and answer the incoming 9-1-1 calls. Fire departments and the Arizona DPS are secondary answering points. Local law enforcement agencies triage the original 9-1-1 call and transfer to the respective fire department for fire or medical incidents. Incidents occurring on the freeways are transferred to the DPS. In 2018, Chandler transferred over

6,000 9-1-1 calls to the DPS.[100] This example is just one of a primary answering point that fields and transfers 9-1-1 calls to the DPS. Maricopa County has 23 primary and three secondary answering points, which also demonstrates another inefficiency because of technical limitations. An incident that requires a transfer delays a response; such as the case for secondary answering points like the DPS. Changes to regional routing can require significant technical upgrades with large costs attached, and they often have some political considerations as well.

The regional design becomes of greater importance in an overflow scenario. Many ECCs have agreements with other centers to accept overflow 9-1-1 calls. In a metropolitan area with dozens of ECCs, the implications of multiple centers rolling over to each other have a domino effect and the potential to overwhelm an entire region. A large-scale incident need not occur. The following case study illustrates a comparable situation.

In June 2017, a wrong way driver was reported on the 101 freeway in the East Valley of the Phoenix metropolitan area (see Figure 3).[101] The freeway in this incident runs through four city jurisdictions but ultimately impacted seven communications centers because of the call volume it generated. In eight minutes, 86 calls were placed to the Chandler Police Department to report this driver, 33 calls to the Tempe Police Department, three to the Scottsdale Police Department, and nine to the Mesa Police Department. All these agencies are primary answering points and receive 9-1-1 calls directly, but because the freeway is the jurisdiction of DPS that does not receive 9-1-1 calls directly, all four of these primary centers began to transfer these 131 calls to the DPS-Phoenix emergency communications center. The 86 calls received by Chandler saturated its center and overflowed into a secondary wireless 9-1-1 call overflow queue, as its wireless calls do not overflow to a different agency. DPS-Phoenix began overflowing to its backup center, DPS-Tucson, located over 100 miles south of the incident location. When the DPS-Tucson emergency communications center began overflowing, calls began overflowing to the City of Tucson's emergency communications center. For about eight minutes during this

[100] Chandler Police Department MIS Data, unpublished data, 2018.

[101] Chandler Police, "Chandler Police Department Versaterm Records Management System."

incident, three centers (Chandler, DPS-Phoenix, and DPS-Tucson) were only handling 9-1-1 calls generated by the wrong way driver, arguably paralyzed for any other emergency in those three jurisdictions. Four other agencies were also handling calls, for a total of seven public safety agencies, all handling the 131 calls to 9-1-1 reporting the same incident.

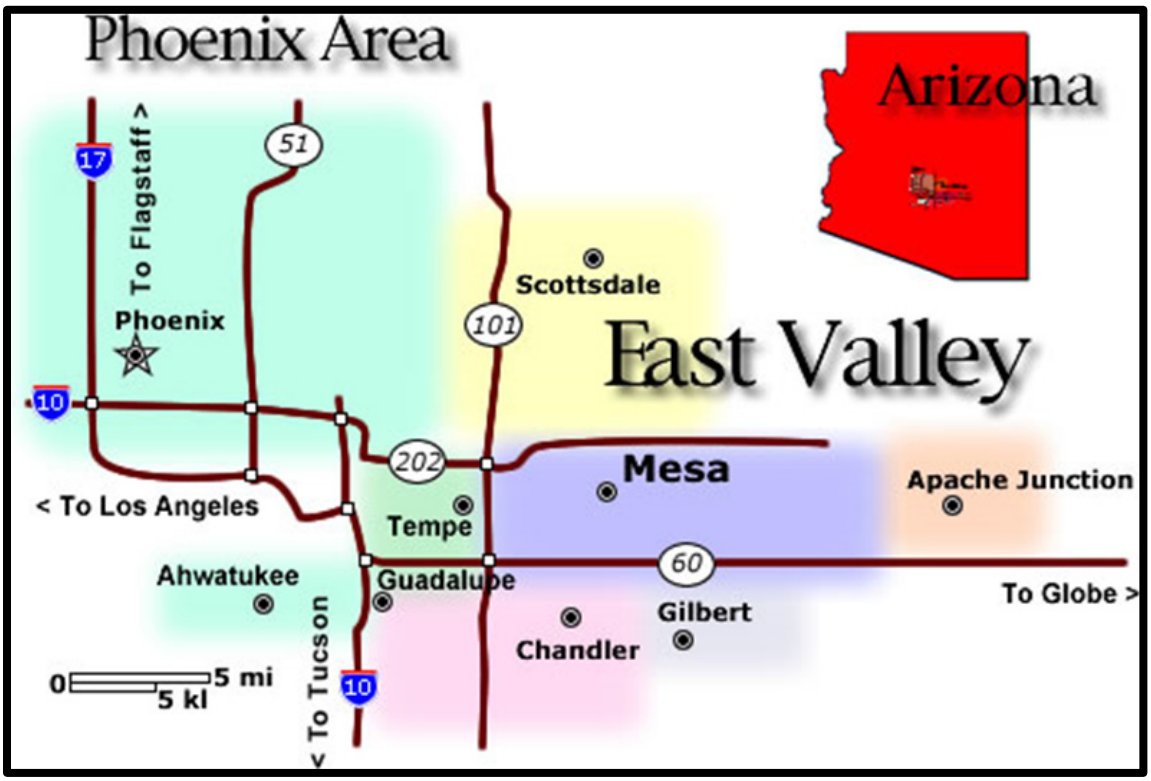


Figure 3. East Valley of Phoenix Metropolitan Region.[102]

This case study illustrates the implications of 9-1-1 system regional design, particularly with respect to allied communications centers. Decisions on backup design must be made as a region to ensure that an event can be efficiently handled and with the least impact on the fewest centers. In this case, Chandler was limited in fielding other emergencies until the surge of wrong way driver calls could be transferred to DPS-Phoenix. Those calls could not be transferred until DPS-Phoenix and DPS-Tucson were again able

[102] Source: "Luxury Real Estate," Lavish Pad, accessed March 17, 2019, http://www.lavishpadz.com/luxuryrealestate.html.

to handle their own call volume. This example uses a wrong way driver. A large-scale disaster would magnify these issues.

Google partnered with the San Francisco Department of Emergency Management to evaluate the 9-1-1 service levels after five years of call volume growth in San Francisco's 9-1-1 center.[103] The October 2015 report discusses the likely correlation between the increase in cell phone ownership and the increase in call volume. Total call volume into the San Francisco 9-1-1 center increased between 2011 and 2014 by 28% for a total of over 1.2 million calls in 2014. From 2012 to 2014, the center saw a 24% increase in redundant calls. These calls were categorized as: duplicate calls regarding the same incident (65%), status checks from individuals waiting for service (23%), cancelled incidents (10%), and, open lines (2%). The 2012–2104 actual numbers of redundant calls in this study were approximately 40,000 for 2012 and 2013, and approached 50,000 in 2014.

In a 2008 audit of the Salt Lake Valley ECC (VECC) and the Salt Lake County Sheriff's Communications Division in Utah, VECC answered 43,700 9-1-1 calls for the Sheriff's Office, and only transferred 29,900 of these calls.[104] The audit states that VECC "does not transfer some duplicate calls pertaining to the same incident."[105] Although the audit does not detail if other scenarios could have contributed to the 13,800 calls not transferred, this number is noteworthy enough to demonstrate the multiple calls generated for the same incident.

A similar type of sample was evaluated by the Chandler Police Department since all 9-1-1 calls are first answered by the local police department and then transferred to DPS. A one-month sample of 9-1-1 calls requesting DPS received by Chandler found 736 calls during October 2018.[106] Of those 736 calls, 620 calls were transferred, which means

---

[103] Diara Dankert, James Driscoll, and Nancy Torres, *San Francisco's 9-1-1 Call Volume Increase: Findings Paper by the Google 9-1-1 Team* (San Francisco, CA: Google, 2015), 3–4, https://docs.google.com/document/d/1b6OT8u01smq0ZV_mtvF1juj9RZT-36rYKtglLcwl3jU/edit#.

[104] Office of the Legislative Auditor General, *Report to the Utah Legislature: A Performance Audit of the 911 System in Salt Lake County* (Salt Lake City, UT: State of Utah, 2009), 21, https://le.utah.gov/audit/09_16rpt.pdf.

[105] Office of the Legislative Auditor General, 19.

[106] Chandler Police, "Chandler Police Department Versaterm Records Management System."

Chandler triaged the remaining calls. In addition to the 736 calls, another 113 calls from cell phones were received during these surges in which the 9-1-1 dispatcher was unable to establish contact with the caller. Either the line was open and the caller did not respond, or the caller hung up and did not answer when the 9-1-1 dispatcher called back. These same 736 calls were also reviewed by time period for surges. The number of 9-1-1 calls per incident ranged from one to 16 calls. The number of incidents ranged from five to 14 different incidents per 24-hour period. These numbers demonstrate how redundant calls are handled between multiple centers, and highlight the impact and delays that transfer requirements have on partnered centers and callers.

Many of these unverified 113 calls reflect another type of redundant call that impacts the efficiency of the ECC, which is called an abandoned call. When a caller hangs up, the 9-1-1 line remains held as busy and notifies the 9-1-1 dispatcher of an abandoned call. The 9-1-1 dispatcher calls the caller back in the order that the call was received. This process is time-consuming. In the same 2015 San Francisco study, the average time to call back an abandoned call originating from a cell phone was one minute 14 seconds, with a range of five seconds to two minutes 30 seconds.[107] For calls originating from landline phones, the average callback time was 43 seconds, with a range of 10 seconds to one minute. This inefficiency in the processing time for the original call ultimately results in delayed answer times for other 9-1-1 calls.

Citizens during Hurricane Harvey experienced extraordinarily long 9-1-1 hold times and hung up, which created an exhaustive line of abandoned calls. These inefficiencies scale up during disasters for an even larger impact. For example, if just five people call 9-1-1, each reaching the hold recording, and then hang up, these five abandoned calls are still holding in the 9-1-1 queue waiting to be called back. If these same five callers continue to call back, for example, four more times, the 9-1-1 calls holding in the queue to be answered by the 9-1-1 dispatchers just increased by 25 from the beginning of the example. These 25 calls could potentially be routed to 25 different 9-1-1 dispatchers with each calling back the five original callers to ascertain if an emergency had actually

[107] Dankert, Driscoll, and Torres, *San Francisco's 9-1-1 Call Volume Increase*, 18.

occurred. If these same callers give up on 9-1-1, and subsequently turn to various forms of social media for assistance, incidents, such as Orlando Pulse and Hurricane Harvey, have shown that friends on social networking sites will begin to contact 9-1-1 on their behalf as well. These contacts increase the number of callers well beyond 25 when the original need was five. Resources are at a premium during a disaster, and these technical limitations are not only inefficient, but create additional life safety issues.

NENA also provides standards on how quickly 9-1-1 calls should be answered, referred to as answer times. According to Standard 56–005.1, "Ninety percent (99%) of all 9-1-1 calls arriving at the Public Safety Answering Point shall be answered within 10 seconds during the busy hour (the hour each day with the greatest call volume, as defined in the NENA Master Glossary). Ninety-five percent of all 9-1-1 calls should be answered within 20 seconds."[108] The purpose of this industry standard is to set service levels and ensure consistent processing of 9-1-1 calls nationwide. Call surges can negatively impact these answer times and affect service levels. When these surges are attributed to redundant calls, the ECC begins to operate inefficiently; other emergencies must wait in the queue to be answered while triaging the redundant calls. The ECC must monitor the causes of these surges that create inefficiencies, and create mitigation strategies.

### 3. Resource Allocation

Once the information is received through the traditional 9-1-1 process, each agency has its own set of policies and standard operating procedures. Resource allocations are based on the information provided by citizens and relayed to the officers. If information is not known, a standard set of practices is in place to ensure emergency services are available for the worst-case scenario.

For example, a traffic collision in which the reporting party does not know if those involved are injured, the standard emergency response is to assume for injuries. Therefore, a routine collision requires a minimum of two officers and the fire department to respond.

---

[108] National Emergency Number Association, *NENA Call Answering Standard/Model Recommendation* (Alexandria, VA: National Emergency Number Association, 2006), 8, https://cdn.ymaws.com/www.nena.org/resource/resmgr/standards/NENA_56-005.1_Call_Answering.pdf.

Common practice is that nearby officers will also respond as needed, including supervisors. If an agency has a traffic unit (typically officers specializing in traffic-related incidents, such as collisions, impaired drivers, and other traffic enforcement-related skills), they may also respond. Although the standard operating procedure (SOP) may recommend two officers for a standard injury collision or unknown injury collision, the result can be four to six officers often responding to incidents. The resource allocation in this scenario is not based on actual information. The agency policy is a starting point that evolves throughout the incident. It is based on the often inconsistent information provided by the caller. The response is also predicated on officer availability in the area.

Incidents are dynamic and change quickly. Witnesses have different perspectives and the quality of reporting can vary. The information provided by callers can range from identical to contradicting accounts. The initial traffic collision report may start with an injury response but can change. For example, in 2018, the Chandler Police Department received 2,895 reports that began as unknown or injury collisions.[109] A review of these incidents at their conclusion revealed the following: 1,244 (43%) injury collisions, 1,005 (35%) were cancelled, 381 (13%) non-injury collisions, 112 (4%) traffic-related motorist assists, 73 (2.5%) no contact on scene, 48 (1.7%) criminal/non-traffic related, 20 (<1%) hit and run collisions, and 12 (<1%) fatal collisions. The difference in these numbers is an indication of an opportunity to become more efficient in resource allocation. Additional tools are required to aid in the situational awareness of the ECC and the responding officers.

The current dispatching process usually begins with filtered information from multiple caller reports and allocating resources based on that limited information. If any information is missing, the dispatching process defaults to standard criteria that is obviously an expensive and inefficient deployment of limited police and fire assets. The next section explores the industry philosophy related to support of the nationwide 9-1-1 infrastructure.

[109] Chandler Police, "Chandler Police Department Versaterm Records Management System."

### 4. Industry Philosophy

The National Emergency Number Association made the following public statement representing the industry's position following the December 2018 9-1-1 outage, as discussed in section C, Chapter III: Wireless Phone Use during Local or Regional Disasters:

> CenturyLink has confirmed a Thursday-night service outage that has impacted its customers' ability to reach 9-1-1. As with past outages, this event again highlights the urgent need to transition America's 9-1-1 centers to more robust and resilient Next Generation 9-1-1 networks. NG9-1-1 can intelligently route around outages, redirect calls to other regions, and use backup facilities in ways that legacy E9-1-1 systems cannot. NENA hopes the incoming Congress will demonstrate its commitment to public safety by prioritizing a coordinated, nationwide transition to NG9-1-1.
>
> NENA applauds the FCC for its swift action to investigate the CenturyLink 9-1-1 outage. We will continue to work closely with government and industry partners to understand the scope and causes of this outage, and look forward to using the lessons learned from this investigation to prevent future outages and reduce their impact on affected 9-1-1 centers and consumers.[110]

This statement demonstrates the priority and strategy of NENA to provide a top-down, nationwide solution to improve the single channel 9-1-1 infrastructure. Their role has historically been to support 9-1-1 standards, training, education, and advocacy.[111] This statement provides no indication that they are moving towards a comprehensive strategy of additional channels to support 9-1-1.

The Association of Public Safety Communications Officials (APCO) is the other representative professional industry, and the larger of the two organizations. Its mission statement states that it is, "an international leader committed to providing complete public safety communications expertise, professional development, technical assistance,

---

[110] Chris Nussman, "NENA Statement on CenturyLink Outage," National Emergency Number Association, December 28, 2018, https://www.nena.org/news/431952/NENA-Statement-on-CenturyLink-Outage.htm.

[111] "NENA's Mission & Vision," National Emergency Number Association, accessed January 24, 2019, https://www.nena.org/page/mission2017.

advocacy and outreach to benefit our members and the public."[112] This organization supports the stated direction of NENA but has a broader approach. As of January 2018, the Association of Public Safety Communications Officials website highlights offerings, such as emerging technology forums, "Envision" conferences for next-generation technology, and has a social media working group listed on its home page.

Still, the industry itself is inherently limited in its tendency towards a nationwide and top-down approach. A balance between standardization and overly cautious exists, particularly in terms of life safety emergency responses. NENA markets a singular focus on the 9-1-1 technology. APCO provides alternatives and a vision towards a more comprehensive approach. The advocacy focus, however, is in the reliance on government for support of the technology rather than the education and empowerment of the local level leaders to support their communities using the alternative reporting options already in use by their community members to work more efficiently in their centers. The professional organizations do not provide an indication that they are ready to support the philosophy at the speed in which the mainstream public has demonstrated they expect. Neither of the organizations provide messaging on their websites which indicates their role in long-term federal advocacy, while guiding local leaders to begin handling solutions of today.

## B. POTENTIAL NEW CHANNELS/INPUTS

A number of media inputs have the potential to become a new channel for emergency reporting in the emergency communications environment. Social media, crowdsourcing, IoT, and apps are examples of these new channels explored in the following section.

---

[112] "About APCO," APCO International, accessed August 19, 2018, https://www.apcointl.org/about-apco/.

### 1. Social Media

Social media use during disasters has evolved from what began as basic documentation of what occurred during the event.[113] In past years, community members would simply take pictures and post observations of the event on social media. Social media has since evolved into a different type of communication tool of documenting personal safety, locating friends and family, locating and offering support and resources, and the recovery of lost items.

Twitter has had an increased presence during disasters since 2010.[114] Following the earthquake in Haiti, 3.28 million tweets were posted, with 20 million tweets during Hurricane Sandy in 2012. The following year during the Boston Marathon bombing, 27.8 million tweets were posted. The nature of these tweets continued to be focused on the dissemination of information, confirmation of safety, and resource information.

Citizens have used social media to lead disaster assistance coordination. In 2011, a mother-daughter team in Missouri started multiple Facebook pages to support natural disasters, such as floods and tornadoes.[115] They researched information from state, federal, local, and volunteer agencies during different natural disasters, and compiled it onto one social media site. Their following was an immediate 7,000 people when the tornado landed in Joplin.

Public officials spoke out about the difficulties that social media created during Hurricane Harvey, and specifically, in the emergency response requests.[116] Emergency responder officials stated it created a complexity for which they were unprepared. Tweets and Facebook posts were shared, which caused multiple 9-1-1 calls for the same post.

---

[113] Kim Stephens, "Joplin Tornado Demonstrates Social Media's 5 Key Roles in Disaster Response and Recovery," idisaster 2.0, May 23, 2011, https://idisaster.wordpress.com/2011/05/23/joplin-tornado-demonstrates-social-medias-5-key-roles-in-disaster-response-and-recovery/.

[114] Tomer Simon, Avishay Goldberg, and Bruria Adini, "Socializing in Emergencies—A Review of the Use of Social Media in Emergency Situations," *International Journal of Information Management* 35, no. 5 (October 2015): 609–19, https://doi.org/10.1016/j.ijinfomgt.2015.07.001.

[115] Tamara L. Spicer, "Being Social: Integrating Social Media into Public Information Support to Emergency Response# Smem" (master's thesis, Naval Postgraduate School, 2013), 43–45, http://www.dtic.mil/docs/citations/ADA579964.

[116] Kelly, "Harvey Highlights Issues of Aging 911 Tech."

Others were forwarding emails of social media posts for the same high-water rescues, even days later. Coordinating these reports to avoid duplicate emergency responses required a new level of staff and resource commitment.

