SJSU SAN JOSÉ STATE UNIVERSITY

Mass Warning Study for the City of San José

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Part 1: Executive Summary

1.1 Purpose of the Study

The San José State University (SJSU) Research Foundation was contracted by the City of San José Office of Emergency Management (OEM) to conduct a study to research and asses the top 3-5 global most effective and integrated mass warning systems that can provide emergency alert and messaging to 90% of both residents and visitors within 10 minutes of notification initiation. Items of interest with regards to the identified systems include what populations are being served, the percentage of population reached for each type, the time it will take to reach most of the population, and other available success metrics. In addition to general system recommendations, the research team was tasked with conducting an assessment of and providing recommendations for addressing 6 disaster scenarios that might require emergency notification, including the Anderson Dam failing at full capacity, a no-notice train derailment in central San José, a gradual onset severe weather event with expected flooding, a delayed onset and no-notice biological terrorism incident, a severe earthquake, and a complex coordinated terrorist attack. The deliverable for this project is to develop a draft mass warning study for the City of San José, which includes: recommendations for a tiered system for public warning and notification (e.g. combination of sirens, text alerts, landline phones, public address systems, etc.), recommended triggers for issuing public alerts and warnings, detailing what City departments should house equipment and be responsible for notification (in accordance with all laws and regulations), detailing which departments are responsible for and should house the equipment for redundant systems, and the recommended protocols for notification for each of the 6 identified threats/hazards.

1.2 Study Approach

This report is based on both descriptions of current emergency response systems in major cities throughout the world and on academic research on existing and proposed future systems that increase our ability to notify most of the population in the least amount of time possible. The findings in this study are supported by the data presented in many technical papers included in the reference section of this report. These papers describe emergency responses to previous disasters throughout the world and perceived performance of the systems in use at that time, as well as new technologies for automatically sensing emergencies and quickly disseminating information about the perceived dangers to the appropriate systems and population sectors. Additionally, the research team interviewed the San José OEM about existing systems and practices and contacted vendors of emergency response equipment to inquire about existing and upcoming systems that may be used to reach the stated goal of providing emergency alert and messaging to 90% of the population within 10 minutes of notification initiation.

1.3 San José Emergency Management: Current State

The City of San José has invested considerable time and effort in developing a comprehensive and integrated emergency response system, processes, and action plans. Dedicated personnel in the San José OEM monitor emergency status 24/7 and are trained to accurately respond to emergencies. Processes are in place for coordinated responses to certain emergency scenarios, such as earthquakes, extended excessive heat conditions, wild fires, or flooding. The City utilizes an integrated alert system

(Everbridge, branded AlertSCC for the County of Santa Clara) that can coordinate simultaneous message dissemination via multiple channels, including the national Integrated Public Alert and Warning System (IPAWS). In addition, the OEM can deploy mobile long-range acoustic devices (LRADs) that can complement AlertSCC and IPAWS in delivering notifications. Most systems do not have the ability to measure the percent of the population that have been notified within a given amount of time.

1.4 Limitations

Limitations exist with all primary current notification systems. These limitations must be addressed to ensure reachability of 90% of the population within 10 minutes.

- AlertSCC's primary limitation is that it can only reach a subset of the population, namely those who actively sign up to receive emergency alerts, those whose contact information has been registered in the Yellow Pages or White Pages, or those who have their contact information stored in the Enhanced 911 (E-911) national database [1].
- While IPAWS can be used to send messages to all cell phones within a given area, irrespective of whether the cell phone owner has signed up to receive alerts, a current limitation of IPAWS is that messages can only use up to 90 UTF-8 (i.e., English-only) characters, restricting the amount of information that can be shared with the public and the languages that can be used to compose the message [2]. An update scheduled for May 2019 will increase the message length to 360 English or Spanish characters, but only Long-Term Evolution (LTE) or newer cell phones will be able to receive these longer messages and Unicode characters used by other foreign scripts are still not supported. Moreover, IPAWS may only be used if the emergency may lead to loss of life or significant wide-spread property damage.
- Both AlertSCC and IPAWS are tools that require due process by authorized emergency personnel. The verification process can require multiple persons to handle the message before it is transmitted, which can delay timely alerts, warnings, or notifications.
- The OEM currently has 4 mobile LRAD devices, whose deployment may take hours (depending on traffic) and whose audible range cannot cover the vast area of the City of San José.