The Coast Guard also kept a strong social media presence while directing urban search and rescue in Houston.[117] It tweeted specifically not to report rescues on social media and provided multiple contact options for those needing an emergency response. A consultant offered, "It is literally trying to drink from a fire hose…It's very labor intensive to watch [social media] and because of the thousand different ways people can hashtag something or keyword something, trying to sort out what's relevant and what's not and what's actionable is very, very difficult."

Less than one month later, after responding to three major hurricanes in three weeks, the USCG had changed its mind. Vice Admiral Sandra Stosz spoke out and asked for national guidelines and protocols.[118] "That's how we rescued the 11,000 people, leaning in on how the public was self-selecting to use social media, because they couldn't get through on 9-1-1 calls."

The convergence of social media and emergency services was highlighted in a study conducted by the American Red Cross. This study surveyed 1,058 adults and found one in five respondents would attempt to notify emergency responders through email, websites, or social media if they were unable to reach 9-1-1.[119] Further, if citizens knew of someone else seeking help, "44% would post a request on their social network for someone else to contact authorities on a friend's behalf; 35% would ask for help directly on an agency's Facebook page; 28% percent would send a direct Twitter message to

---

[117] Marcus Gilmer, "Social Media Proves to Be a Positive Force in Flooded Texas," Mashable, August 29, 2017, http://mashable.com/2017/08/29/social-media-harvey-rescues-force-for-good/#VoN7w0oymOqk.

[118] Nicole Ogrysko, "Recent Hurricanes Have the Coast Guard Rethinking Social Media's Role in Rescue and Response," Federal News Radio, September 21, 2017, https://federalnewsradio.com/management/2017/09/recent-hurricanes-have-the-coast-guard-rethinking-social-medias-role-in-rescue-and-response/.

[119] Heather Blanchard et al., *White Paper: The Case for Integrating Crisis Response with Social Media* (Washington, DC: American Red Cross, 2010), 4, https://idisaster.wordpress.com/2010/08/26/arc-releases-white-paper-the-case-for-integrating-crisis-response-with-social-media/.

emergency responders."[120] Of these same respondents, 74% stated that they expected an emergency answer in response to their social media post on Twitter or Facebook in less than an hour.[121]

In 2016, a study was conducted to determine how Twitter messages could detect real-time traffic incidents in the Philadelphia and Pittsburgh area.[122] A methodology was created to crawl public tweets, search by keywords, and filter for actionable information. The information gathered from the tweets was compared to the information gathered through traditional means in traffic centers or 9-1-1 centers to determine what types of time delays and what types of information was received on both channels. The study found that Twitter provided more information on the weekends than weekdays, more information during the day than night, and during peak hours, and more information on the arterial roadways. Traffic incidents and the quality were also more likely to be reported in the center of the city and declined as it moved out of the city.

The study also found that additional traffic collisions were reported on Twitter and never reported to an official government agency.[123] Of the tweets that were crawled and filtered, only 5% were found to be traffic related and could be geolocated. Of those 5%, they were compared to the government agencies and the reporting systems and it was determined that 87% of the Twitter reports were accurate. Further research needs to be conducted on the timing of the notification of the tweet, as the current research allows for a 30-minute reporting discrepancy and did not measure which channel was a faster reporting option.

---

[120] Blanchard et al., 4.

[121] Blanchard et al., 4.

[122] Yiming Gu, Zhen (Sean) Qian, and Feng Chen, "From Twitter to Detector: Real-Time Traffic Incident Detection Using Social Media Data," *Transportation Research Part C: Emerging Technologies* 67 (June 2016): 321–42, https://doi.org/10.1016/j.trc.2016.02.011.

[123] Gu, Qian, and Chen, 340.

### 2. Crowdsourcing

Waze is a Google mobile app that provides motorists with an interactive navigational tool, as described in Section C of Chapter I, Overview of the Work. The crowdsourcing nature of the app provides users with the ability to report traffic collisions, traffic jams, hazards in the roadway, road closures, or police officers in the area. Research has demonstrated that motorists are reporting traffic collisions on Waze over four minutes earlier than the first 9-1-1 call. The European Union (EU) conducted pilot projects in Italy, France, and Austria to determine the feasibility of using Waze as a tool in the emergency response.[124] In its final report published in March 2018, Waze was determined to have value in the emergency reporting process in providing citizens with a new channel for citizen reporting, decreasing the notification time, and providing real-time information to citizens. The report further outlined potential future uses in route planning for first responders and monitoring unusual traffic patterns for city planning purposes.

Zello emerged as a rescue and response social media tool during Hurricane Harvey.[125] This walkie-talkie app became a communication tool managed by the Cajun Navy and ultimately crowdsourced for dispatching and locating volunteers to assist with rescues. It followed somewhat formal protocols using volunteers who verified information, logged, dispatched volunteers, and tracked rescues. Zello is one example of many apps that exist either to support a specific function, event, or jurisdiction.

### 3. IoT and Advanced Sensors

RapidSOS is a Next Generation 9-1-1 clearinghouse that links connected devices to 9-1-1.[126] Its first success in the 9-1-1 environment is passing device-based location data on 9-1-1 calls by using GPS, Bluetooth, Wi-Fi access points, accelerometer, and barometric

---

[124] Waze and European Emergency Number Association, *Waze Final Report: Exploring the Use of Waze for Emergency Response, A Pilot Project by Waze and EENA* (Menlo Park, CA, Brussels: Waze and European Emergency Number Association, 2018), 1–21.

[125] Holly Hartman, "I Downloaded an App. and Suddenly, Was Part of the Cajun Navy," *Houston Chronicle*, September 5, 2017, http://www.houstonchronicle.com/local/gray-matters/article/I-downloaded-an-app-And-suddenly-I-was-talking-12172506.php.

[126] "RapidSOS + NG911," RapidSOS, 2018, https://www.rapidsos.com/ng911clearinghouse/.

pressure technology to provide the most accurate location, including limited altitude information. The results have demonstrated more accuracy than the traditional network-based location data sent on 9-1-1 calls. RapidSOS is also capable of sending any type of connected device information, such as home security, connected car, and apps. It currently has wearable devices that could be used on vulnerable populations, or used as an added layer for personal security. Real-time medical information can be transferred through devices to provide early notification of specific medical information for medical intervention.

RapidSOS also has telematics abilities that can send crash notifications through 9-1-1 (Figure 4).[127] The notification transmits information for first responders, such as speed at time of impact, location of impact, airbag deployment, number of occupants, and pictures from inside the vehicle. It also offers home alarm 9-1-1 notification data, such as security, fire, smoke, carbon monoxide, and temperature monitoring. RapidSOS has the ability to pass this unlimited emergency data through 9-1-1 and replace the 512 bytes of traditional data currently passed on the current 9-1-1 screen (Figure 4).

[127] "RapidSOS & Airbus DS Communications: The Future of Emergency Response," RapidSOS, YouTube, video, 3:50, August 10, 2017, https://www.youtube.com/watch?v=DHiA1pXGNQw.

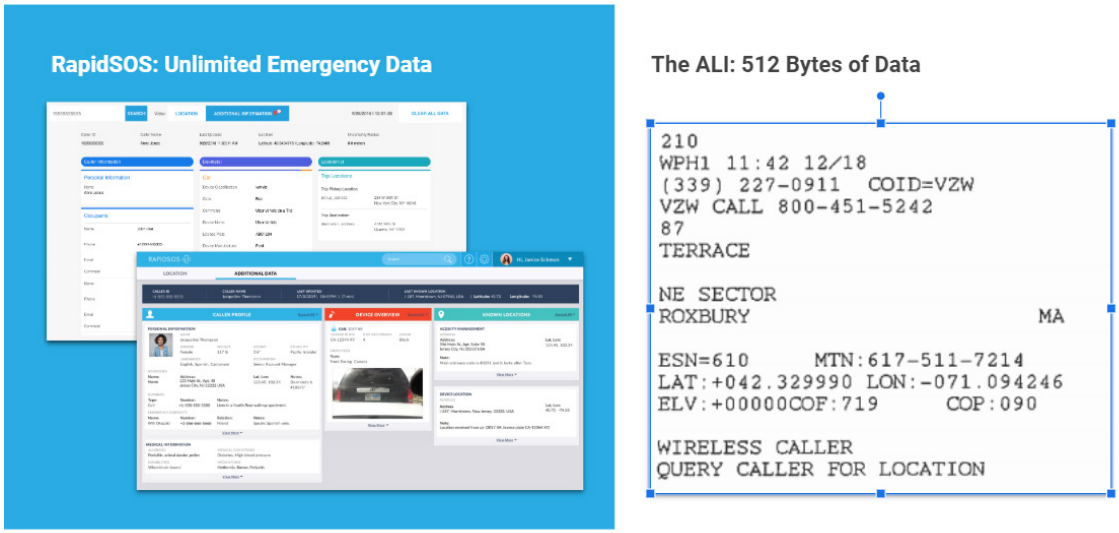


Figure 4. Future Data Possibilities Compared to Current 512 Byte Limitations.[128]

Acoustic sensors can be used at intersections to monitor for a traffic collision. When the acoustic sensor "hears" a collision, it triggers an alarm and activates the cameras for the dispatcher to verify if a collision actually occurred. Based on the information viewed on the camera, an emergency response can be sent immediately without any witness or victim contact on 9-1-1. Very little information is available on deployments of this technology.

All new cars and light trucks in the United Kingdom (UK) were mandated to deploy eCall as of March 31, 2018.[129] OnStar is a version of eCall familiar in the United States for crash notifications. eCall can notify authorities of incidents either automatically or manually. The new regulation sends the incident information to the local emergency number (999) operator, including the location and type of vehicle. Depending on the type of eCall system, the 999 operator may have continued verbal contact with an occupant or

[128] Source: RapidSOS.

[129] "What We Do," BAPCO, accessed August 18, 2018, https://www.bapco.org.uk/what-we-do/.

updated data information from the vehicle, or it may be limited to the one initial notification.

The first certified app by the British Association of Public Safety Communications Officials (BAPCO) was the Real Rider crash detection app.[130] A motorcyclist can activate the app and start recording prior to a ride. If a crash is detected, the rider has two minutes to cancel the alarm before the location and any pre-programmed medical information is automatically sent to 999. One of the highlights marketed is that speed information is not recorded or sent with the notification. This automatic notification provides timely information, such as location, and is especially useful when a rider is unable to contact 999 or when there are no witnesses.

TapSOS is under review for the next 999 certified app as of late 2018.[131] This app is designed for the deaf and hard of hearing, speech impaired, or situations in which it is unsafe to speak to the 999 operator. TapSOS is designed as "highly visual," using a series of pictures that can be easily followed by those who may not speak English.[132] Interestingly, this app was designed after emergencySMS had been in existence in the United Kingdom for approximately six years.[133]

#### 4. Video-to-911

Carbyne is an Israel-based company that provides similar next generation technology.[134] Fayette County, Georgia partnered with Carbyne to provide live video stream 9-1-1 functionality with enhanced location services. Callers still first call 9-1-1, but if the dispatcher is unable to find the caller, if the caller is unable to speak, or the 9-1-1 operator is needed to have a view of the incident, a web link can be sent to the caller to access the live video option. The dispatcher can then use the additional information to

---

[130] "Motorcycle Crash Detection," REALRIDER, 2017, https://www.realrider.com/crash-detection/.

[131] BAPCO, "What We Do."

[132] "TapSOS," TapSOS, accessed August 19, 2018, https://www.tapsos.com/.

[133] "About Emergencysms," EmergencySMS, accessed August 19, 2018, http://www.emergencysms.org.uk/about_emergencysms.php.

[134] "About," Carbyne, accessed December 9, 2018, https://carbyne911.com/about/.

determine what may be occurring. Carbyne's offering is unique in that the caller is streaming the video, it is not a two-way video, and the voice and SMS texting option remains available during the video stream. Multiple communication options are available for a caller in danger. For example, if individuals are not safe to communicate, they can provide a live stream and text with the 9-1-1 operator. The 9-1-1 operator can hear the caller's environment and see what is streaming, but the callers do not have to communicate verbally. As of December 2018 Fayette County, Georgia is the only public safety agency fully deployed in the United States.[135]

The West Midlands Fire Service in the United Kingdom operates a similar program.[136] The UK 999eye program allows operators to send callers a link to a reporting party for live stream or still pictures. If the reporting party accepts the link, the video or pictures are sent to the emergency operator. This approach to live stream material in the ECC is progressive and unique. The West Midlands Fire Service has experienced success with the live stream video in determining the scale of a fire, as well as GPS coordinates for location accuracy. Pictures can be sent to the operator if it is preferred or if inadequate bandwidth is available for live streaming.

The 999eye program was expanded to law enforcement with the Gwent Police Department in England.[137] The plan with the Gwent Police Department was to pilot the program with 999 for two months and then expand to 101 calls. No follow up documentation online or on the agency's website was found to determine if the program was continued beyond the pilot project.

---

[135] "Deployed in Fayette, Georgia, Case Study," Carbyne, January 2, 2018, https://carbyne911.com/fay
ette-case-study/.

[136] "Capita and West Midlands Fire Service launch 999EYE," Capita, November 2, 2016, https://www.capita.com/news/news/2016/capita-and-west-midlands-fire-service-launch-999eye/.

[137] Richard Hartley-Parkinson, "Trial That Lets You Send Live Footage during 999 Call Directly to Police," *Metro* (blog), November 14, 2017, https://metro.co.uk/2017/11/14/999eye-trial-lets-you-send-live-footage-direct-to-police-when-reporting-crime-7077042/.

## C. SUMMARY AND CONCLUSIONS

This chapter illustrates the limitations for the typical ECC to manage overwhelming call volumes. Technical limitations exist at the system design level, as well as local and regional call volume thresholds. Technical, operational workflow, and philosophical inefficiencies can be identified throughout the emergency communications environment. Social media, apps, and other media inputs offer potential new channels and solutions to mitigate some of these limitations.

The following chapter evaluates one of these potential new channels into the emergency communications environment. The Waze navigational tool will begin the implementation process into the Chandler Police emergency communications center as a supplemental reporting option using business model generation and the nine building blocks.

THIS PAGE INTENTIONALLY LEFT BLANK

# V. BUSINESS MODEL GENERATION

## A. INTRODUCTION

The previous chapter identified channel possibilities and channels that have been successfully implemented both in the United States and globally. The following chapter evaluates one channel, the Waze navigational tool, as a potential reporting tool integrated into an ECC. The evaluation process uses business model generation followed by deconstructing the model into nine building blocks. The business model is then applied to an actual ECC actively transitioning into the multichannel environment. Each of the building blocks are applied to create the overall strategy to implement Waze into the Chandler Police Department's ECC environment.

## B. BACKGROUND

Traffic collisions are a notable type of call in the emergency communications environment because of their frequency and the surges of call volume they can generate reporting the same incident. They can also span the full range of public safety response, from a delayed report required for insurance purposes or a non-injury traffic collision to a range of injuries, up to and including a fatal traffic collision. Traffic collisions impact a large population of the community either through direct involvement in the collision or indirectly through the impacted traffic flows and subsequent quality of life. Cell phones made a significant difference in the reporting of traffic collisions, which creates redundancies in the ECC. What once was a witness or two running to the nearest pay phone or neighbor to call 9-1-1 has now developed into typically having multiple witnesses or people simply passing by, sometimes well after the fact, all calling 9-1-1 about the same incident.

In 2018, the Chandler Police Department responded to 25,577 traffic collisions within the city's jurisdictional boundaries.[138] The periods with the highest frequency of

[138] Chandler Police, "Chandler Police Department Versaterm Records Management System." It does not include highways or county islands.

collisions are generally 0700–1000 and 1500–1800.[139] A one-month sampling of City of Chandler data was reviewed to determine the average number of 9-1-1 calls received per injury collision during these high collision periods of the day.[140] These collisions generated an average of three 9-1-1 calls to report one collision, with a range of one to nine calls. Of the 215 calls in this sample, only 86 (40%) were victims, witnesses, or at the scene. The remaining 60% were uninvolved and simply passing by.[141] A significant difference exists in the reporting quality of data, ranging from someone involved, someone on scene who can perform life-saving measures, or a person simply passing through not wishing to be more involved than making a phone call. In addition to the volume of calls, the duration of calls plays a factor in the impact on an ECC. During this one-month data sample, the average length of time from the first call reporting the collision until the last call or notation of contact with a caller was just under three minutes, with a range of less than one minute up to nine minutes. ECCs must look for ways to become more efficient and better manage the redundancies during these call surges. Other emergencies do not stop during these call surges, and seconds matter to the heart attack victim waiting on hold while a dispatcher triages the fourth person reporting the same traffic collision.

It is the responsibility of the 9-1-1 dispatcher to receive reports of traffic collisions and to gather the relevant information from the caller to send to first responders. The 9-1-1 dispatcher also records information, such as location, the severity of injuries, whether the caller was involved, a witness, or came upon the scene post-collision. After an initial report containing relatively detailed information, unless pre-arrival medical instructions are required, the majority of subsequent calls provide very little value to responding officers. With few exceptions (e.g., a witness to a serious injury or hit and run collision or someone who can assist a victim with medical treatment at the scene prior to first responder arrival), additional callers may validate that collision and its severity, but offer few additional

---

[139] "Arizona Motor Vehicle Crash Facts 2017," Arizona Department of Transportation, accessed May 13, 2018, https://www.azdot.gov/motor-vehicles/Statistics/arizona-motor-vehicle-crash-facts.

[140] Reported as injury or unknown injury, as unknown injuries are treated as injury collisions until verified otherwise.

[141] Chandler Police, "Chandler Police Department Versaterm Records Management System." The data analyzed was October 2018.

benefits. An alternative reporting tool that would reduce redundant reports from non-involved (i.e., those who are not witnesses or not providing medical care) has the potential to reduce the center's 9-1-1 call volume.

Waze is a Google mobile application that provides commuters with an interactive navigational tool. Users have the ability to report traffic collisions, traffic jams, hazards in the roadway, road closures, and police officers in the area. The app has both a practical and a social element. The crowdsourced information can be used to re-route users to avoid an extended commute time. Users can interact with other commuters, earn points for reporting and validating incidents, or even choose a facial expression to personalize their icon on the map.

Waze began a Connected Citizens Program to create bi-directional communication between municipalities and Waze users. The current municipal users are primarily divisions, such as traffic engineering, city streets departments, or Department of Transportation. They are most often used for traffic management, particularly during storms or major events, and to communicate road closures and hazards. Waze provides updates to these municipal users in time intervals ranging from every couple of minutes to an hour.

A 2018 study reported that U.S. drivers are reporting traffic collisions 40% of the time on Waze before reporting to 9-1-1.[142] Using Waze data has resulted in a five minute faster response time for first responders in some locations. In a 2017 presentation to the United Nations, internationally, 70% of traffic collisions are reported on Waze before the local emergency number receives the notification, which results in a response time that is over four minutes faster.[143] These reports present raw data, as Waze is not implemented and in operation in a live 9-1-1 center environment in the United States, no practical means are available to validate the data or the reported results. However, the data does seem to

---

[142] CCP Partner Onboarding, *What is Waze?*, 32–33.

[143] Adam Fried, *Connecting Cities and Citizens to Improve Urban Mobility* (New York: United Nations Statistics Division, n.d.), 30–31, accessed December 29, 2018, https://unstats.un.org/Unsd/geoinfo/UNGEGN/docs/11th-uncsgn-docs/Waze_UN_Presentation.pdf.

point to the possible value of social media data for improving emergency services response time.

## C. PROJECT DESCRIPTION

The goal of this project is to implement Waze directly into the Chandler Police ECC to have immediate, real-time communication with the public. The initial scope of the project is limited to the Chandler Police Department; however, if it is determined to be a beneficial source of information, the plan would be to propose a regional deployment in the Phoenix metropolitan area (Figure 5).

Figure 5. Chandler Police Emergency Communications Center

The Chandler Police Department is one of 26 member agencies that belong to the Maricopa Regional 9-1-1 System. In 2018, over 3 million 9-1-1 calls were received by approximately 360 positions receiving 9-1-1 calls across these 26 centers.[144] This regional

[144] 9-1-1 Study Committee, *Maricopa Region 9-1-1 Status Report and Outlook* (Phoenix, AZ: Maricopa Association of Governments, 2017), 3, http://www.azmag.gov/Portals/0/Documents/911MS_2017-02-10_Maricopa-Region-911-Status-Report-and-Outlook.pdf?ver=2017-04-06-110710-417.

system is an interconnected 9-1-1 system managed by the member agencies through the Maricopa Association of Governments' PSAP Managers Group, and supported by the Maricopa Region 9-1-1 (MR 9-1-1) Administrator and maintenance team. The City of Phoenix is the established contract agent for the system, according to resolutions passed by member agencies in 1989. While the Maricopa Region staff is technically considered City of Phoenix employees, it is responsible for the planning, budget, installation, and system maintenance for the 26 member agencies of Maricopa County. It also acts as the liaison between the member agencies and the State 9-1-1 Office.

One benefit of a regional 9-1-1 system is the consistent level of service provided across a large metropolitan region. Maricopa County is the fourth most populous and fastest growing county in the United States with a 2017 population of 4.3 million people.[145] The majority of Arizona's population is located in Maricopa County with the remaining population spread across 14 counties in a seven million statewide population. Citizens within this dense metropolitan area are not familiar with specific jurisdictional boundaries and expect the same level of service irrespective of jurisdictions designated by public safety.

The role of the author at the time of this writing is the Communications Manager of the Chandler Police Department, which is responsible for the oversight of the police ECC for the City of Chandler, Arizona. This role includes decision-making authority related to 9-1-1 policies and procedures, budgetary authority for that portion of the budget related to emergency communications, selection of 9-1-1 system technology, and the selection and training of users for the project. Additional related responsibilities included chairperson of the Maricopa County Public Safety Answering Point Managers Group and chairperson of the Next Generation 9-1-1 working group tasked with exploring next generation technology and making recommendations to the region's Managers Group. This position provides opportunities to enhance both the formal and informal relationships with

[145] Jessica Boehm, "Maricopa County Is Fastest-Growing in Nation, According to U.S. Census Data," azcentral, March 22, 2018, https://www.azcentral.com/story/news/local/phoenix/2018/03/22/maricopa-county-fastest-growing-county-nation-according-u-s-census-data-phoenix-mesa-scottsdale/449043002/.

the MR 9-1-1 professionals, and provides a platform to socialize next generation technology related to emergency communications in the region.

In 2017, Waze became a discussion topic among early adopters in the emergency communications industry. Statistics on traffic incident reporting times began to emerge and the European Union began a pilot project on the use of Waze. The concept of Waze as a supplemental reporting channel appeared to present opportunities, so the project began as an exploration of the technology and an evaluation of its potential value as an augment to the current emergency communications environment. The Maricopa Region technical team assumed the technical lead on the project because Waze data could be integrated on the regional 9-1-1 map in the Phoenix region. Access to the no-cost Connected Citizens Program through Google was granted, and the project began. This project was a side project by all involved, a low priority project, with no dedicated funding source.

The Maricopa Region technical team programmed Waze to integrate on the 9-1-1 map and shared it with the Chandler ECC. No predefined operational means were implemented to use the Waze information, so the plan was first to send it to the dispatch supervisors for initial feedback and then the dispatchers for additional feedback. It was anticipated that operational procedures would evolve ad hoc based on the scenarios experienced by the users. Recommendations and adjustments would be made along the way and policies would thereafter be developed. This same agile, incremental, and iterative process has been used successfully in the Chandler ECC, with both technical and non-technical projects.

The following sections discuss the project using the concepts of business model generation. Waze is partially implemented as of February 2019 and should be completed by mid-2019. The following sections present the experiences of the Chandler ECC and lessons learned while implementing this new channel into the ECC.

## D. BUSINESS MODEL CONCEPT: MVP, FINDING YOUR WAZE

The MVP is the most basic solution that demonstrates value and satisfies the early adopter customer segment. The MVP for transitioning to a multi-channel environment is

implementing a different type of emergency reporting channel than the traditional communication channels currently available in ECCs.

Waze was chosen to evaluate as a potential reporting channel into the ECC because of its ability to report traffic incidents through crowdsourcing. These reports are shared on a navigation app owned by Google, and Google shares the information with municipal partners free of charge. Waze is reported to be used by 100 million people worldwide, and traffic collisions are a frequent incident encountered daily by public safety.[146]

The Waze MVP has two operational components. First, it must receive sufficient real-time traffic incident information in a format that allows 9-1-1 dispatchers to determine if first responders are needed. The information must be timely and able to correlate with the existing incoming 9-1-1 reports. Second, Waze has the capability for city representatives to contribute traffic-related information onto the Waze map that may impact users during their commute. When a roadway will be shut down for an extended time for a traffic collision or any other police situation, 9-1-1 dispatchers can add that information to the map. If a water main breaks and floods the roadway, or the power goes out in an area affecting traffic signals, that information can be added to the map, as it may create a delay in a user's commute.

Waze can also be used for planned special events to advise the public of parking areas, road closures, or one-way streets. As parking areas reach capacity, those areas can be removed from the map and cars rerouted to new parking areas to keep traffic flowing in the area. During a marathon, roads are scheduled to open and close at general times. Real-time updates can be added to the maps, a useful tool for nearby impacted residents or those trying to access businesses in the area.

The MVP requires both of these project goals be implemented. The nature of crowdsourcing relies on the number of users providing information. To maximize that number, a demonstrated value-add to the program must be presented at its outset. Quality of life issues, such as special events, or heavy traffic conditions, particularly during the hot

---

[146] "Free Driving Directions, Traffic Reports & GPS Navigation App by Waze," Waze, accessed December 16, 2018, https://www.waze.com/about.

summer months, are an opportunity in which the police department can offer to improve community member's travel experience. If the city added traffic information and pointed citizens to Waze for notifications and special events, the hope is that more citizens will begin to use Waze and subsequently contribute to real-time traffic incidents as well. Both parts of the MVP work synergistically to support one another.

The initial MVP was focused on the emergency reporting process. The priority was to implement Waze to receive the potential early notifications of traffic-related incidents. Once the data was reporting on the 9-1-1 map, two conspicuous problems arose. First, the majority of Waze reports in the Phoenix metro area were on the highways and not the city streets. The Chandler Police Department is responsible for responding to traffic incidents on the arterial roadways. Thus, the quantity of Waze reports was relatively low compared to the number of traffic incident reports region-wide. Second, an overwhelming number of traffic incidents occurred when looking at the map from a regional view (Figure 6).

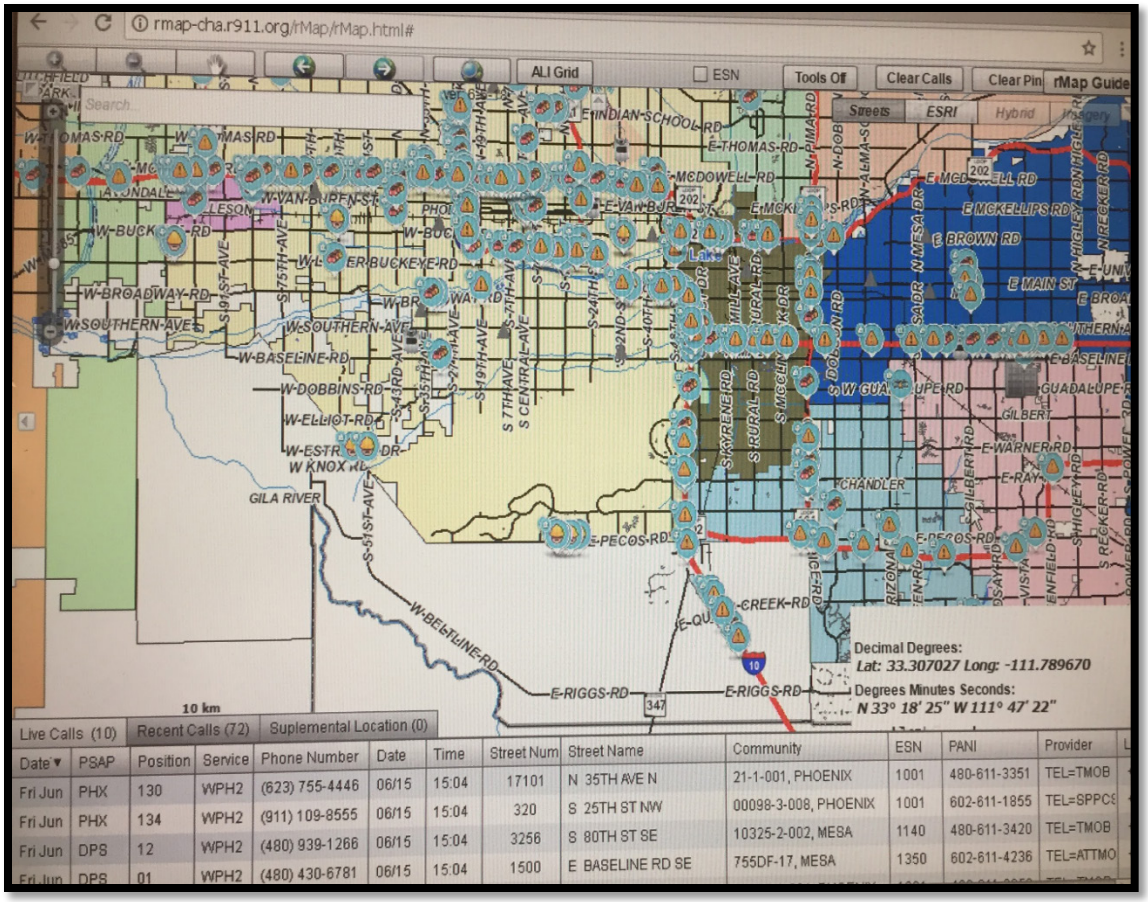


Figure 6. An Overwhelming Amount of Data at the Regional View

The filters set up reported traffic jams, crashes, road closures, and hazards. The high number of incidents presenting on the 9-1-1 map became less intrusive when the map was zoomed into the city level. Each city in the Phoenix metro region has a different background color on the 9-1-1 map to assist 9-1-1 dispatchers with jurisdictional boundaries. Chandler is designated with a blue background. The Waze icons reporting the traffic incidents are also blue to create an issue with no contrast between the icon and the background (Figure 7). An ESRI layer option can be selected by the user to provide a different background. A 9-1-1 call will overlay the Waze reports on the icon and the background. An ESRI layer option can be selected by the user on the same screen as well (Figure 8).

Figure 7. Waze Reports on Default Blue Background

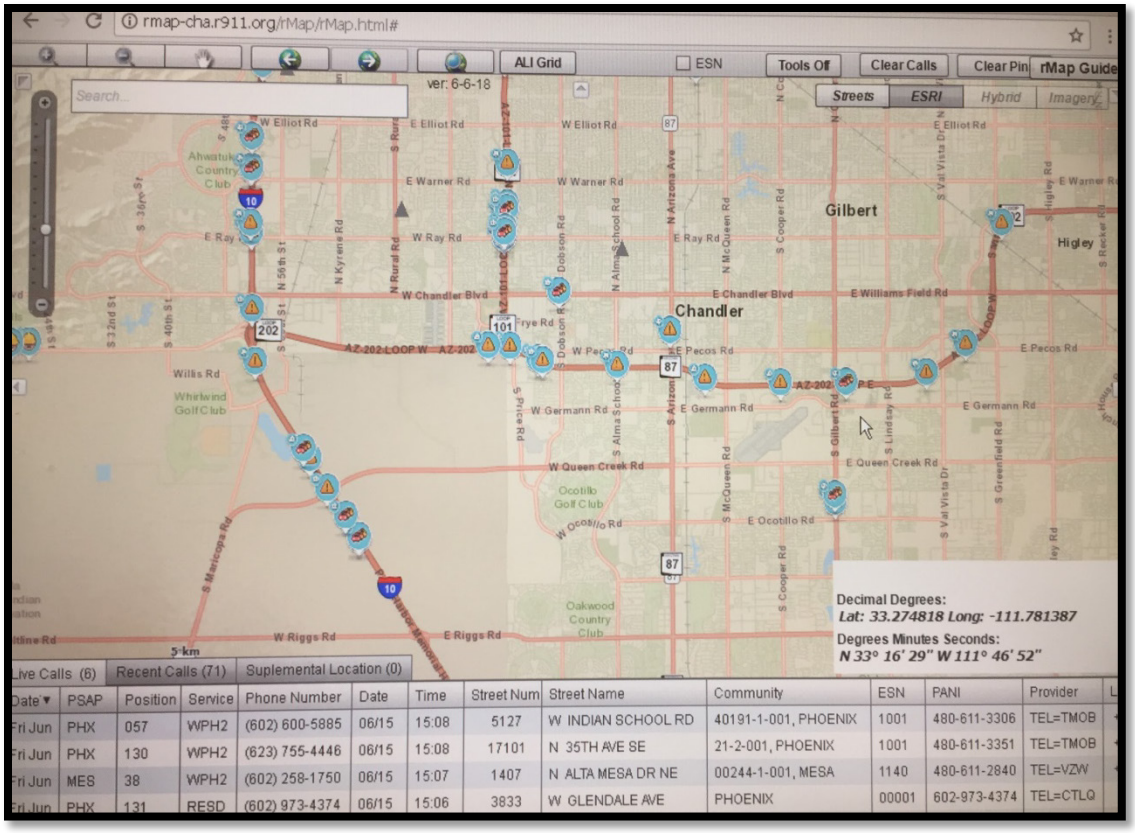


Figure 8. Waze Reporting in City of Chandler on ESRI Background

The mobile app has additional options, such as gas prices and police officer locations. However, traffic-related incidents were the only options brought into the ECC (Figure 9). Despite the high number of incidents, the decision was made to keep all traffic incidents reporting, with the option to turn filters on and off. The decision point was two-fold; first, it was early in the project and provided flexibility as the project moved forward; and second, it was also a long-term decision that could provide regional flexibility for each ECC to choose which traffic incidents it wanted to view.

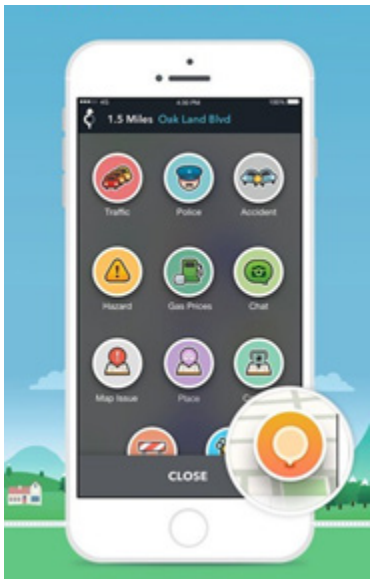


Figure 9. Waze Mobile Application.[147]

The second MVP, for police and other city representatives to contribute traffic-related information to the map, was added to the business model after seeing the limited number of traffic incident reports within the city limits. Police departments actively engage their community members during special events and communicate in real-time using social media. Using Waze as a bi-directional communication tool could provide the means to generate value and increase community usage in Waze, and potentially begin an ongoing community conversation about its value.

## E. BUSINESS MODEL CONCEPT: NINE BUILDING BLOCKS

The business model concept is composed of a nine-step process (Figure 10).

[147] "Best GPS Navigation apps for Android and iPhone," Best Apps Guru, February 10, 2019, http://bestappsguru.com/best-navigation-apps-gps-android-iphone/.

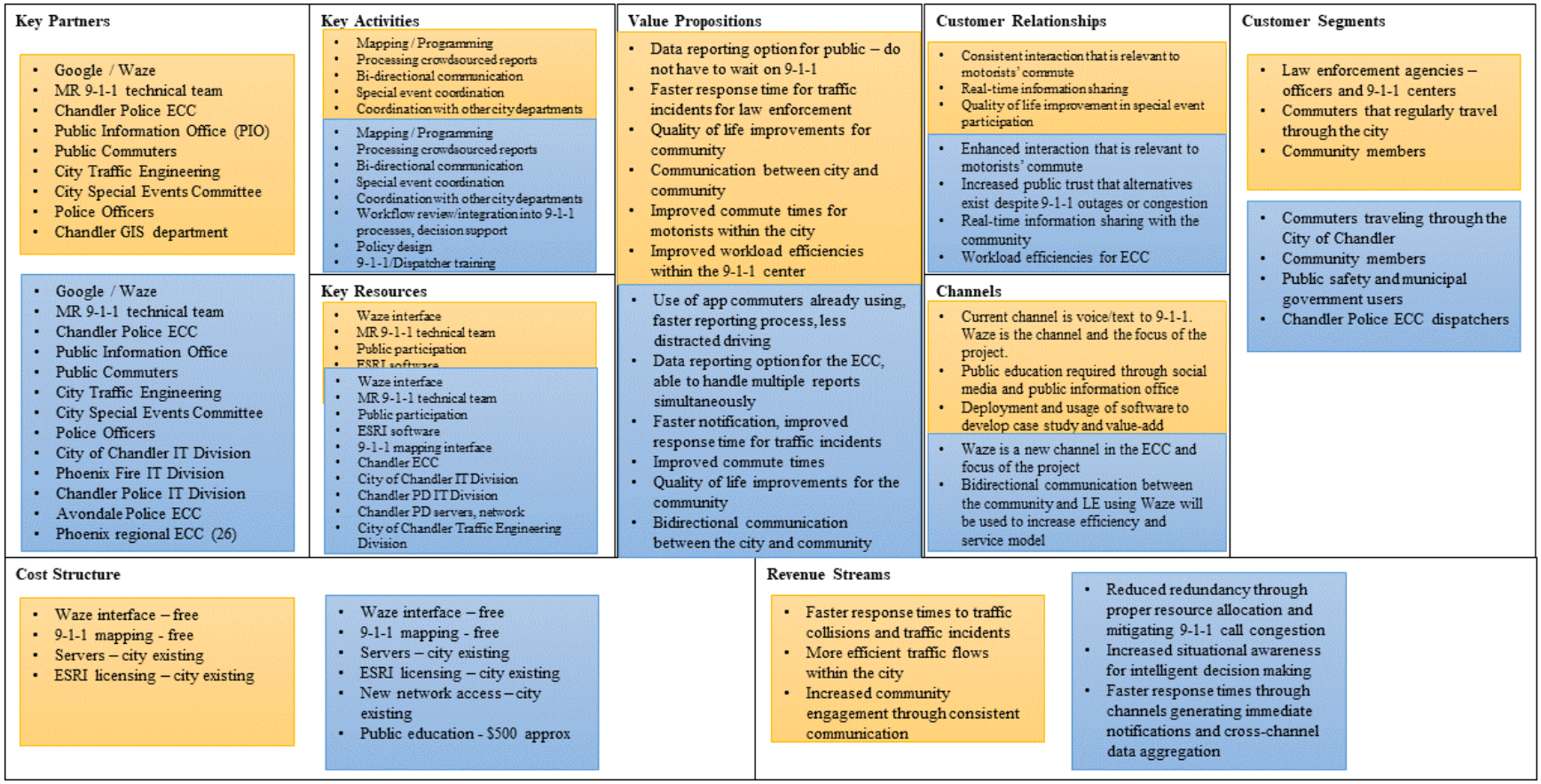


Figure 10. Business Canvas Model: Implementation of Waze into an Emergency Communications Center

The following sections describe each of the nine steps with respect to the Waze project.