Additional limitations exist that may not need to be immediately addressed but could be included in long-term planning for improving overall notification performance. These include:

- The performance of the overall notification system cannot be gauged in real time for a given geographic area, which limits OEM's ability to focus messaging efforts (e.g., relocating LRAD devices, increasing in-person notification efforts, etc.) to areas least notified so far during a wide-spread notification event.
- While the AlertSCC (Everbridge) system is capable of interfacing with several different alerting channels (WEA, EAS, NOAA, etc.), only a small portion of these systems are designed to provide message receipt confirmation feedback from recipients. Moreover, when the OEM alerts a person via multiple alerting channels, the feedback status is not currently available to be used in prioritizing alerts to people who have not already been successfully alerted via another channel.
- Current response protocols rely on a series of person-to-person notifications that can greatly increase emergency notification delay.

- Most of the current systems cannot be used to communicate alerts for non-English speaking/reading populations.

The research team faced several difficulties in drafting this mass warning study that limited our ability to provide some of the requested deliverables, including reachability statistics, estimated system costs, and department responsibilities.

1. Existing studies and research do not provide explicit message dissemination efficiency results data for the desired reachability goal of alerting 90% of the population within 10 minutes of an event. In many cases, this is due to the inability of existing systems to accurately measure the percent of the population that has been reached. Many of the systems provide only one-way message dissemination without the ability to ascertain whether the message was successfully received. The few anecdotal cases where system performance measures are mentioned are not well documented and would not likely translate to the San José emergency response ecosystem. We provide recommendations for developing processes and technology for gathering of reachability statistics during system tests and future San José emergency responses.
2. The research team encountered problems when researching costs for the deployment and annual system maintenance costs for proposed systems. In general, companies did not wish to engage with academics on such discussions, since we are not the primary decision makers in such a project. We contacted five of the most promising emergency notification system developers, including LRAD Corp., Everbridge Nixle, AlertSense, Backberry Athoc, and Hyper-Reach, but have only received one quote to date covering some of the requirements, which we provided to the OEM team. Moreover, an integrated system with all the suggested components recommended in this report may not yet exist. We suggest that, once the City has decided on a strategy for the next generation of their emergency response system, the OEM develop a Request for Proposal (RFP) engaging local software and hardware development companies in developing the solution.
3. In this study, we provide general suggestions detailing which departments may be involved in a coordinated emergency response, using generic department or team names. However, as academics, we do not believe that we can assign responsibilities for these tasks to specific departments within the City of San José or Santa Clara County. This assignment is beyond the scope of academic research and should be addressed internally within the City Management or by bringing the matter before the City Council.

Given these limitations, this study focuses on identifying and analyzing notification hindrances in the City's emergency management system and proposes potential changes that take advantage of novel state-of-the-art technologies in order to significantly improve emergency communication response times.

1.5 Recommendation Synopsis

Based on the analysis of the existing emergency response infrastructure and both existing and upcoming technologies, this report provides recommendations for improving the City's emergency response systems and procedures. The City uses a tiered approach that employs multiple methods of communication for alerting the public. It may consider maintaining and expanding these methods, as well as using technology and improved processes to reduce the time between emergency prediction or detection and the start of notifications. Immediate improvement recommendations include:

- Expand the fleet of available LRADs.
- Develop a siren infrastructure with comprehensive coverage of the City.
- Implement and test the recommended protocols for notification for the 6 researched scenarios with messages in multiple languages.
- Develop similar protocols for additional scenarios.
- Increase public education and outreach efforts to ensure appropriate public response during emergencies.

Long-term improvements for the City of San José's emergency response system include:

- Encourage state and federal OEM agencies to develop an opt-out cell phone-based notification system that may be used in extreme circumstances, e.g., when notification of 90% of the population within 10 minutes or less is necessary to prevent loss of life or major wide-spread property damage.
- Develop agreements and technology integration with various agencies outside the purview of the City of San José, such as the Santa Clara Valley Water District (SCVWD), to receive real-time sensor data that may be used to predict and/or gauge the severity of emergency events.
- Invest in new technologies, such as advanced sensors, Internet of Things (IoT) computing devices, and cloud-based data analytics, which could be used to predict some emergency events and analyze current conditions throughout the City in real-time.
- In partnership with Silicon Valley technology companies, develop an integrated cloud-based smart emergency warning system that would be able to efficiently and automatically respond to certain emergency scenarios.
- Develop a smart Web-based emergency dashboard and smart-phone app that can support both emergency responders and the public, providing appropriate information and functionality for each.