### 1. Customer Segments

Customer segments are the groups in which the organization is focused on serving. The implementation of Waze will first serve commuters traveling in the City of Chandler, regardless if they are residential or business members of the community, attending special events, or simply passing through the city. It is communicating information in real-time that can impact their commute while driving through Chandler.

Community members are a potentially overlapping customer segment, with different needs at different times. Those who are frequently in the city conducting business or living in the city are impacted by special events, construction, and unexpected police incidents. Waze provides real-time communication for those frequently impacted and invested in the community.

Public safety and municipal government users are also a principal customer segment. Public safety can use Waze information to avoid specific areas to travel to an area faster and can notify the public to keep clear of an area. Placement of road closures by public safety and municipal government users can help reroute commuters, and thus keep traffic moving and city employees less exposed to higher traffic volumes.

A different type of customer segment is the members of the ECC professional staff. They will be receiving the notifications of the traffic incidents and managing the information, a significant change from their current processes. The goal is to create a more efficient workflow within the center, in which some of the redundant 9-1-1 calls are channeled into the Waze reporting option to reduce the call surges that often overflow the ECC. The Waze notifications also have the potential to act as a predictor of a 9-1-1 call surge, wherein the communications employees can prepare as appropriate.

### 2. Value Proposition

The value proposition is the product or service offered to the customer. The value proposition of the multichannel environment offers the community and members of the

public safety agency the ability to leverage the same communication tools used in their everyday lives to report incidents into the communications center. Smartphones have multiple options, such as text, picture and video messaging, apps, and social media for everyday communication.

The value proposition for implementing Waze as an emergency reporting tool is that commuters already using the app will simultaneously be notifying other Waze users and the ECC of traffic incidents. It will not require an additional step to call 9-1-1. The new Waze reporting process can prevent the commuter from having to wait on 9-1-1 during call surges while they are driving. Commuters who simply drive by a traffic incident, are not involved or witnesses, add little value to the voice emergency reporting process with multiple reports. These reporting parties can maintain their focus while driving by pushing two or three colored buttons on their navigational app, instead of a phone call lasting several minutes. Similarly, the receiving 9-1-1 dispatcher can monitor the multiple data inputs simultaneously, unlike 9-1-1 calls that can only be handled one at a time. This process becomes a more efficient process for all involved.

Earlier notifications into the ECC and improved response times are possible using Waze. If the 2018 U.S. reports that 40% of traffic incidents are reported on Waze prior to 9-1-1 also applies in Chandler, the value proposition is also an improved response time for first responders. The entire reporting process using 9-1-1 is much longer than reporting on Waze. Reporting a traffic incident requires fewer steps for a commuter when the navigational tool is open than dialing 9-1-1. For example, the commuter may need to exit out of an app or unlock a smartphone. The added potential time spent on hold during a surge and then speaking to a 9-1-1 dispatcher to report the details of the traffic incident is significantly longer and less efficient for information of very little value.

Waze can improve commute times and manage traffic congestion. Google cites an example of a Waze test on Seaport Boulevard in Boston, MA that resulted in an 18% month-over-month reduction in commute time over a three-month period.[148] The navigational tool consistently updates and reroutes users based on information added by

[148] CCP Partner Onboarding, *What is Waze?*.

other users to provide the shortest or fastest route. The more users, the more data, the faster the commute. This type of information is the crowdsourcing nature of Waze.

The quality of life can improve for the community with the increased use of Waze. Traffic-related issues and commute times are directly related to the quality of life in a community. Nobody wants to spend more time in traffic than is absolutely necessary. If public safety can address quality of life issues while responding more quickly and more efficiently to traffic-related incidents, everyone wins.

Waze provides an additional, real-time communication tool between local public safety and the community. Community engagement is the bedrock of law enforcement. If the community feels they are having an ongoing conversation with their police department on the things that matter to them in their everyday lives, they are more likely to feel the police are part of the community.

### 3. Channels

Channels are the ways in which the value proposition is communicated to the customer segments. Waze is the channel in this project and is the means by which commuters can report traffic incidents using an existing mobile app already in use as part of their daily commute. The Waze implementation as a new emergency reporting communication channel is the focus of this project.

### 4. Customer Relationships

Customer relationships are the interaction between the organization and the customer segment. The relationship between the public safety agency and the community relies on communication. The multichannel environment is intended to enhance that communication by using relevant communication channels and communicating in real-time. Additional channels can increase the public's trust that they will be able to reach the police and fire department when they experience an emergency, despite ever-increasing 9-1-1 outages experienced throughout the country. It can also increase their perception that public safety is carrying out their public service obligation, as evidenced by the studies that many believe these options already exist. For those less-urgent situations, community

members may perceive the additional channels as a customer service and quality of life benefit provided to their communities, because they are options in the reporting process. The ability for a commuter simply to push a button on an already-open navigational tool can improve the perception of their local police department being more contemporary. Members of the community do not likely recognize the accessibility immediately and reduced wait times on 9-1-1 until they are not met.

Waze provides police departments with the ability for improved notification times and bidirectional information sharing with members of their communities. This ability allows for consistent interaction relevant to motorists' commute, for special events, or for up-to-date information on local construction or road closures. Waze allows for consistent bi-directional conversations with the community, and thereby, another way to enrich the community-police relationship. If commuters know that the police department is monitoring Waze for reports, and the police department is also adding incidents to the map with an icon identifiable as their local police department, the interactive communication tool is building relationships with the community through frequent information sharing. As Waze evolves, perhaps developing a way to acknowledge or "like" a reported incident could provide a personalized response, letting the commuter know the police department is in receipt of the report.

The emergency communications personnel will be the principal processors of information in both directions. They will filter the incoming information from Waze, as well as determine what notifications should be shared on the map in real-time. The relationship with the communications personnel will be essential to develop this program.

### 5. Goals/Revenue Stream

The four goals of transitioning to a multi-channel environment are listed as follows. These criteria were applied to the Waze implementation project. The first goal is to reduce 9-1-1 reporting redundancy by providing alternative channels for reports providing low quality information thereby to mitigate 9-1-1 call congestion. Second, situational awareness will be increased for more effective decision-making. Thirdly, faster response times through channels generating immediate notifications and cross-channel data

aggregation will be experienced. Finally, increased customer service and quality of life will result through bi-directional communication with the community

### 6. Key Resources

Key resources are the basic needs required of the organization to support the business model. The following key resources were required to implement Waze. Many of the key resources and key partners are the same.

Initially, six key resources were required for the project: Waze interface (provided by Google), the services of the Regional 9-1-1 technical team, public participation (providing data), the ESRI software, the 9-1-1 mapping interface, and finally, the 9-1-1 center and staff.

As the project evolved, additional resources were identified, which included: the Chandler Police information technology (IT) division (to assist with the project when the regional 9-1-1 team encountered the server limitations), the Chandler Police servers and network (these servers were available for the project, but when the project was turned back over to the Regional 9-1-1 team, they were no longer needed), and the City of Chandler IT Division (the technical support needed for the City's Traffic Engineering Division). This division became another stakeholder in the process if Traffic Engineering was going to be an immediate user in Waze, rather than a phased in user. The City of Chandler Traffic Engineering Division (the traditional municipal department that uses Waze in the Connected Citizen Program) was also added as a key resource. Although intended to be incorporated later in the project, it reached out during this project and explained it had just begun the process of bringing on Waze into its division as well. This inclusion had the potential to change the strategy and timeline of incorporating its division.

The original plan was to begin with the police department on Waze. First, it would receive notifications of traffic incidents and then add the bi-directional communication component of real-time and scheduled community notifications. The next step was to expand to other city departments, such as traffic engineering and streets. Traffic Engineering contacted me early in the project and explained it was trying to implement Waze in its department. It said it had applied for a Waze license through Google and was

denied because a municipality could not have more than one license. I had applied and was approved for the license when exploring the possibilities of the project; however, the license currently in use for this project was with the Regional technical team. Shortly thereafter, the City's Communications and Public Affairs Department also contacted me because it was also interested in deploying Waze, but learned the police department owned the license.

Most Waze municipal partners are traffic engineering and streets types of departments. I realized this situation became somewhat delicate and required an acknowledgment that I was operating outside of their industry norms. From their perspective, I had potentially delayed or blocked them from a project in their department. It was likely that our project would take longer since it was uncharted territory and a side project, while their industry potentially had a template that they could implement fairly quickly. The other difficulty was that I technically had the license that could be given to them, but it was not the best option for the long-term strategy. Two accounts adding to the same area could cause overlapping and contradicting information; it needed to be centralized.

Another concern was the number of technical staff involved. For one of the Chandler municipal departments to implement Waze, the Chandler City IT and GIS staff would need to become involved. This would mean a third group of technical staff would be involved since the inception of this project. There was no clarity on timelines, priority, or level of support for this project in the other municipal departments.

The best option seemed to be open communication of each department's goals, and ultimately, to create a comprehensive citywide strategy. Follow up conversations established that the other departments were in the early exploration phase of understanding the functionality provided by Waze the potential benefits for their individual departments. They were not immediately ready to deploy Waze. Scenarios were discussed with overlapping responsibilities, such as scheduled special events, as the basis for a comprehensive strategy. They were invited to look at the deployment and offered status updates. The long-term plan to incorporate 26 ECCs could also act as support, even a catalyst, for other municipal departments in the Phoenix region to implement Waze.

### 7. Key Activities

Key activities are the organizational functions for the business model to be successful. The initial Waze data available to municipal users in the Connected Citizens Program did not present in the same format as the crowdsourced information appears to mobile users. It is also not presented real-time by default. For the data to be valuable, the traffic incident reporting needed to be available on the 9-1-1 map in a timely manner. Programming adjustments were made by MR 9-1-1 to present the Waze data to the 9-1-1 map every 60 seconds for the entire city and to make it into a readable format for emergency communications professional staff.

Numerous other programming changes were made to accommodate workflow and 9-1-1 operator user considerations. The focus in the early part of the process was to create the ability to receive reports of traffic incidents and respond as necessary with the least amount of delay.

The key activities identified at the beginning of the project included:

- Mapping/programming
- Processing crowdsourced reports
- Bi-directional communication
- Special event coordination
- Coordination with other city departments

As with countless technical projects, the initial focus in this area was in the technical design. As learned throughout the project, the user and operational component was not adequately addressed at the outset of the project. This gap highlights the importance of ensuring the right stakeholders are involved. The following key activities would need to be included: workflow review and integration into current 9-1-1 center overall processes, decision support (what to do with the data, when, who makes the decision, what those decisions are based on), dispatcher training, and policy design.

### 8. Key Partnerships

Key partnerships are the network of relationships and partnerships that form to create alliances to support the business model. These partners can be suppliers to provide resources, strategic alliances with competitors, or joint venture models. This project has gleaned a long list of key partners.

The original key partners at the beginning of the project were anticipated as: Google (parent company of Waze), MR 9-1-1 technical team (the regional team that manages the 9-1-1 system for the Phoenix metropolitan area), Chandler Police ECC professional staff (manager as project lead, supervisors, dispatchers, and emergency call takers as developers of the program), public information officers (spokesperson who manages public announcements, education and media releases), city traffic engineering (responds to issues involving problems with traffic signals or damaged roadways; also assists with special events and construction projects), city special events committee (assists with the planning of special events, including traffic patterns, road closures, parking and public communication plans), police officers (respond to the traffic collisions in the city, manage special events), and public commuters (drivers who report traffic conditions encountered while commuting; crowdsourced information is used to shorten commute times).

As the project experienced different pivot points, additional partners were added: two different City IT Departments (Phoenix Fire IT supports the 9-1-1 technical team and the Chandler IT department supports Chandler Traffic Engineering), Chandler Police IT (Chandler Police has an internal IT department to support the police department), and the Avondale police ECC.

Later, it was realized that the city geographic information system (GIS) department (responsible for maintaining the city mapping services) was no longer needed. Also, the regional ECCs in Phoenix metro region could become team members in the future.

The Phoenix Fire Department is the sponsoring agency for MR 9-1-1 and therefore provides resources and support. The Arizona State 9-1-1 Office, out of the Office of Grants and Federal Resources, provides state funding for the 9-1-1 infrastructure and ECCs in the

Maricopa Region managed by the Regional 9-1-1 technical team. An overall mixed funding and resource support is thus created for the Regional 9-1-1 technical team.

Shortly into the process, the Phoenix Fire Department conducted an agency-wide technical audit to include servers and software used in this project. To remain at no cost to the regional team, and subsequently, the project, aspects of the number of servers in use and ESRI licensing required review and restructuring. To continue this project using the existing resources would create a significant cost versus the current no-cost solution.

After preliminary administrative discussions, the regional technical team met with members from the Chandler Police department's IT division to discuss the alternatives. The possibilities were identified and the project's technical management was turned over to the Police IT division. The regional technical team would provide local access to the 9-1-1 maps, and programming would be turned over to the Chandler technical team. The cost would remain at zero with the added assumption that access to the City of Chandler network and resources were free.

While in the project queue for the Chandler Police Department's IT division, the regional technical team learned a new no-cost ESRI option was possible. Once the options were researched, the regional technical team made adjustments to the original programming and a new version of Waze was sent out to the dispatch supervisor team for testing. Waze was again live at no cost. The technical management was turned back over to MR 9-1-1.

Once the newest programming was completed, Waze was loaded on the dispatch supervisors' 9-1-1 maps. The guidance provided to the supervisors was minimal and purposely left open so as not to limit any feedback that could be operationally relevant. The goal was to evaluate how Waze could be used. The team had previously discussed the research on Waze and its potential benefits; the next step was to apply it to the actual data received.

The feedback after three weeks was nearly non-existent, with only one of seven supervisors providing feedback. This pattern was not typical for a supervisory team that had positively led a division in implementing several new types of technology over the last

several years. Some of these projects were nearly complete overhauls in some of their primary work processes; other systems added to their workload. A new goal for weekly feedback was established to ensure a frequency of interaction with Waze.

It was also learned during this time that a new technical glitch was causing the screen icons to disappear. In further discussions, it was learned it was a temporary ESRI licensing issue and further research was required for a long-term solution.

The feedback after another few weeks was still limited and demonstrated an overall lack of understanding of the potential of the Waze data or how the mobile app worked. Two supervisors within the team were approached as a potential new way to communicate the project in operational terms. One supervisor, because of the administrative role and project assignments, has more frequent informal interaction and communication regarding manager-level projects. This interaction provides exposure to the daily insights of strategic planning, brainstorming, and up-to-date conversations with the regional 9-1-1 technical team. The second supervisor had attended a national conference with a session that offered a Waze panel discussion. She learned that the European Union had produced a final report following its pilot project at three centers. She researched and reviewed the report, asked questions, and independently considered the operational implications. Each of these supervisors brought a different perspective, and as peers, could communicate in a way that a manager could not. During a supervisor meeting, these supervisors were able to add to the discussion in a peers-only environment. Follow up discussions indicated a better understanding, although the feedback became only slightly more frequent. The technical hurdles also likely contributed to this minimal improvement. Waze was then provided to the entire center. The group was asked to monitor this early version of Waze, think creatively for potential use cases, and provide feedback.

I also learned at an Early Adopters Conference that one of the industry-leading peers from Charleston County, South Carolina was exploring the possibilities of Waze. His ECC is a consolidated center that dispatches police, fire, and EMS. He was approaching Waze from a different angle. The Waze incidents were running through a data analytics platform and gathering data, which was a different approach than Chandler's open-ended scenario-based approach.

Charleston County was running its data through a large platform, but it led to the consideration of manually pulling sample data to look for key efficiency points. Comparing a sample of the reporting times of traffic collisions on Waze to traffic collision reports on 9-1-1 was one considered data set. The second considered data set was the number of duplicate traffic collision reports on Waze and the number of duplicate 9-1-1 calls. A comparison of these two data sets would potentially provide data towards the value proposition. He shared additional ideas for using specific components of the data that the author had not considered as well. For example, a Waze user is given a reliability number based on a Likert scale. A policy that considers using the Waze reliability score as a decision point is something that decision makers could consider. After comparing notes, the priority operational goals were similar.

### 9. Costs

This project was a side project for both MR 9-1-1 and the Chandler Police ECC. As such, this project did not have any dedicated funding. Early exploratory discussions reviewed the needed resources and the initial review showed no immediate outlay of expenses based on four assumptions. First, the Waze interface was free through the Connected Citizens Program. Second, the 9-1-1 mapping would occur using the existing, thin client managed by the MR 9-1-1 technical team. Thirdly, the MR 9-1-1 technical team would use and manage existing servers. Finally, the ESRI licensing would not require any additional costs and would be managed by the MR 9-1-1 technical team.

The major pivot points in the project of moving the technical management between the regional 9-1-1 technical team and the Chandler Police IT division were based on cost avoidance, specifically the server support and ESRI licensing. No additional cost is entailed for hardware, software or other technical support specific to the Waze project.

Two other categories of related project costs were anticipated. First was the cost of the human resource component of the project for their continued technical and project support. The project is in its early stages and will require attention when time allows. As the program is developed, policies will need to be developed and users formally trained. Once it is an ongoing program, it will need to be maintained. Changes in Waze will need

to be monitored and accommodated for emergency communication needs. The second category is the cost of public education. The Chandler Police Department strives to engage the community through a variety of interactions and has visibility at community events. Previous community outreach regarding new emergency communications technology has allowed for the purchase of items, such as pencils, stickers, flyers, and other toys with information on the technology printed on them. This cost may be $500, but it is optional. Social media and YouTube videos are created in-house for information releases. The police department's website is maintained with access to information and media releases as well. For major technology releases, the media is invited into the ECC for press releases when appropriate. The cost of public education is minimal for this project.

## F. BUSINESS MODEL CONCEPT: CUSTOMER DEVELOPMENT PROCESS

The Customer Development Process is made up of two phases, search and execution. The search phase includes both customer discovery and customer validation. The purpose of the customer discovery process is to develop a hypothesis and determine if customers actually have the problem believed to exist. Customer validation is intended to determine if the customer need is congruent with the hypothesis. The second phase is the execution phase, which includes customer creation and company building. These functions actually carry out the building of the company. Each of these two phases is discussed in the following sections.

### 1. Search Phase: Customer Discovery and Customer Validation

The hypothesis as applied to the expansion of channels in the ECC is that a multi-channel environment will provide the community with options to report emergencies using channels that represent the modern means of communication, such as social media and apps like Waze. The hypothesis also includes that a channel, such as Waze, can provide the means for earlier notification and re-route lower quality reporting sources, such as non-witnesses and those not involved in traffic collisions who traditionally call 9-1-1 during a call burst to Waze, which can be handled more quickly and efficiently.

### 2. Execution Phase: Customer Creation and Company Building

The execution phase was not completed during this project. Data gathering continues, as are adjustments to the types of data collection to narrow down notification times. The data collected from injury collisions during the high collision times in Chandler over the one-month sample revealed an opportunity to re-route a number of calls from lower quality reporting sources to a data-reporting source, such as Waze. The data gathered from the DPS transfer call surges also demonstrates an opportunity for a cooperative interagency response to transition some phone reporting to a data-reporting option like Waze.

## G. REFLECTION

The potential use cases are still under construction at the time of this writing. Based on the October 2018 statistical sample of 9-1-1 calls the Chandler ECC received for injury collisions during high collision times, a review of callers was conducted to determine how many calls were received and to characterize the types of callers. Frequently during call surges, people call who have simply driven by the collision. These callers were not involved, did not witness the collision, and were not on scene to provide any lifesaving or medical assistance. One Waze enhancement is to conduct a public education campaign for users (otherwise uninvolved) to refrain from using 9-1-1 when merely passing an accident. Only those drivers or witnesses directly at the scene, involved, or witnesses to the collision, should also call 9-1-1.

The following key lessons were learned during the implementation of Waze into the Chandler Police emergency communications center:

### 1. Develop Your Network

Key partners proved to be invaluable during this project. At the point in which the servers maintained by the Regional 9-1-1 team would not be able to support Waze at no additional cost, the Chandler Police IT group was willing to discuss options to keep the project moving. Everyone acknowledged the value of the project. Considerations included the costs for licensing at Phoenix Fire, licensing costs if purchased by Chandler, temporary

licensing costs, timelines to pause the project, and various technical alternatives. The ultimate decision was that the Regional 9-1-1 team would provide access to its 9-1-1 mapping system, a usually secure system, and turn the project over to the Chandler Police Department IT team who had access to the servers and licensing at no cost. It was understood that that this access would be added to its pending list as a side project, not a need. The Chandler Department IT team is a highly skilled, progressive, and service-oriented group, which means that its pending list of competing priorities is constantly growing without the staffing to support it.

The complementary skill sets and expertise between both the regional technical team and Chandler Department IT provided options to keep the project moving. Involving additional key partners provided a potential new way to reach the goal. These key partners brought their own knowledge and access to key resources to work towards a solution. No territorialism or politics was involved, only professionalism.

### 2. Be Flexible in Your Decision Making

When turning the project over to Chandler Department IT, this decision point had the potential to change the long-term strategy. If Waze was to be hosted on Chandler servers, uncertainty was created in its potential acceptability for regional use. It was the original intention for the regional technical team to host the solution and Chandler to be the beta site. If successful, Waze would have the potential to roll out to the other 25 agencies in the Phoenix metropolitan area. The decision was to move forward with the internal solution as the MVP to provide time to explore options for a regional solution, the standard solution in the Phoenix metropolitan region. The alternative was to pause the project until the ESRI licensing could be resolved. This delay seemed akin to sacrificing the project before testing, in anticipation of a long-term hurdle.

### 3. Play Nice With Your Peers

The interest in the program by the other city departments required a broad perspective of the project's usefulness across the city. This project could have derailed should other leaders have believed I was operating outside of administrative norms and blocking another city department from operating within its industry norms. Competing

interests, timelines, and levels of understanding of Waze resulted. Effective communication with the end goal of meeting each department's needs was the solution. At the time of this writing, major stakeholders have agreed to a citywide development strategy.

### 4. Have a Communications Plan Ready

The biggest communication failure was in the communications center. When Waze was integrated on the Chandler 9-1-1 map, the feedback provided by the dispatch supervisor team was limited. The Chandler ECC has a reputation for being progressive and an early adopter in the region. It has also served as a testbed agency for MR 9-1-1 with new technology projects. Not infrequently are employees in this communications center requested to develop projects from imperfect first versions; user involvement is a consistent practice.

In retrospect, the flexible rollout was intended to avoid limiting the possibilities, but this strategy was not received as intended. Some potentially perceived it as limited guidance and communication. The disconnect was potentially not realized earlier because of the following: (1) my assumption that everyone understood what we were looking for concerning operational feedback, such as scenarios and use cases, (2) a high level of adaptability in the past led to the assumption that this project would be no different, and (3) I assumed the intent of limited guidance was understood and accepted. The supervisor team did not receive any purposeful communication strategy, likely attributed to operations as the communication of daily business. This strategy is in contrast to technical communication and project management that requires more deliberate thought, communication, and clarification when coming from an operational background. In the future, not all communication can be taken for granted. The same level of purposeful communication should occur and time should be spent to ensure the message is understood. The other haphazard assumption was that after multiple progressive projects, including technology projects in which they have been fully involved, that their response would be the same. I did not look for signs of caution or apprehension. Each project in the future should be approached individually.

### 5. Make Friends, You Will Need Them

Throughout the project, I had been discussing the idea to partner on the project with a progressive regional peer: The Avondale Police Department. His center is located in the West Valley of the Phoenix metropolitan region, whereas Chandler is located in the East Valley. Their city population is approximately one-third the size of Chandler with significantly different demographics and geography. The benefit of the regional 9-1-1 technical team project oversight came to fruition when it was able to add Waze to its 9-1-1 maps remotely. When Chandler's center was starting to reach an impasse on providing feedback, Avondale began testing Waze at its agency. A partner agency provided a peer to begin brainstorming development ideas with another manager, including the regional implications. He provided a fresh perspective on how he was working on the operational component to gather feedback from users, and both centers began to approach the project together, looking at how to gather data and providing joint feedback to the regional 9-1-1 technical team.

While Waze continues to be an active project and the MVP for this writing, the exploration process of additional channels continues. The Chandler Police ECC currently uses additional reporting tools and is actively researching ways to streamline processes, allow for earlier notifications, and find ways for bi-directional, real-time communication with the community.

The following chapter discusses some of these new channels, their development and use cases. It also discusses the next steps for transitioning the ECC into a true multi-channel environment and the potential human resource implications.

THIS PAGE INTENTIONALLY LEFT BLANK

# VI. THE MULTI-CHANNEL ENVIRONMENT

ECCs are often responsible for additional types of emergency and non-emergency reporting within the center. The Chandler Police Department receives city alarms, monitors different types of GPS tracking devices, and has access to cameras. The Chandler Police ECC has other important sources of requesting police services. These sources include non-emergency text messaging, automated secure alarm protocol (ASAP) to PSAP, and text-to-911. Each is discussed in this chapter. In addition, a number of new data sources are now under consideration and are discussed at the end of the chapter.

## A. NON-EMERGENCY TEXT MESSAGING

This web-based channel provides the community with the option to call or text the primary non-emergency police 10-digit phone number. Many police departments use a five-digit short code for texting anonymous tips. However, another police department wrote an article in an industry magazine as the first ECC to tie text messaging to its primary non-emergency phone number and had found it successful. After researching the vendor and its product, it was implemented in Chandler. The purpose of this implementation was multi-faceted. The desire was for the community not to have to remember another contact phone number or short code, and to begin preparing the community for text-to-911. Another desire was to provide the community with a more contemporary communication tool.

Non-emergency text messaging went live as a text messaging-only service, even though the functionality also allowed for pictures and video. Nearly immediately, the public also began sending in pictures and video. It became apparent the public did not differentiate between the services. Pictures of suspicious vehicles, suspects, graffiti, and parking violations are some of the most frequently types of pictures sent by members of the community. Screenshots of social media posts indicating school threats and concerns of individual threatening self-harm are also fairly common. Another unanticipated use is that citizens also share their location by dropping a pin on a map and sending a screenshot rather than describing their location.

The text messaging option provided a level of anonymity. Questions from around the nation were received from people who wanted to ask basic questions of a police department without "bothering" their local police department. It also appealed to a younger demographic who would ask questions about how to become a police officer, or how to help friends they were worried about that did not necessarily need a police officer at that time. The deaf community reached out to say "thank you" for providing access to the police department without requiring a relay service.

Non-emergency text messaging was also used for emergencies. Domestic violence victims sent pictures of injuries and damage of their home and indicated they had not been able to leave their home for days. One in particular did not want to call because she was afraid she would be arrested for her warrant and she was concerned about what would happen to her children. Assurances were provided to her through text messaging that she would not go to jail for her warrant so she should provide her address and get the help she needed. Since text-to-911 was not available in the region at the time, it was her next available option. During an escalating barricade incident in which the suspect shot an officer with a bow and arrow, the suspect refused to negotiate by phone and instead sent text messages through this service. Although not the ideal solution, it provided a secondary option to maintain some type of contact with the suspect. On another occasion, a child reported from the back seat of a car that a parent had been doing drugs in the park and they were now driving home.

Very little guidance was given to the 9-1-1 dispatchers when this service was implemented. The reported information was handled as if it was received by phone call, and the supervisors could monitor the incoming texts. The primary guidance was to keep 9-1-1 and non-emergency as separate as much as possible. No major operational issues occurred. Non-emergency text messaging was first tested internal to the organization, and it has since evolved into an internal customer service option as well. Officers will use it for non-urgent communication with their dispatchers to free up phone lines and the radio, and so they do not have to wait on hold as well.

Non-emergency text messaging was implemented in February 2015. During the first fiscal year (July 2015–July 2016), a total of 1,182 text contacts were posted, to include

68 pictures and videos. Officers responded to 409 incidents as a call for service, or 35% of the non-emergency text contacts. This number was much higher than anticipated for the first year of implementation. The rest were primarily information requests or internal customer communication. Only 11 were spam, and 57 were wrong numbers. In 2018, almost 5,000 text contacts were posted, with approximately 350 pictures and videos submitted by community members.

These statistics reflect an alternative channel in which citizens can report primarily non-emergency incidents into the Chandler Police Department. It also provides a way in which the overall workflow into the ECC can be prioritized, since phone calls are handled on a first come, first serve basis. Due to the anonymity the text messaging option provides, and some of the texts received are not specific to Chandler, it is likely that the total workload of the center may have increased with the implementation of text messaging. However, multiple text messages can be handled at one time, and often, a phone call and text message can be handled simultaneously. The potential thus exists to mitigate the overall processing time when compared to processing phone calls one at a time.

## B. AUTOMATED SECURE ALARM PROTOCOL TO PUBLIC SAFETY ANSWERING POINT

This automated alarm process circumvents the voice call taking process in the ECC.[149] When an alarm is received, and the third party alarm call center determines a need for dispatch, the alarm company no longer calls the ECC and speaks with a 9-1-1 dispatcher who enters it into the computer. This new automated process sends it directly into the law enforcement computer system through a secure interstate public safety network called Nlets.[150] This new process saves minutes and human error by removing the voice call taking process. Follow up contact can be made by messaging the alarm company, rather than phone calls, which is especially efficient during large storms.

---

[149] "ASAP to PSAP Service," The Monitoring Association, updated March 11, 2019, https://tma.us/asap/.

[150] "Who We Are," Nlets, accessed February 21, 2019, http://www.nlets.org/about/who-we-are.

The automated alarm protocol was made available in 2011. As of October 2018, 52 ECCs are live nationwide with this interface.[151] Some limitations have been encountered. Nlets requires state protocols, so each state must be set up. It then requires compatibility with the computer aided dispatch system and each individual alarm company must also sign up for it. As of October 2018, 22 alarm companies are signed up for the automated alarm protocol, with 12 in the testing or implementation phase.

In 2018, Chandler received a total of 7,713 alarms.[152] Approximately 34% of these alarms (2,649) were received through the automated alarm program. Prior to this automated process, these alarm activations would have been phone calls received into the ECC, which is the same place where 9-1-1 calls are received.

## C. TEXT-TO-911

Text-to-911 was implemented in all 26 agencies in the Maricopa Region in April 2018. An executive committee comprised of representatives from MR 9-1-1, two East Valley police agencies, two West Valley police agencies, Phoenix Police Department and both regional fire departments was formed. That committee addressed topics, such as policy, training, operations, and public relations.

Chandler was able to have several participants in the text-to-911 implementation process. I was able to participate in the executive committee, which also provided an opportunity for site visits at the Los Angeles Police Department, California Highway Patrol, and San Bernardino County Sheriff's Office. A supervisor was able to teach at the regional train-the trainer, and another supervisor was able to participate in the public relations component with the deaf, hard of hearing, and speech-impaired community. Three leaders were immersed in the project prior to implementation and were thus well equipped to help lead the implementation within the City of Chandler.

Internal training included classroom, hands-on training, and scenarios using officers on the road. Some were simple tests, while others were worst-case scenarios to

---

[151] The Monitoring Association, "ASAP to PSAP Service."

[152] Chandler Police, "Chandler Police Department Versaterm Records Management System."

overflow the center. Small adjustments were made, but overall, the implementation was much easier than anticipated.

Chandler has received text-to-911 reports of domestic violence victims who have been unable to leave their homes and assault victims unable to speak freely. The deaf community has used text-to-911 to report a heart attack, a welcomed relief to have direct access to emergency services, no doubt. There were just under 5,000 text conversations in the first year of text-to-911 in the Maricopa Region.[153] The overall usage is relatively minimal, but for reports as those experienced by Chandler, the implementation is worth it.

## D. PENDING NEW CHANNELS

An unlimited potential number of opportunities exist to gather additional information. The multi-channel environment promises many new and exciting opportunities, such as reduced redundancy through proper resource allocation and mitigating 9-1-1 call congestion, increased situational awareness for more effective decision-making, faster response times from channels generating immediate notifications, cross-channel data aggregation, and increased customer service and quality of life through bi-directional communication with the community. The following sections describe a few new technologies now under development to enhance ECC operations further.

### 1. Video-to-911

Skype, Apple's FaceTime, Facebook's Messenger, and Google's Duo are examples of frequently used video chat options used for personal use in everyday life. The ability to send video when reporting emergencies has the potential to provide first responders with situational awareness prior to arriving on scene, as well as gather evidence for criminal cases.

The emergency communications industry in the United States has been hesitant to accept unfiltered livestream videos into the center. The addition of video exposes 9-1-1 dispatchers to visual images of emergencies, which indicates a cautious approach is

[153] Liz Graeber, "911 Totals 2018," accessed March 29, 2018.

necessary. The international emergency communications community, such as the United Kingdom, the European Union, and Israel, has implemented a phased-in approach to video-to-911.[154] During a 9-1-1 call, if the dispatcher determines that a live video stream is appropriate, a link can be sent to the caller. This link begins the process for the callers to authorize or deny access to the camera on their cellphones. Once permission is granted, the 9-1-1 dispatcher can view the live stream camera at the scene. Several vendors provide options of a chat function, similar to text messaging that can also be used simultaneously with the video session.

The first ECC in the United States launched video-to-911 in September 2018. Fayette County, Georgia contracted with Carbyne, an Israel-based company, to provide this service.[155] I met with company representatives in November 2018 during an Early Adopters Summit in November 2018. I learned of another ECC in Ocean County, New Jersey that had implemented the service with others in discussion. Interest in the industry is rising. This incremental approach solution mitigated a major concern expressed by the industry.

MR 9-1-1 was also familiar with this technology. After follow up discussions with the regional 9-1-1 technical team and the vendor, the decision was to test video-to-911 in Chandler with the long-term consideration for a regional deployment across 26 agencies. The plan during the test period is to gather use cases and bring to the regional Next Generation working group for discussion into future regional possibilities.

Carbyne presented a demonstration of its product to Chandler the following month. Video-to-911 is more sensitive in nature than text-to-911, so Chandler key partners, such as members of command staff, public information officers, criminal investigations, school resource sergeant, legal advisor, human resources, technical staff, and dispatch supervisors were invited to the presentation. It was also presented to the regional communications managers the following day. Implementation and training for Chandler communications

---

[154] Neil Spencer, "999Eye System Is 'World First,'" *West Midlands Fire Service* (blog), June 8, 2017, https://www.wmfs.net/999eye-smartphone-system-world-first/.

[155] Carbyne, "Deployed in Fayette, Georgia, Case Study."

employees was scheduled for the beginning of February 2019. Avondale also began discussions to test in the West Valley of the Maricopa region beginning March 2019.

### 2. Acoustic Crash Sensors

While attending the Northwestern Police Staff and Command School in April 2017, acoustic crash sensor technology was briefly mentioned. The resonating benefit was that the acoustic sensor could be placed at an intersection and then connected to a camera. Once this sensor "hears" a potential crash, it activates an alarm and the camera is activated for verification. It is an immediate notification of a crash without a 9-1-1 call.

A brief online search revealed old research and current technology vendors, an odd combination. I spoke with one of our PD IT analysts to learn more about the technology, potential costs, contacts he may have in the city's traffic engineering department or private industry. Of significant interest was the idea that artificial intelligence (AI) could be incorporated into the system to "teach" the system the difference between a crash and ambient noise. I then reached out both to the current police traffic division lieutenant, and the lieutenant assigned to move into the unit in four months since this project would be lengthy.

The incoming traffic lieutenant and I then met with the city's traffic engineering, since it oversees the city traffic cameras. We learned that the acoustic crash sensors were already installed in many of the existing municipal traffic cameras, and only required the installation of a $150 microphone. The level of microphone "training" or AI programming could not be determined until after installation and testing.

No other cities were known to be using this technology for traffic collision notifications into an ECC. No political or other technical issues were identified with the project. Traffic engineering was going to research through its industry contacts any city using the technology that could make any recommendations on microphones. It was going to contact the camera manufacturer for recommendations on compatible microphones and equipment. The only other identified limitation was staffing the installation of the microphone.

The next decision was to determine which intersection to begin testing. Two types of cameras are used in the City of Chandler intersections: pan, tilt, zoom (PTZ) cameras that can be moved across the entire intersection and cameras that are fixed on the approach area of the intersection. For purposes of this technology, the PTZ cameras were most appropriate, as injury crashes were more likely to occur at the intersection. The decision was made to start by testing two intersections that already had the sensor technology installed in PTZ cameras. The two intersections would ideally be chosen from intersections that were in the top 10 collision intersections of the city every year for the last five years. Of those qualifying intersections, those two intersections that had the most severe crashes were chosen.

Access to the traffic cameras is available to dispatch center supervisory staff through an internet connection, although it is rarely accessed in the current environment. No formal policy is place, but other cameras monitored in dispatch have a memorandum of understanding that explicitly states that access is only authorized in response to incidents. The accepted practice is synonymous.

As discussions regarding traffic cameras occurred, recurring political and cultural messages arose: (1) Traffic engineering will never allow dispatch to have camera access, and (2) City Council does not approve access to the cameras because it gives the perception of surveillance. As an employee of the city for seven years, this practice has been a culturally accepted truth. However, the ECC has had access to the traffic cameras for years. It has not been incorporated operationally, so there was no practical way for that message to be corrected.

As more questions were asked for historical context and to explore potential hurdles that could be encountered with this project, patterns emerged and one case study surfaced as the stated belief of the foundation of the political and cultural concerns. These could be summed up in three common themes. First, the prior requests were made for investigative purposes, which was different from the current proposed use of the cameras. Acoustic crash sensors are activating in response to a potential emergency that will alarm the ECC, which then views the cameras in response to that alarm. Again, this process is different from a surveillance or investigative tool looking for information. Other cameras in dispatch follow

the same process (e.g., shopping mall cameras). A policy can be created that mirrors an accepted process already in place. Second, a significant period of time has passed, likely a decade, since the official requests for camera use or review of cameras in that recurring scenario were made in the city. The previous decision makers, such as city council and police executive staff, are no longer in those positions. The backdrop of the request was a high profile case with nationwide attention for investigative purposes; technology in general has changed significantly, and the overall acceptance of technology has evolved in a decade. Any independently expressed stance by city council on surveillance issues is not precluded, but acoustic crash sensor technology does not seem to fit the recurring expressed 10-year old assumptions. Third, it was believed that traffic engineering had denied the ECC access to the cameras. The belief was that it was a political battle of access. It was ultimately learned that it was a technical denial. Bandwidth concerns arose regarding the number of users accessing the system. Bandwidth issues 10 years later could easily be reconciled with current technology. For purposes of this project, a crash alarms the ECC, and a dispatcher or two activates the cameras at that intersection. Tiered system access could be created and then limited. Users could be blocked based on system limitations to ensure system efficiency. Ten years of technology provides new options, along with new management and a new perspective.