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Alert and warning of the public is of vital importance to emergency managers in terms of disaster preparedness, response and resilience for large cities such as San José. As the tenth largest city in the nation and third largest city in California, San José has a culturally diverse population exceeding one million people. Consequently, when natural and man-made calamities such as earthquakes, floods, or terrorist attacks occur, it is paramount that the City disseminate effective emergency communication to its public and provide alert and warning as broadly, quickly, and effectively as possible, and through a variety of communication channels.

This study reviews the current status of emergency management for the City of San José and, based on extensive research of global emergency response systems in major cities/countries and recent advances in sensor, communication, and data processing technologies, provides recommendations for short-term and long-term improvements to the City's emergency response systems. Additionally, current and recommended notification protocols are provided for 6 emergency scenarios, including the Anderson Dam failing at full capacity, a no-notice oil train derailment in central San José, a gradual onset severe weather forecast with expected 100-year flooding, a delayed onset and no notice biological terrorism incident, a severe earthquake, and a complex coordinated terrorism attack.

Part 2: The San José Emergency Management System

The state of California recently passed Senate Bill No. 833 (2017-2018, hereafter SB 833) [3], requiring the Governor's Office of Emergency Services (Cal OES), in consultation with telecommunication carriers and other specified entities, to develop general voluntary guidelines for alerting and warning the public of an emergency. The bill declares that local communities should appoint designated alerting authorities and ensure that they have the proper training and equipment to deliver necessary emergency communication. Moreover, the bill points out the necessity of a tiered system using multiple communication mediums, and not just opt-in systems, to protect lives and save property during wide-spread emergencies. Research also suggests that the public may need to receive messages via multiple mediums to consider the alert important and take action [4].

The San José OEM has already implemented many of the guidelines in SB 833. It partners with local and national agencies and monitors news and social media to receive notifications of active or impending emergencies. The November 2018 draft of the City of San José Emergency Operations Plan (EOP) [5] provides a pragmatic framework for the City's preparation, preparedness for, response to, recovery from, and mitigation against the impacts of natural and man-made disasters and emergencies.

When public warning or alert notification is deemed necessary, an authorized OEM employee utilizes Everbridge, an integrated communication and emergency notification platform, to broadcast appropriate information to sections of the City's population deemed at risk. Everbridge facilitates simultaneous notification via many channels, including location-based Short Message Service (SMS), cell phone broadcast, mobile phone push notifications, general SMS, voice/phone calls, email, and Common Alerting Protocol (CAP)-compliant systems, such as sirens, TV, radio, and electronic display boards (EDB) [6]. Additionally, Everbridge may be used to transmit notifications via county, state, or national systems, such as the Emergency Alert System (EAS) and Wireless Emergency Alerts (WEA) systems through the federal IPAWS system.

Table 1 provides a list of dissemination channels currently available in San José. For each channel listed in column 1, we provide information regarding expected message transmission times (Speed), the size of the area covered by the transmission (Coverage), the degree to which the message can be sent to a group of people that are located in a specific location or dispersed throughout the city (Concentration), and the ability for citizens to understand the message (Comprehensiveness). In the remainder of this section, we will further describe emergency communication tools and channels currently available in San José and point out some of their limitations towards the stated goal of emergency alerts reaching 90% of the population within 10 minutes.

Table 1: Characteristics of Emergency Message Dissemination Channels [4]

Dissemination Channels	Speed (minutes)[1]	Coverage[2]	Concentration[3]	Comprehensiveness[4]
Wireless emergency alerts (WEA)	< 10	Widespread	Dispersed	Very Low
Wireless communications (SMS)	< 10	Widespread	Dispersed	Very Low
Dedicated tone alert radios	< 10	Limited	Concentrated	High
Tone alert and NOAA weather radio	10-30	Widespread	Dispersed	High
Internet apps	10-30	Widespread	Dispersed	Very High to Medium
Radio	30-60	Widespread	Dispersed	High to Low
Social media	10-30	Widespread	Dispersed	Low
Text telephone (TDD/TTY)	10-30	Widespread	Dispersed	Low
Reverse telephone distribution systems	10-30	Limited	Dispersed	High
Loudspeakers and public address (PA) systems	10-30	Limited	Concentrated	Medium
Broadcast sirens	10-30	Limited	Concentrated	Medium
Audio sirens and alarms	10-30	Limited	Concentrated	Very Low
Message boards	10-30	Limited	Concentrated	Low
Television broadcast	30-60	Widespread	Dispersed	Very High to Medium
Television message scrolls	30-60	Widespread	Dispersed	Low
In-person notification	> 60	Limited	Concentrated	High