The conundrum still existed that the majority of infrastructure existed in the traffic cameras unbeknownst to the police department. The microphone was the only needed equipment to begin testing, yet no other local law enforcement agencies were using this technology. The research found was limited to academic research, how the technology worked and how it could be used. No case studies were located globally on implementation by a law enforcement agency, lessons learned, or integration into an ECC. Vendors of the hardware did not market case study successes with law enforcement partners. It seemed too good to be true, so it was concerning that a significant piece of information was lacking. It also seemed to leave many unanswered questions as to why other agencies would not be using this technology. Do people know the technology exists? Do they not have the technology? Do people not have time to implement? Is surveillance the concern? It was surprising to find out the city already had much of the technology in the cameras and

deployed, it just had not been fully implemented or operationalized. Do other cities also have the infrastructure and not know it?

I spoke with a commander at a neighboring law enforcement agency with long-term leadership in his agency's traffic division. He was familiar with the technology, and said that in the 1990s, the technology was discussed and some movement made, but it was difficult to separate ambient noise from the actual crashes, which resulted in too many false positives to make the technology worth the investment. The technology was also more expensive 25 years ago. He explained that interest in the industry waned and the long-standing leadership remembers that either it did not work, newer leadership has not looked into the technology, or the story has been passed down that it does not work. He said he had heard some discussion that the new technology had improved the false positives, but he was not familiar with any agencies implementing the technology. He said he had a contact in his city's traffic engineering department that he could put me in touch with who was progressive with emerging technology.

At the Early Adopters Summit, I presented on the Chandler projects and later spoke with a representative from Massachusetts Institute of Technology (MIT) Lincoln Laboratories who was working on a project of embedding AI into body worn cameras. His work encompassed building specific conditions into a police officer's body worn camera to alarm the ECC. Discussion occurred as to whether that same process could transfer into this project in terms of training the sensors to remove the ambient noise, as well as having the cameras do more work for the dispatcher.

In a follow up phone call, the details of his work and the acoustic sensor project were discussed in more detail. The expressly delineated limitations of Lincoln Laboratories were further discussed. It was learned that our work did not exactly align, but that he did know of a professor on campus specializing in transportation and whose work might align. He stated that he had a meeting with him scheduled and would mention this project to the professor and gauge his level of interest.

Three months into the project, a request came from executive management of the police department to determine what would be needed to gain access to the traffic cameras.

I provided the current status and updates on this project. Also, the Police IT Manager was in attendance in this meeting who explained that he had purchased a microphone for the acoustic crash sensors and had coordinated with traffic engineering to install it in a specific intersection. Although both knew this direction was worthwhile in exploring, and had spoken with each other in the past about moving in this direction, neither knew the other had taken steps towards starting the project.

This project was an interesting lesson learned about key partners, key resources, and the various ways to accomplish the goal. Little traction had occurred with traffic engineering since the last meeting. Its communication may have shifted to the Police IT division as the project lead. I had approached the project in a manner that traffic engineering would take a larger lead in the project because its cameras were the key resource to the project coming to fruition. Police IT took a different approach. The project is for the police department's key activities, and the cameras are just one key resource. Although I was trying to drive the project, along with the traffic division, the project could be completed in different ways. Police IT took the lead on this project. It is now working to deploy the sensors at the first intersection.

### 3. Twitter

This test project is based on the 2016 Philadelphia and Pittsburgh research that traffic collisions are accurately tweeted, many earlier or in lieu of calling 9-1-1. I contacted our intelligence unit who occasionally uses social media monitoring. The first recommended source was Tweetdeck.

If the pattern of data followed the same as the Waze reporting, it was likely a higher number of traffic collision reports on the highways would result. I reached out to my peer at DPS and learned that it had a social media team that monitored some type of social media on the highways in real time, but it was unclear exactly what they monitored. She provided the team's contact information and said it would likely be open to any discussion. She also offered to share data on traffic collisions if a need arose to compare times, reports, or locations. Although the Philadelphia and Pittsburgh academic research did not include

highway information, the inherent geography of Chandler includes three highways, which allows for inclusion or exclusion moving forward when testing.

Next, I contacted the Chandler Police IT social media expert, who suggested another option: Datasift. This option considered the technology and the political environment of law enforcement and social media. Twitter has express policies and education for law enforcement information posted on its website.[156] It has also been vocal about its stance on not assisting governmental agencies with surveillance.

Thus, it is difficult to define what is perceived as surveillance and gathering data not intended for government use versus providing a new channel potentially to improve the emergency reporting tool, and thus, improve public service. The next question is how to determine if the channel can be worthwhile without knowing what data exists. The research conducted in Philadelphia and Pittsburgh demonstrated that the public is reporting traffic collisions on Twitter, which then becomes a privacy and security debate. Does the public want the police department to know and does the police department have the right or obligation to go looking for the information?

The research, such as the American Red Cross study mentioned earlier, demonstrated a public expectation that emergency responders will respond to requests made on social media, but social media sites and other groups, such as the American Civil Liberties Union (ACLU), have been vocally against social media monitoring by public safety.

The Chandler Police ECC currently tweets information on the official police Twitter account regarding real-time incidents. Often, traffic incidents and police incident notifications are tweeted for community members to stay clear of the area. Hashtags are used, such as #TrafficAlert, to alert the public of traffic incidents. One option to ensure the public's intent is to report is to institute a standard hashtag. However, it can be an enormous public education to ensure the consistent hashtag is used. Possible typos are a liability, and commuters traveling through the city are potentially more likely to be excluded. This

---

[156] "Guidelines for Law Enforcement," Twitter Help Center, accessed February 21, 2019, https://help.twitter.com/en/rules-and-policies/twitter-law-enforcement-support.

project was put on hold until some of the more philosophical answers could be vetted from an organizational standpoint.

### 4. Highway Cameras, Wrong Way Sensors

Arizona DPS works closely with ADOT. DPS has a team of police officers assigned to the Department of Transportation's Traffic Operations Center to coordinate responses and share technology. DPS has been an advocate to extend these benefits to the ECCs in the region, to include providing access to the freeway cameras. The Department of Transportation camera access was given to the regional 9-1-1 technical team and integrated on the 9-1-1 map, but the cameras had not been integrated into operations, and ultimately, were removed from the map. The highways are the jurisdiction of DPS in Arizona, not local law enforcement, but incidents often overlap and assistance between jurisdictions frequently occur.

The ability for local law enforcement to view the cameras at the overpass and coordinate with DPS could provide real-time information for incidents on the highway that could impact local law enforcement, such as significant traffic collisions, road closures, debris thrown from the overpass, or suicidal subjects on the overpass. Since DPS is a secondary answering point in the Phoenix metro region, local law enforcement ECCs answer all 9-1-1 calls in the area of the highway that an incident is occurring and transfers them to DPS. Although not an efficient workflow for an emergency response, it does provide local law enforcement with situational awareness and forewarning in the event assistance may be needed.

A specific type of situation that requires real-time joint coordination with a high risk element is the wrong way driver incident. Cameras can increase the efficiency of information exchange between the local law enforcement agencies and DPS from the current interoperability processes. Local law enforcement may close off ramps or respond to the highway to help intercept the wrong way driver as these incidents are dynamic and can be fatal.

ADOT implemented a thermal detection system on the freeway ramps in a 17-mile test area in Phoenix. Once the thermal camera senses a vehicle driving in the wrong

direction, the cameras will automatically focus highway cameras on the wrong way driver, illuminate wrong way driver signs, alert other drivers through overhead messaging boards, and thermal cameras will alert at one mile intervals to notify state troopers so they can get ahead of the wrong way driver and intercept. This thermal detection system is the first in the nation and is stated to have been successful in detecting 15 wrong way drivers as of June 2018.[157]

I coordinated with DPS for a site visit at the Traffic Operations Center and witnessed how the system works. The detection system is sensitive enough to activate when a maintenance vehicle backs up on the shoulder of the road, and the alarm is noticeable enough that an activation cannot be missed. ADOT cited six successful activations in which DPS has been able to engage in the incident and successfully intercept the wrong way driver. The average difference in time between the sensor activation and the first 9-1-1 call is about 3½ minutes but also does not include the time required to process the call and relay up to date location information. These sensors provide immediate notifications, decrease the response time and provide updated location information with accurate vehicle descriptions. They are efficient and provide a high level of situational awareness in a high-risk situation.

This type of activation is different from the traditional complexity of the wrong way driver incident. When callers report a wrong way driver on the highway, that location is only accurate for that moment since they are going in opposite directions. State troopers then must catch up to the wrong way driver, not drive against the flow of traffic, and time their interception window to minimize the exposure to innocent drivers. The highways also run through multiple city jurisdictions, so DPS relays each of these notifications by radio directly into all 26 ECCs in the Phoenix metropolitan area for assistance by the local city law enforcement agency.

DPS receives dozens of wrong way drivers in the 200 miles of highways of the Phoenix metro area each month on average, either through the Department of

---

[157] "Overview," Arizona Department of Transportation, accessed December 27, 2018, https://www.azdot.gov/projects/central-district-projects/i-17-wrong-way-detection-system/overview.

Transportation's thermal detection system or through 9-1-1. The installation of wrong way thermal detection sensors near the City of Chandler is not immediately planned. The success of the program however has led to discussions of future expansion. If the thermal detection systems were to expand and impact Chandler, even a simplified, but direct alarm notification would be a worthy discussion to begin an earlier response process to wrong way drivers.

MR 9-1-1 added the ADOT cameras back to the 9-1-1 map in the Chandler ECC on the same layer as Waze. The plan is to integrate these cameras into operations that require a joint response with DPS. I contacted a colleague at DPS and coordinated a joint training to include the supervisor of the DPS team assigned to the Traffic Operations Center, the subject matter expert on the thermal detection system for wrong way drivers with ADOT, and all Chandler emergency communications staff. The training is intended to provide a broader understanding of the technology, additional solutions for operations, and an opportunity for questions and information sharing between agencies.

Moving forward, the priority is to increase familiarity and use cases with the cameras. The operational response will continue to be through radio technology, with the supplemental ability to access highway cameras for incidents on or near the highways. The cameras should increase situational awareness and provide a more efficient interagency response. If thermal detection sensors become available in the Chandler area, the transition will likely be a smoother transition.

### 5. Noonlight

Noonlight is a smartphone application that connects any device and generates alarms for traffic crashes, smoke detectors, medical emergencies, or personal safety panic alarms.[158] Once the alarm is activated, Noonlight's third-party operators attempt contact with users by text or phone call. If users do not cancel the alarm using their personalized PIN, the ECC of the users' current location is notified. The nature of the emergency, users profile, and live GPS information is passed with the notification.

---

[158] "Connecting Your Apps and Devices to Save Your Life," Noonlight, accessed December 27, 2018, https://noonlight.com/.

Countless personal safety apps purport assistance beyond 9-1-1. This app was intriguing because it offers an automated notification option through Nlets, like the automated alarm protocols.[159] Noonlight can then route automated notifications directly into the dispatch computer as well. After discussion with the Chandler technical team, minimal setup was required, as the infrastructure was already in place.

The decision was made to move forward and limited to in-house testing only. Preliminary information only would be gathered to evaluate the possibility of taking the information to the Next Generation Working Group for review and additional testing participants. Two other agencies in the region using the automated alarm protocol may be interested in testing the automated version as well. The mobile app brought a lot of uncertainty and questions. The service it provides overlaps with other projects, but it also filled identified gaps. The automated manner in which it reports is a significant benefit and worth testing. The long-term survivability was questionable when existing vendors had the potential to provide the same service, and potentially, expand in the future. The time commitment required to invest in researching this app, and subsequent apps, was also a consideration.

The public education component was also a consideration when the Waze public education was still pending and video-to-911 would need to occur if the testing period was successful. The community appetite and absorption of multiple types of new technology at once was of concern. If the additional channels could not be remembered or successfully acculturated before a new one was added, the success of the new channel would be unlikely. Change management inside both the police department and the community needed to be a consideration.

The British Association of Public Safety Communications Officials designed a process to certify apps that can be connected directly into its emergency number (999).[160]

---

[159] Peter Holley, "This App Knows When You've Been in an Accident—and Then it Calls 911 for You," October 2, 2018, https://www.washingtonpost.com/technology/2018/10/02/this-app-knows-when-youve-been-an-accident-then-it-calls-you/?noredirect=on&utm_term=.c39f9aebe13b&wpisrc=nl_sb_smartbrief.

[160] BAPCO, "What We Do."

App developers are required to meet specific requirements and send it through a technical and operational testing process with host agencies. If it meets certification criteria, it can be integrated into 999 and it is considered officially endorsed by public safety. As the chair of the Next Generation Working Group, I decided a similar process could be developed that would assist the region in vetting emerging technology and the issues that the Noonlight app brought to light. The testing could be decentralized to different agencies, and a list of technology tested and recommended for the region could be maintained. Ideas or recommendations could be submitted for research or testing to the Next Generation Working Group as well. For those short-staffed agencies that do not have technical support or have a more risk-averse culture, the Next Generation Working Group can take the lead in finding host agencies to test.

### 6. Aggregating Platform

During these projects, the search for a platform that could centralize and aggregate the data continued. Motorola provides a platform called CommandCentral Aware used in real-time crime centers.[161] New Orleans and Detroit are successful use cases in which computer-aided dispatch systems, license plate readers, cameras, and an unlimited number of other systems are integrated and aggregated. These real-time crime centers are independent of, and staffed by, personnel other than emergency communications personnel. However, the concept and process of what CommandCentral Aware offers is similar to the multi-channel transition. No known implementations are taking place within an ECC.

I began researching the case studies, speaking with our vendor partners and exploring options. The platform is highly customized, and therefore, not agile in its setup and did not provide an option for a beta test. Cost was a concern, both at the implementation

[161] "Situational Awareness Software," Motorola Solutions, accessed February 20, 2019, https://www.motorolasolutions.com/en_us/products/command-center-software/command-and-control/commandcentral-aware.html#taboverview; "The City of New Orleans Case Study," Motorola Solutions, accessed February 20, 2019, https://www.motorolasolutions.com/en_us/products/command-center-software/nola.html.

phase and long-term sustainability. Discussions included potential for grants, such as school safety and highway safety.

Political climate became the priority of which channel within CommandCentral Aware to first implement. The Chandler Police Department and Chandler Unified School District have an excellent partnership, and during this time, had created action items that focused on school safety and their ongoing partnership. Following the lean strategy principles, incorporation of this school district's cameras could be the first channel added to CommandCentral Aware. The Chandler Unified School District has 45 schools with a 2018 student population of 45,940.[162] The school district has an additional staff of 5,118, which makes it the second largest employer in the city of Chandler. Floor plans of each of the schools could be entered with camera icons for access. Differing nomenclature is thus alleviated between schools and becomes operationally valuable during time-sensitive critical events. I met with the sergeant in charge of the school resource officer program. She stated that the superintendent of the school district had agreed to give the police department access to the cameras.

The MVP in this project is to be the Chandler Unified School District since it is the largest district, and the smaller school districts within the Chandler city limits, charter and private schools can be added afterwards. The ECC could provide the information gathered from the cameras during an incident rather than on-site school security or police officers who could be more valuable in a different capacity.

CommandCentral Aware offers the ability to add channels individually and as needed. The aggregation component it offers is the link to the computer-aided dispatch system, which tracks all police incidents. During an active school incident, if a suspect is outstanding, while the emergency communications staff is monitoring the cameras, logic can be built in to alert on new incidents, such as suspicious persons, alarms, trespass calls, or anything relevant within a geographically defined area. An alert could be triggered for

[162] Chandler Unified School District, *CUSD Annual Report* (Chandler, AZ: Chandler Unified School District, 2019), 1, http://www.cusd80.com/site/Default.aspx?PageID=658.

an outstanding suspect potentially involved in the school incident, but outside the range of the cameras.

A secondary functionality chosen in the first phase of Command Central Aware was the license plate reader platform. Motorola suggested this option because it was a solution already owned by Motorola, and therefore, available for a very minimal cost. The license plate reader program is currently a program managed by the detective division, and not a program in which the communications center is actively engaged. However, if access were possible, potential opportunities could result.

I had learned that the St. Louis Metro Police Department had a progressive license plate reader program in its real-time crime center and arranged for a conference call with the supervisory team overseeing the program. The team was able to provide information on its implementation of its real-time crime center, to include its decision points for its choice of a different vendor, as well as information on it license plate reader program. The implementation information was helpful regarding project management topics moving forward with CommandCentral Aware. After speaking with the team about the license plate readers, enough information was available to lead me to believe that opportunities exist for the ECC to offer the detectives support in some real-time monitoring of notifications of that program.

I also spoke with two other companies working in similar products. One company offered a cloud-based solution to provide emergency communications solutions. However, programming adjustments would be required to create the platform not inherently built into its existing solution. Follow up discussions determined possibilities existed, and the potential solution could prove to be highly agile. The timeline and costs were unknown. Another company is currently aggregating multiple channels and using the same processes outside of the emergency communications environment, but for an entirely different life safety purpose. Both these discussions have possibilities, but take time to develop into reliable products.

Motorola's CommandCentral Aware is the best platform available at the time of this writing. The lean strategy was part of the earliest discussions of this project. Motorola

was in support of this methodology and took the time to ensure full understanding, to include our scenario-based explanations. This strategy is especially important because CommandCentral Aware has historically been used in real-time crime centers, but not in ECCs. A site visit to the New Orleans Real-Time Center is scheduled in the upcoming months to watch it in use and speak firsthand with users.

After researching these platforms, we identified a need for private partners to recognize the industry need to move into the multi-channel environment and to design a platform ready to accommodate any potential channel. Rarely does a designated funding source take the lead in innovation and emerging technology. Creating cost prohibitive platforms will reduce the potential for ECCs to move into this environment.

## E. SKILL EVALUATION

As potential scenarios were designed to determine which channels would be the priority in incorporating into the multi-channel environment, and how they could be aggregated, it became apparent that the employee skill sets required to manage the future ECC were evolving. Managing data-driven information and interpreting it for actionable data is different than managing an emotionally distraught caller on 9-1-1.

In discussions with the MR 9-1-1 Administrator, the idea was discussed of merging experts in data with experts in emergency communications to create a potential new job description for the future position. We had met a representative from Google who works with public safety and understands emergency communications operations. I reached out to her to explore the possibility of collaborating to brainstorm on this potential new job description, to which she agreed. Charleston County, SC is also looking at beta testing a similar position and has a job description in place. While the newly recommended skill sets may not be immediately justifiable as minimum requirements in current hiring processes, applicants can be interviewed with these pending skills in mind for their success in the future. As skills become relevant, they will be included in the current job description.

## F. NEXT STEPS

All these potential new channels will continue moving forward, although at different rates. The following section provides an overview of the next steps the Chandler Police ECC will take for the key technologies discussed earlier.

### 1. Waze

Continue to monitor real-time traffic incidents and begin the data collection process. Work with Google and the Maricopa Region technical team to streamline the reporting process, which includes reducing the time the technology takes to process the user report. Chandler and Avondale will collaborate to begin developing potential protocols. These protocols will need to include whether the Waze notifications will be sufficient to dispatch officers, regardless of additional voice reports on 9-1-1. Programming needs are still required to begin the bi-directional communication process with the community. Once in place, Chandler will work with the other municipal departments to create citywide Waze protocols.

### 2. Video-to-9-1-1

Train all staff and live beta test video-to-911. Protocols will be created for testing in the live environment, with some discretion afforded for the development of use cases. Supervisors will be provided additional training to develop additional familiarity and be able to provide support to employees making discretionary decisions in its usage. Decisions will be made in its value and cost. Information will be brought to the region's next generation working group for consideration into a regional deployment.

### 3. Acoustic Crash Sensors

Support Chandler Police Department IT as the project leads on this project as it approaches the time to test the technology and workflow. Policies of camera access should be formalized and congruent with other camera access. Adjustments for users and new scenarios as presented will be iterative.

### 4. Freeway Cameras

Reinforce the training provided through scenarios and on the job application during joint operational incidents and proficiency checks. Additional wrong way sensor implementation projects will be monitored.

### 5. Twitter

Follow up with DPS to learn about its social media programs to assess if any would be applicable in Chandler and any partnership opportunities. Keep a finger on the pulse of Twitter and other social media for potential future ideas. Consider creating a continuity of operations backup plan for large disaster emergency reporting that could be activated immediately.

### 6. Regional Working Group

Explore a formalized process within the regional Next Generation Working Group to test potential new channels and apps, such as Noonlight. This group can make recommendations on which technology should be regional deployments and which is best suited for individual agency deployment.

### 7. CommandCentral Aware

Move forward with determining the requirements for the implementation of CommandCentral Aware. Potential funding sources are under review and a site visit at the real-time crime center in New Orleans is tentatively scheduled. Gather additional details on the school district cameras and develop scenario-based use cases.

### 8. Job Descriptions

Collaborate and begin the brainstorming process with Google and other industry-leading peers to create an early version of the potential new skills required for the job functions of the multi-channel ECC.

## G. SUMMARY AND CONCLUSIONS

This chapter evaluated the supplemental reporting channels currently implemented in the Chandler Police ECC, as well as potential new channels as the center continues to work towards a comprehensive multi-channel environment. Although none of these channels are fully implemented, this chapter demonstrates that great strides can be made in the investigation and exploration of new channels within a limited time frame, such as the constraints imposed on this thesis.

The results and conclusions of this project and research are discussed in the final chapter. The lessons learned during this case study are outlined, as well as recommendations for future research.

THIS PAGE INTENTIONALLY LEFT BLANK

# VII. RESULTS AND CONCLUSIONS

## A. INTRODUCTION

This final chapter presents the results and conclusions that can be drawn from the projects conducted at the Chandler Police Department emergency communications center at the time of this writing. Disasters and 9-1-1 outages highlight the limitations of the current 9-1-1 system, despite constant technological and operational adaptations. Data-driven communication tools already in use by the community are channels in which ECCs can evaluate as opportunities to implement and transition into a multi-channel environment. This thesis used a combination of research, actual implementation of a new channel, and the use of business model generation to produce the results discussed in this chapter.

## B. PROBLEM STATEMENT

Disasters, terrorist attacks, and network outages are representative of the limitations of the current single channel environment and the public's response when 9-1-1 is not enough. The 9-1-1 system was created 50 years ago. Adaptations continue to be made to accommodate the ever-evolving technology requirements, but operational limitations still exist. Data-driven technology has become the primary communication channel in today's society and emergency communications leaders must incorporate these new channels into the emergency reporting options they provide their communities.

## C. SIGNIFICANT CONCLUSIONS

Preparing for disasters begins with creating an efficient multi-channel environment in the everyday workflow of the ECC. Defining complementary channels that aggregate information offers opportunities for more effective decision-making and situational awareness. The multi-channel environment therefore provides a dynamic capability and allows for flexibility based on type of incident, and scalability from the routine to the disaster.

This thesis is a case study demonstrating the process of channel expansion within an ECC over the course of approximately six months. The limitation of coordinating live projects within a fixed timeline did not result in full deployments; however, the lean strategy methodology provided opportunities for lessons learned and a model for continued channel expansion in the Chandler Police emergency communications environment. This thesis demonstrated that significant strides can be made in a relatively short amount of time. These projects were considered side projects, conducted within a limited timeline, and had no designated funding.

A shift has occurred within the Chandler Police emergency communications center in order to continue in this trajectory. The mission of the ECC is to respond to requests for emergency services, with 9-1-1 as the first channel in which to do so. Leaders will develop a strategic plan to incorporate additional channels based on their community's needs, trends, and resources. The channels chosen in this thesis were individualized and chosen to meet the mission, to address a specific problem, or bridge a gap. Text messaging has taken 25 years to reach 25% of the ECCs in the United States. The focus moving forward will not be on implementing a specific technology. Rather, it will be on the community's needs, and finding the technology required to support that mission.

The channels discussed in this thesis were also evaluated in terms of how the multi-channel environment can address the current 9-1-1 system inefficiencies and create a more efficient and effective decision-making environment. Rural, urban, law enforcement, and fire agencies will all have different issues and priorities. The channels discussed in this thesis were in context of the Chandler Police Department and Phoenix metro region community needs and political environment. They were weighed against the key resources, key partnerships, and channels available in order to choose the appropriate channel in response.

This multi-channel ECC provides a higher level of situational awareness, which in turn, provides a higher level of quality of service to both the community and first responders. The literature reflects that loyalty and increased customer service is built on quality of service in the business sector. Law enforcement relies on the loyalty and public

trust to be effective in its community. These projects seek to support the relationship the police department has with their communities.

It was evident that there was a sense of true ownership in moving the Chandler Police emergency communications center into the next generation at the local public safety management level, and the 9-1-1 system administrative and technical level. Despite the two decades of industry discussions to move towards Next Generation 9-1-1 platforms and infrastructure, it is not yet resolved. Reliance on the national industry organizations or professional associations to create a "one-size-fits-all" strategy, unified system, or set of sanctioned standards or policies in a world changing at a record-setting pace, is a passive and short-sighted approach. At the traditional pace of public safety technology adoption rate, it will not catch up. Community life safety needs in the community are most readily identified at the community level. We could no longer wait until the national organizations drive the next step.

Regional and state implications were carefully considered at each step. Regional programs can support the needs of individual communities by sharing technical expertise, beta testing technology, and ensuring consistency across jurisdictional boundaries. Grants and other funding options may be greater with joint projects. The influx of options may warrant a regional working group to share the load, as shown in the six months of this thesis. The responsibility to advocate for Chandler's needs lies with Chandler, but a regional awareness was maintained, so each agency is not individually managing each technology in a silo.

Exploration, awareness, and curiosity were more important in this process than technical knowledge. These projects began as conversations, readings, presentations, or a different iteration of the technology. None of the projects at the outset was presented as a package ready for purchase and deployment by an ECC. Waze was not designed for the public safety communications environment, but the value was easily identified in the crowdsourcing platform. Video-to-911 is emerging and readily discussed in the industry, but the exploration began through video coursework at the Center for Homeland Defense and Security (CHDS). Israel was using a video medical app that reported to emergency responders. It was not applicable at the time, but this process had potential. After following

it for a year, it was modified for law enforcement emergency communications and the company expanded to the United States. Acoustic crash sensor technology was a brief mention in a command school that triggered interest into the possibilities. Academic research revealed a study on traffic collision reporting on Twitter, the *Wall Street Journal* highlighted an article on Noonlight, and regional exposure generated interest in the highway cameras. No single source exists for generating potential new channels. Curiosity, the willingness to explore, and a mindset of moving the ECC forward, were central to finding these channels.

The exploration process requires transferring concepts and processes from an alternative channel into the emergency communications environment. In other words, it is likely uncharted territory at every turn. The business model canvas allows leaders to look at the nine building blocks to ensure the core principles were considered at the outset. Lean strategy provides a methodology in which iterations can be made frequently, and failures are less likely to be as catastrophic, which is a critical component in the emergency communications industry.

Following leads opened up opportunities, established networks, and built key partnerships. Sometimes these leads did not move the project forward, but established a relationship for the future and a potential new channel down the road. During this process, a myriad of people were engaged in some capacity throughout the various projects. Many people were interested in helping for different reasons. Some shared the vision to move to the multi-channel environment for one of many reasons, others shared an interest in emerging or interesting technology projects, while others were professional relationships simply willing to help a colleague.

Key partners were integral to all the projects. The caution with key partners was recognizing the politics, the players, and the importance it plays in the project. A showcase example is traffic engineering ready to begin the Waze project as the industry standard, and managing a potential perception of emergency communications stalling its project. Meanwhile, a concurrent project of the acoustic crash sensors seemingly requires its involvement because it owns the traffic cameras. Awareness of the entire ecosystem cannot be overstated.

This thesis demonstrated that each channel was unique and required an individualized approach. Project managers, beta test sites and users, technical support, priorities, and overall project direction changed. The agile focus of the lean strategy methodology allows these pivot points to occur without catastrophic consequences. The projects continued to move forward each time with a new clarity in direction. The vision to move to a multi-channel environment remained unwavering.

The nature of the ECC is inherently filled with risk. Life safety can never be taken for granted, but the realism is in the impossibility of vetting out every potential liability. Even still, avoiding all risk has the potential to create liability. Alternative reporting channels provide redundancy to 9-1-1. A hesitancy to implement a new channel because of the risk involved decreases the options for redundancy, and thereby increases risk. In the emergency communications operational response, emergencies received on 9-1-1 are tiered and prioritized. The same should be true in managing the transition to the multi-channel environment. The culture of the industry however is risk management and reducing liability whenever possible. When implementing new projects, the risks must be defined early in the project and communicated to key partners. The driver or project manager must establish both the organization's capacity for risk, as well as his personal threshold for risk. These risks should be congruent with that of the key stakeholders and political environment. Steps to mitigate the project's risks should be taken with the full understanding that no solution will eliminate all of them. Ensuring subject matter experts are fully engaged, partnering with another agency during the process, or moving slowly through the implementation process, are some non-technical ways in which the leaders can mitigate some risks throughout the process.

The priority was to create complementary channels that expand information capacity and aggregate information between them, as recommended in the literature. More information working together creates efficiency and situational awareness. Care was taken to avoid simply creating additional pipelines of information and avoid creating additional inefficiencies and information overload. The goal was for all channels to be complementary and work together for effective decision-making, redundancy options, and efficient emergency reporting.

An agile and agnostic platform is needed to provide a centralized way in which the channels discussed and implemented in the Chandler Police emergency communications center could be housed and aggregated. This platform would provide a dynamic path in which the contemporary, relevant communication channels of the day could be accepted, and those no longer providing value could be sunset as appropriate.

## D. IMPLICATIONS OF THE WORK

This case study revealed the following lessons during the transition of the Chandler Police ECC from the single channel environment into a multi-channel environment.

- The Chandler Police ECC requires a rebranding of the philosophy and culture in order to better align with the mission of the ECC.

The mission of the ECC is to respond to requests for emergency services, with 9-1-1 as the principal way in which to do so. The technology should not drive the mission because the mission is not to simply answer 9-1-1. One first step is to change the name from the traditionally named 9-1-1 center to the Chandler ECC. This symbolic move is important for signaling changes are afoot to the ECCs' technology menu.

- Providing for the needs of the community is a priority in the decision-making and technology adoption, rather than relying on the development of nationwide best practices and recommendations by industry organizations.

Moving forward, channel expansion will be based on an assessment of community needs, and limitations of the region's 9-1-1 system or practices.

- It is necessary to actively pursue new channels that will mitigate current limitations, and increase decision-making effectiveness and situational awareness.

The majority of new channels are not currently designed for implementation into the ECC. The implementations discussed in this thesis required creativity, multiple iterations, and lean strategy thinking. Exploration and curiosity started the conversation,

while key partnerships and experts will move the project forward. The creation of a multi-channel environment for an ECC creates scalability and redundancy. Failure to do so could result in facing the publicly driven channel emergence for the first time during a disaster.

- Collaboration with regional and state partners help leverage shared resources and ensure regional consistency in services.

Meeting Chandler's individual community needs was considered in relationship to the regional and state impact. It was important to maintain a consistent level of service throughout a region, as citizens often do not understand jurisdictional boundaries. Sharing resources, such as software licensing, technical and operational expertise, and funding has the potential to reduce the redundant investment by each agency within a region. A regional working group can facilitate the vetting and testing of new technology, create partnerships between agencies, and reduce the impact on individual agencies.

- An agile, aggregated platform designed to accommodate the needs of the multi-channel emergency communications environment is needed to accommodate the future number of inputs.

The agnostic platform should be able to connect new channels, aggregate them, and incorporate the multiple programs already required in the current emergency communications environment. Incorporating this platform is ideal in the early transition to the multi-channel environment to avoid the current retrofit issues of 9-1-1. The platform must be agile to accept and decommission channels as needed.

- Human resource needs, such as evaluating any newly required skill sets, hiring practices, and training required for success in the multi-channel ECC should be critically evaluated.

The additional and change in skill sets in the multi-channel environment creates a distinct evolution in job function. Job descriptions will be evaluated and adjusted as new channels are added to the ECC while simultaneously planning for the long term. Comprehensive training and proficiency monitoring will be ongoing as channels are added and new skills are required of professional staff.

## E. RECOMMENDATIONS FOR FUTURE STUDY

The proliferation of channel choice will warrant a deeper dive into the analytics each channel provides. Classifications of emergency reporting values can be based on volume of data, speed of reporting, and quality of the data. A review of channels to ensure a balanced and holistic approach will support the aggregation and complementarity mentioned in this thesis.

A multi-channel environment will provide additional information from multiple sources, which increases the likelihood of false-positives. If the new data reporting has the ability to produce earlier notifications, and seemingly more accurate information, this reporting can also potentially be used in nefarious ways, such as "swatting." Technical steps and user training to recognize such indications must be considered to mitigate these incidents.

Human resource considerations will be an ever-evolving consideration. The single channel environment exposes 9-1-1 dispatchers to auditory trauma. New channels, such as pictures, videos, and cameras reveal new potential trauma exposures. Research is only beginning on this topic in emergency communications.[163]

The evolution into the next generation ECC will generate case studies and lessons learned. Real-time crime centers and fusion centers are available in some regions of the country. Further case studies into each center's function, its potential overlaps and delineation of roles, how it works together, and customization options by region is worth researching.

[163] Jeremy D. DeMar, "Next Generation 9-1-1: Policy Implications of Incident Related Imagery on the Public Safety Answering Point" (master's thesis, Naval Postgraduate School, 2017).

# LIST OF REFERENCES


9-1-1 Study Committee. *Maricopa Region 9-1-1 Status Report and Outlook*. Phoenix, AZ: Maricopa Association of Governments, 2017. http://www.azmag.gov/Portals/0/Documents/911MS_2017-02-10_Maricopa-Region-911-Status-Report-and-Outlook.pdf?ver=2017-04-06-110710-417.

ABC News. "Orlando Nightclub Shooting 911 Calls Released." YouTube. Video, 8:33. August 31, 2016. https://www.youtube.com/watch?v=HLzG_IsW_3E&t=224s.

Anti-Defamation League. *Murder and Extremism in the United States in 2016*. New York: Anti-Defamation League, 2017. https://www.adl.org/sites/default/files/documents/MurderAndExtremismInUS2016.pdf.

APCO International. "About APCO." Accessed August 19, 2018. https://www.apcointl.org/about-apco/.

Arizona Department of Transportation. "Arizona Motor Vehicle Crash Facts 2017." Accessed May 13, 2018. https://www.azdot.gov/motor-vehicles/Statistics/arizona-motor-vehicle-crash-facts.

———. "Overview." Accessed December 27, 2018. https://www.azdot.gov/projects/central-district-projects/i-17-wrong-way-detection-system/overview.

BAPCO. "What We Do." Accessed August 18, 2018. https://www.bapco.org.uk/what-we-do/.

Best Apps Guru. "Best GPS Navigation apps for Android and iPhone." February 10, 2019. http://bestappsguru.com/best-navigation-apps-gps-android-iphone/.

Blanchard, Heather, Andy Carvin, Melissa Elliott Whitaker, Merni Fitzgerald, Wendy Harman, Brian Humphrey, and Patrick Philippe Meier et al. *White Paper: The Case for Integrating Crisis Response with Social Media*. Washington, DC: American Red Cross, 2010. https://idisaster.wordpress.com/2010/08/26/arc-releases-white-paper-the-case-for-integrating-crisis-response-with-social-media/.

Blumberg Stephen J., and Julian V. Luke. *Wireless Substitution: Early Release of Estimates from the National Health Interview Survey, July–December 2016*. Washington, DC: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics, 2017. https://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201705.pdf.

Boehm, Jessica. "Maricopa County Is Fastest-Growing in Nation, According to U.S. Census Data." azcentral, March 22, 2018. https://www.azcentral.com/story/news/local/phoenix/2018/03/22/maricopa-county-fastest-growing-county-nation-according-u-s-census-data-phoenix-mesa-scottsdale/449043002/.

Brous, Paul, Marijn Janssen, Daan Schraven, Jasper Spiegeler, and Baris Can Duzgun. "Factors Influencing Adoption of IoT for Data-Driven Decision Making in Asset Management Organizations." In *Proceedings of the 2nd International Conference on Internet of Things, Big Data and Security*, 70–79. Porto, Portugal: SCITE PRESS—Science and Technology Publications, 2017. https://doi.org/10.5220/0006296300700079.

Brynjolfsson, Erik, and Kristina McElheran. "The Rapid Adoption of Data-Driven Decision-Making." *American Economic Review* 106, no. 5 (May 2016): 133–39. https://doi.org/ 10.1257/ aer.p20161016.

Capita. "Capita and West Midlands Fire Service launch 999EYE." November 2, 2016. https://www.capita.com/news/news/2016/capita-and-west-midlands-fire-service-launch-999eye/.

Carbyne. "About." Accessed December 9, 2018. https://carbyne911.com/about/.

———. "Deployed in Fayette, Georgia, Case Study." January 2, 2018. https://carbyne911.com/fayette-case-study/.

CCP Partner Onboarding. *What is Waze?*. San Francisco: SFBay, Institute of Transportation Engineers, 2018. http://www.sfbayite.org/wp-content/uploads/2018/05/9%20Google%20Waze%20Onboarding%20Deck%202018%20.pdf.

Chandler Police. "Chandler Police Department Versaterm Records Management System." Accessed January 7, 2018. http://www.chandlerpd.com/data/.

Chandler Unified School District. *CUSD Annual Report*. Chandler, AZ: Chandler Unified School District, 2019. http://www.cusd80.com/site/Default.aspx?PageID=658.

City of Chandler, Arizona. "Leading Employers." January 2018. http://chandleraz.gov/default.aspx?pageid=305.

Clark, David E., and Brad M. Cushing. "Predicted Effect of Automatic Crash Notification on Traffic Mortality." *Accident Analysis & Prevention* 34, no. 4 (July 2002): 507–13. https://doi.org/10.1016/S0001-4575(01)00048-3.

CTIA. "Americans' Wireless Data Usage Continues to Skyrocket." Accessed July 2, 2018. https://www.ctia.org/news/americans-wireless-data-usage-continues-to-skyrocket.

———. *CTIA 2016 Annual Wireless Industry Survey Snapshot*. Washington, DC: CTI, 2017. https://api.ctia.org/docs/default-source/default-document-library/ctia-wireless-snapshot.pdf.

———. "Our Mission." Accessed July 2, 2018. https://www.ctia.org/about-ctia/our-mission.