1. *Speed refers to the amount of time, in minutes, necessary to transmit the message to the target audience, not including time needed by the OEM to prepare the message. Values range between Very Fast (<10 minutes) and Slow (> 60 minutes).*
2. *Coverage is the size of the area that can be reached by the channel (Widespread denotes a large area; Limited denotes a small area).*
3. *Concentration is the degree to which the people that the channel reaches are co-located or dispersed (Concentrated means that the message is delivered to targeted locations only, while Dispersed means that the message may reach everyone in the coverage area).*
4. *Comprehensiveness refers to the ability to convey the content needed for effective response classes, used in this table are as follows: Very Low (alerting only); Low (very little information conveyed); Medium (many but not all essential contents conveyed); High (all relevant content conveyed); Very High (all relevant content conveyed with enhanced graphics).*

2.1 Emergency Operations Center (EOC)

The City of San José's Emergency Operations Plan (EOP) states that, in case of a local or national emergency, the City Manager, Assistant City Manager, Deputy City Manager, OEM Director, Chief of Police, Fire Chief, or their designees may activate the Emergency Operations Center (EOC) [5]. The EOC provides a centralized location where designated city management and emergency management personnel can coordinate decision-making and response to a critical incident, major emergency, or disaster. A primary and an alternate location for the EOC are equipped with necessary hardware and software tools to facilitate coordination and emergency response, including redundant private wireless network communication channels with first responders, airports, hospitals, and county or state EOCs, and access to the alert and information dissemination tools described in the remainder of this section.

During an emergency, communication must be coordinated between all responding agencies in order to provide consistent direction to the public for response to the emergency (e.g., evacuate or shelter-in-place). When the EOC is activated, the OEM can establish a Joint Information Center (JIC) to coordinate public information sharing about the emergency. Additionally, Department Operations Centers (DOCs) may be activated in various departments that must be coordinated with during the response, such as Transportation, Fire, Police, Public Works, etc. The OEM facilitates information coordination during an emergency through several systems, including WebEOC, a Web-based emergency management information system that consists of a set of information boards detailing different aspects of the emergency evaluation and response. The boards are displayed on television screens throughout the EOC and can also be accessed via the Web. WebEOC enables the OEM and local emergency response agencies to have a common operating picture and situational awareness during an emergency.

2.2 Santa Clara County Emergency Alert System (AlertSCC)

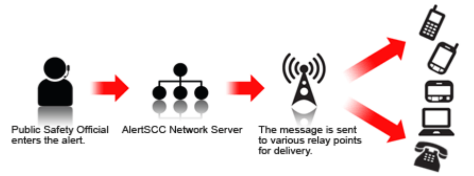

Figure 1 AlertSCC message dissemination [1]

Santa Clara County has developed a centralized emergency alert system, an instance of the Everbridge platform branded AlertSCC, to facilitate efficient distribution of alerts and warnings to the County's residents and visitors. San José has partnered with the County of Santa Clara to allow trained OEM personnel and 911 Dispatchers to use AlertSCC to quickly reach the City's population and businesses, even in case of emergencies localized to the City of San José. As shown in Figure 1, AlertSCC uses the Internet and state-of-the-art wireless communication networks, along with traditional telephone land-lines and Voice-over-IP technology to send alerts to the Santa Clara County population. Authorized personnel from the San José OEM or the County use AlertSCC to simultaneously send voice messages to home phones and cell phones, text messages to cell phones and other text-capable wireless devices, email messages, and messages to teletypewriter (TTY) capable devices for deaf and hard of hearing individuals.

AlertSCC's primary limitation is that it can only reach a subset of the population, namely those who either actively sign up to receive emergency alerts, whose contact information has been registered in the Yellow Pages or White Pages, or who have their contact information stored in the Enhanced 911 (E-911) national database [1] or other contact databases the county may be able to acquire. The system requires opt-in by the population, and a very small percent of the population has registered to date. As of November 2017, only 3.5% of the county's population had signed up for the alert service [7]. Moreover, visitors are often not aware of the availability of the service and will likely not sign up if they are in the county for a short period of time. Transforming AlertSCC into an opt-out system (rather than opt-in) would increase the county's ability to reach its residents with alerts. However, it requires cooperation from local telecommunications companies or utility partners to compile and update contact information lists.

Another limitation of the system is its efficiency contacting residents via traditional telephone calls. While text and TTY messages can be quickly broadcast to many subscribers, voice calls take 30-60 seconds each to transmit and simultaneous transmission of voice alerts is limited by the number of available phone lines. At its limit, the system can place 61,500 simultaneous calls. In general, only a subset of these lines will be available for emergency notification, and it may take several hours to call all of the City's residents and visitors.