———. *Wireless Snapshot 2017*. Washington, DC: CTIA, n.d. Accessed May 27, 2019. https://api.ctia.org/docs/default-source/default-document-library/ctia-wireless-snapshot.pdf.

Dankert, Diara, James Driscoll, and Nancy Torres. *San Francisco's 9-1-1 Call Volume Increase: Findings Paper by the Google 9-1-1 Team*. San Francisco, CA: Google, 2015. https://docs.google.com/document/d/1b6OT8u01smq0ZV_mtvF1juj9RZT-36rYKtglLcwl3jU/edit#.

DeMar, Jeremy D. "Next Generation 9-1-1: Policy Implications of Incident Related Imagery on the Public Safety Answering Point." Master's thesis, Naval Postgraduate School, 2017.

Ebbers, Wolfgang E., Marloes G.M. Jansen, Willem J. Pieterson, and Lidwien A. L. van de Wijngaert. "Facts and Feelings: The Role of Rational and Irrational Factors in Citizens' Channel Choices." *Government Information Quarterly* 33, no. 3 (July 2016): 506–15. https://doi.org/10.1016/j.giq.2016.06.001.

Eisenhardt, Kathleen M., and Jeffrey A. Martin. "Dynamic Capabilities: What Are They?" *Strategic Management Journal* 21 (2000): 1105–21. http://mail.tku.edu.tw/myday/teaching/992/SEC/S/992SEC_T3_Paper_20100415_Eisenhardt%20Martin%20(2000)%20-%20Dynamic%20capabilities%20what%20are%20they.pdf.

Elgendy, Nada, and Ahmed Elragal. "Big Data Analytics in Support of the Decision Making Process." *Procedia Computer Science* 100 (2016): 1071–84. https://doi.org/10.1016/j.procs.2016.09.251.

EmergencySMS. "About Emergencysms." Accessed August 19, 2018. http://www.emergencysms.org.uk/about_emergencysms.php.

Ericsson. *Ericsson Mobility Report*. Stockholm, Sweden: Ericsson, 2017. https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf.

FDNY Center for Terrorism and Disaster Preparedness. *Orlando Terror Attack*. New York: FDNY Center for Terrorism and Disaster Preparedness, 2016. https://info.publicintelligence.net/FDNY-OrlandoAttack.pdf.

Federal Communications Commission. *AT&T Mobility, LLC, No. EB-SED-17-00024532*. Washington, DC: Federal Communications Commission, 2018.

———. “Chairman Pai Announces Investigation into CenturyLink 911 Outage.” December 28, 2018. https://www.fcc.gov/document/chairman-pai-announces-investigation-centurylink-911-outage.

———. “Consumer Help Center.” Accessed July 2, 2018. https://www.fcc.gov/consumers/guides/911-wireless-services.

———. “Harmful Consumer Wireless Behavior and Practices.” October 14, 2014. https://www.fcc.gov/news-events/blog/2014/10/14/harmful-consumer-wireless-behavior-and-practices.

———. “Text 911 Master PSAP Registry.xlsx.” Accessed July 2, 2018. https://www.fcc.gov/files/text-911-master-psap-registryxlsx.

———. “T-Mobile to Pay $17.5 Million to Resolve 911 Outage Investigation.” December 8, 2015. https://www.fcc.gov/document/t-mobile-pay-175-million-resolve-911-outage-investigation-0.

Federal News Radio. “Recent Hurricanes Have the Coast Guard Rethinking Social Media’s Role in Rescue and Response.” September 21, 2017. https://federalnewsradio.com/management/2017/09/recent-hurricanes-have-the-coast-guard-rethinking-social-medias-role-in-rescue-and-response/.

Fried, Adam. *Connecting Cities and Citizens to Improve Urban Mobility*. New York: United Nations Statistics Division, n.d. Accessed December 29, 2018. https://unstats.un.org/Unsd/geoinfo/UNGEGN/docs/11th-uncsgn-docs/Waze_UN_Presentation.pdf.

Gilmer, Marcus. “During Harvey, Social Media Rose to the Challenge as a Force for Good.” Mashable, August 29, 2017. https://mashable.com/2017/08/29/social-media-harvey-rescues-force-for-good/.

———. “Social Media Proves to Be a Positive Force in Flooded Texas.” Mashable, August 29, 2017. http://mashable.com/2017/08/29/social-media-harvey-rescues-force-for-good/#VoN7w0oymOqk.

Goersch, Daniel. *Multi-Channel Integration and Its Implications for Retail Web sites*. Gdansk, Poland: ECIS 2002, 2002. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.107.8423&rep=rep1&type=pdf.

Google Docs. “Comments of the National Association of State 911 Administrators.” Accessed July 2, 2018. https://drive.google.com/file/d/0B_rtue3opT_JMFhNOW9peHJoZ0E/view.

Graeber, Liz. “911 Totals 2018,” March 29, 2018.

Gray, Douglas. *Improving Cybersecurity Governance Through Data-Driven Decision-Making and Execution*. Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2014. http://www.dtic.mil/dtic/tr/fulltext/u2/a610301.pdf.

Greater Harris County 9-1-1 Emergency Network. "Greater Harris County 9-1-1 Emergency Network (GHC 9-1-1)." 2017. http://www.911.org/.

Gu, Yiming, Zhen (Sean) Qian, and Feng Chen. "From Twitter to Detector: Real-Time Traffic Incident Detection Using Social Media Data." *Transportation Research Part C: Emerging Technologies* 67 (June 2016): 321–42. https://doi.org/10.1016/j.trc.2016.02.011.

Hartley-Parkinson, Richard "Trial That Lets You Send Live Footage during 999 Call Directly to Police." *Metro* (blog). November 14, 2017. https://metro.co.uk/2017/11/14/999eye-trial-lets-you-send-live-footage-direct-to-police-when-reporting-crime-7077042/.

Hartman, Holly. "I Downloaded an App. and Suddenly, Was Part of the Cajun Navy." *Houston Chronicle*, September 5, 2017. http://www.houstonchronicle.com/local/gray-matters/article/I-downloaded-an-app-And-suddenly-I-was-talking-12172506.php.

Holley, Peter. "This App Knows When You've Been in an Accident—and Then it Calls 911 for You." October 2, 2018. https://www.washingtonpost.com/technology/2018/10/02/this-app-knows-when-youve-been-an-accident-then-it-calls-you/?noredirect=on&utm_term=.c39f9aebe13b&wpisrc=nl_sb_smartbrief.

Johnson, Ben, and Jana Kasperkevic. "Barely Anyone Used Text-to-911 during Hurricane Harvey." Marketplace, August 30, 2017. http://www.marketplace.org/2017/08/30/tech/barely-anyone-used-text-911-during-hurricane-harvey.

Kabadayi, Sertan, Yuliya Komarova Loureiro, and Marina Carnevale. "Customer Value Creation in Multichannel Systems: The Interactive Effect of Integration Quality and Multichannel Complexity." *Journal of Creating Value* 3, no. 1 (May 2017): 1–18. https://doi.org/10.1177/2394964317697608.

Kelly, Heather. "Harvey Highlights Issues of Aging 911 Tech." CNN Money, September 1, 2017. http://money.cnn.com/2017/09/01/technology/future/911-tech-harvey/index.html.

Kirby, Paul. "Texas 911 Agency Cites NSI Call Nuisance." *National Public Safety Telecommunications Council* (blog). March 22, 2017. https://blog.npstc.org/2017/03/22/texas-911-agency-cites-nsi-call-nuisance/.

Lavish Pad. "Luxury Real Estate." Accessed March 17, 2019. http://www.lavishpadz.com/luxuryrealestate.html.

Monitoring Association, The. "ASAP to PSAP Service." Updated March 11, 2019. https://tma.us/asap/.

Moravec, Eva Ruth. "Texas Officials: Hurricane Harvey Death Toll at 82, 'Mass Casualties Have Absolutely Not Happened.'" *Washington Post*, September 14, 2017. https://www.washingtonpost.com/national/texas-officials-hurricane-harvey-death-toll-at-82-mass-casualties-have-absolutely-not-happened/2017/09/14/bff3ffea-9975-11e7-87fc-c3f7ee4035c9_story.html.

Motorola Solutions. "Situational Awareness Software." Accessed February 20, 2019. https://www.motorolasolutions.com/en_us/products/command-center-software/command-and-control/commandcentral-aware.html#taboverview.

———. "The City of New Orleans Case Study." Accessed February 2019. https://www.motorolasolutions.com/en_us/products/command-center-software/nola.html.

MTS Painting. "Painting in Phoenix Area Neighborhoods." Accessed March 17, 2019. https://mtspainting.com/about-mts-painting/painting-service-area/painting-in-phoenix-area-neighborhoods/.

National Center for Statistics and Analysis. *Early Estimate of Motor Vehicle Traffic Fatalities in 2017*. Washington, DC: United States Department of Transportation, National Highway Traffic Safety Administration, May 2018. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812542.

———. *NHTSA 2016 Quick Fact*. Washington, DC: United States Department of Transportation, National Highway Traffic Safety Administration, 2018. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812451.

———. *Police-Reported Motor Vehicle Traffic Crashes in 2016*. Washington, DC: United States Department of Transportation, National Highway Traffic Safety Administration, 2018. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812501.

National Emergency Number Association. "9-1-1 Origin & History." Accessed July 2, 2018. https://www.nena.org/page/911overviewfacts?.

———. "9-1-1 Statistics." Accessed July 29, 2018. https://www.nena.org/page/911Statistics.

———. "Cell Phones and 9-1-1." Accessed July 2, 2018. https://www.nena.org/default.aspx?page=911Cellphones.

———. *E9-1-1 Voice Circuit Requirements: Providing a P.01 Grade of Service, Technical Information Document 03–50.* Alexandria, VA: National Emergency Number Association, 2007. https://c.ymcdn.com/sites/www.nena.org/resource/resmgr/Standards/NENA_03-506_v1.1_E9-1-1_Voic.pdf.

———. "NENA's Mission & Vision." Accessed January 24, 2019. https://www.nena.org/page/mission2017.

———. *NENA Call Answering Standard/Model Recommendation*. Alexandria, VA: National Emergency Number Association, 2006. https://cdn.ymaws.com/www.nena.org/resource/resmgr/standards/NENA_56-005.1_Call_Answering.pdf.

———. *Nena Standards for E9-1-1 Call Congestion Management Nena 03–006*. Alexandria, VA: National Emergency Number Association, 2003. http://c.ymcdn.com/sites/www.nena.org/resource/collection/1F053CE7-3DCD-4DD4-9939-58F86BA03EF7/NENA_03-006-v1_E9-1-1_Call_Congestion_Management.pdf.

National Weather Service. "Major Hurricane Harvey–August 25–29, 2017." June 18, 2018. https://www.weather.gov/crp/hurricane_harvey.

Neslin, Scott A., and Venkatesh Shankar. "Key Issues in Multichannel Customer Management: Current Knowledge and Future Directions." *Journal of Interactive Marketing* 23, no. 1 (February 2009): 70–81. https://doi.org/10.1016/j.intmar.2008.10.005.

Neslin, Scott A., Dhruv Grewal, Robert Leghorn, Venkatesh Shankar, Marije L. Teerling, Jacquelyn S. Thomas, and Peter C. Verhoef. "Challenges and Opportunities in Multichannel Customer Management." *Journal of Service Research* 9, no. 2 (November 1, 2006): 95–112. https://doi.org/10.1177/1094670506293559.

Nlets. "Who We Are." Accessed February 21, 2019. http://www.nlets.org/about/who-we-are.

Noonlight. "Connecting Your Apps and Devices to Save Your Life." Accessed December 27, 2018. https://noonlight.com/.

Nussman, Chris. "NENA Statement on CenturyLink Outage." National Emergency Number Association, December 28, 2018. https://www.nena.org/news/431952/NENA-Statement-on-CenturyLink-Outage.htm.

Office of the Legislative Auditor General. *Report to the Utah Legislature: A Performance Audit of the 911 System in Salt Lake County*. Salt Lake City, UT: State of Utah, 2009. https://le.utah.gov/audit/09_16rpt.pdf.

Ogrysko, Nicole. "Recent Hurricanes Have the Coast Guard Rethinking Social Media's Role in Rescue and Response." Federal News Radio, September 21, 2017. https://federalnewsradio.com/management/2017/09/recent-hurricanes-have-the-coast-guard-rethinking-social-medias-role-in-rescue-and-response/.

Osterwalder, Alexander, Yves Pigneur, and Tim Clark. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. 1st ed. Hoboken, NJ: Wiley, 2010.

Payne, Adrian, and Pennie Frow. "The Role of Multichannel Integration in Customer Relationship Management." *Industrial Marketing Management* 33, no. 6 (August 2004): 527–38. https://doi.org/10.1016/j.indmarman.2004.02.002

Peden, Margie M., and World Health Organization, eds. *World Report on Road Traffic Injury Prevention*. Geneva: World Health Organization, 2004. https://www.researchgate.net/profile/Margaret_Peden/publication/260288299_World_Report_on_Road_Traffic_Injury_Prevention/links/00b4953bd0f0d23cf0000000/World-Report-on-Road-Traffic-Injury-Prevention.pdf?origin=publication_detail.

Penn, Stephen P., and Eric B. Dent. "Attaining Data-Driven Decision-Making through Social Discourse." *The Journal of Applied Management and Entrepreneurship* 21, no. 2 (April 1, 2016): 26–44. https://doi.org/10.9774/GLEAF.3709.2016.ap.00004.

Pew Research Center: Internet, Science & Tech. "Mobile Fact Sheet." February 5, 2018. http://www.pewinternet.org/fact-sheet/mobile/.

Pieterson, Willem. "Citizens and Service Channels: Channel Choice and Channel Management Implications." *International Journal of Electronic Government Research* 6, no. 2 (April 2010): 37–53. https://doi.org/10.4018/jegr.2010040103.

Plevin, Rebecca E., Robert Kaufman, Laura Fraade-Blanar, and Eileen M. Bulger. "Evaluating the Potential Benefits of Advanced Automatic Crash Notification." *Prehospital and Disaster Medicine* 32, no. 2 (April 2017): 156–64. https://doi.org/10.1017/S1049023X16001473.

Public Safety and Homeland Security Bureau. *April 2014 Multistate 911 Outage Report*. Washington, DC: Federal Communications Commission, 2015. https://www.fcc.gov/document/april-2014-multistate-911-outage-report.

RapidSOS. "RapidSOS + NG911." 2018. https://www.rapidsos.com/ng911clearinghouse/.

———. "RapidSOS & Airbus DS Communications: The Future of Emergency Response." YouTube. Video, 3:50. August 10, 2017. https://www.youtube.com/watch?v=DHiA1pXGNQw.

REALRIDER. “Motorcycle Crash Detection.” 2017. https://www.realrider.com/crash-detection/.

Reddick, Christopher G., and Michael Turner. “Channel Choice and Public Service Delivery in Canada: Comparing e-Government to Traditional Service Delivery.” *Government Information Quarterly* 29, no. 1 (January 2012): 1–11. https://doi.org/10.1016/j.giq.2011.03.005.

Ries, Eric. *The Lean Startup: How Today’s Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. 1st ed. New York: Crown Business, 2011.

Sharma, Rajeev, Sunil Mithas, and Atreyi Kankanhalli. “Transforming Decision-Making Processes: A Research Agenda for Understanding the Impact of Business Analytics on Organisations.” *European Journal of Information Systems* 23, no. 4 (July 2014): 433–41. https://doi.org/10.1057/ ejis.2014.17.

Silverman, Lauren. “Facebook, Twitter Replace 911 Calls For Stranded In Houston.” NPR, August 28, 2017. https://www.npr.org/sections/alltechconsidered/2017/08/28/546831780/texas-police-and-residents-turn-to-social-media-to-communicate-amid-harvey.

Simon, Tomer, Avishay Goldberg, and Bruria Adini. “Socializing in Emergencies—A Review of the Use of Social Media in Emergency Situations.” *International Journal of Information Management* 35, no. 5 (October 2015): 609–19. https://doi.org/10.1016/j.ijinfomgt.2015.07.001.

Sivarajah, Uthayasankar, Muhammad Mustafa Kamal, Zahir Irani, and Vishanth Weerakkody. “Critical Analysis of Big Data Challenges and Analytical Methods.” *Journal of Business Research* 70 (January 2017): 263–86. https://doi.org/10.1016/j.jbusres.2016.08.001.

Spencer, Neil. “999Eye System Is ‘World First.’” *West Midlands Fire Service* (blog). June 8, 2017. https://www.wmfs.net/999eye-smartphone-system-world-first/.

Spicer, Tamara L. “Being Social: Integrating Social Media into Public Information Support to Emergency Response# Smem.” Master’s thesis, Naval Postgraduate School, 2013. http://www.dtic.mil/docs/citations/ADA579964.

Stephens, Kim. “Joplin Tornado Demonstrates Social Media’s 5 Key Roles in Disaster Response and Recovery.” idisaster 2.0, May 23, 2011. https://idisaster.wordpress.com/2011/05/23/joplin-tornado-demonstrates-social-medias-5-key-roles-in-disaster-response-and-recovery/.

Stewart, Alan. “Text Messaging.” *Encyclopædia Britannica*, February 24, 2017. https://www.britannica.com/technology/text-messaging.

Stickles, Jimmy L., James M. Kempema, and Lawrence H. Brown. "Effect of Mobile Phone Proliferation on Crash Notification Times and Fatality Rates." *The American Journal of Emergency Medicine* 36, no. 1 (January 1, 2018): 24–26. https://doi.org/10.1016/j.ajem.2017.06.047.

Stone, Merlin, Matt Hobbs, and Mahnaz Khaleeli. "Multichannel Customer Management: The Benefits and Challenges." *Journal of Database Marketing & Customer Strategy Management* 10, no. 1 (September 2002): 39–52. https://doi.org/10.1057/palgrave.jdm.3240093.

TapSOS. "TapSOS." Accessed August 19, 2018. https://www.tapsos.com/.

Thornburg, Kristopher M. "Disruptive Emergent Systems in Disaster Response." Master's thesis, Naval Postgraduate School, 2019.

Twitter Help Center. "Guidelines for Law Enforcement." Accessed February 21, 2019. https://help.twitter.com/en/rules-and-policies/twitter-law-enforcement-support.

Waze and European Emergency Number Association. *Waze Final Report: Exploring the Use of Waze for Emergency Response, A Pilot Project by Waze and EENA*. Menlo Park, CA, Brussels: Waze and European Emergency Number Association, 2018.

Waze. "Free Driving Directions, Traffic Reports & GPS Navigation App by Waze." Accessed December 16, 2018. https://www.waze.com/about.

Wilson, Hugh, and Elizabeth Daniel. "The Multi-Channel Challenge: A Dynamic Capability Approach." *Industrial Marketing Management* 36, no. 1 (January 2007): 10–20. https://doi.org/10.1016/j.indmarman.2006.06.015.

Wu, Jingshu, Rajesh Subramanian, Matthew Craig, Marc Starnes, and Anders Longthorne. "The Effect of Earlier or Automatic Collision Notification on Traffic Mortality by Survival Analysis." *Traffic Injury Prevention* 14, no. sup1 (January 1, 2013): S50–57. https://doi.org/10.1080/15389588.2013.799279.

Yoder, Jean. "Fatality Analysis Reporting System (FARS)." NHTSA, November 14, 2016. https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars.

Žliobaitė, Indrė. "Measuring Discrimination in Algorithmic Decision Making." *Data Mining and Knowledge Discovery* 31, no. 4 (July 2017): 1060–89. https://doi.org/10.1007/s10618-017-0506-1.

# INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California