<u>Protocol:</u> The OEM has trained personnel that can initiate AlertSCC alerts. The alert is first validated and then a message is prepared by a communication specialist. The message may also be translated into

Spanish and other languages for dissemination via other channels. The AlertSCC alert is initiated through the OEM's Everbridge software. AlertSCC is currently used to send links in English to versions of the message in multiple languages, however, the software does not currently have imbedded language capability.

2.3 Integrated Public Alert and Warning System (IPAWS)

SB 833 underscores the need to have trained authorized personnel and backups available 24/7 that can use federal alert systems to alert the public in case of a wide-spread emergency that may lead to loss of life or property. IPAWS is the nation's alert and warning infrastructure, used to quickly provide the public with life-saving information in case of such major events. Figure 2 shows the overall IPAWS architecture. The system is managed by the Federal Emergency Management Agency (FEMA) and allows federal, state, local, tribal and territorial alerting authorities to transmit, via a single interface, alerts and warnings using the EAS, WEA, the National Warning System (NAWAS), National Oceanic and Atmospheric Administration (NOAA) Weather Radio (NWR), All-Hazards Emergency Message Collection System (HazCollect), and other public alerting systems [2].

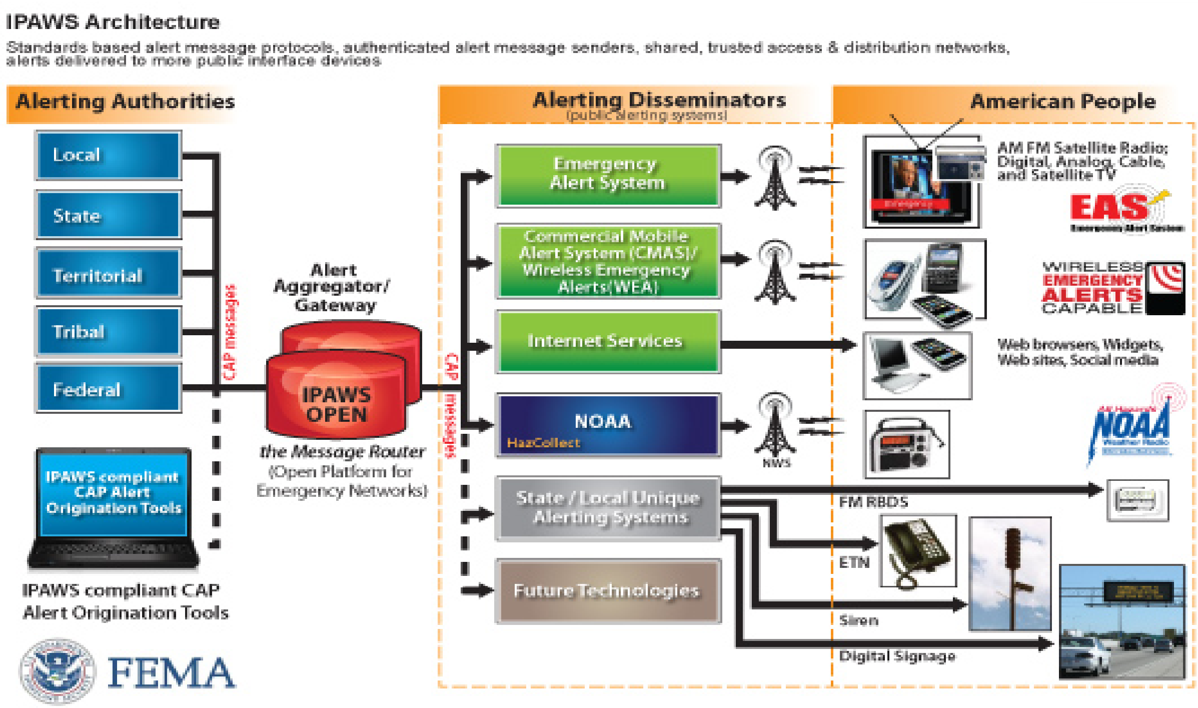

Figure 2 The IPAWS architecture [8].

2.3.1 Emergency Alert System (EAS)

The EAS is a national public warning system that requires broadcasters, cable television systems, wireless cable systems, satellite digital audio radio service (SDARS) providers, and direct broadcast satellite (DBS) suppliers to provide the President with the communications capability to address the American people within 10 minutes of a request during a national emergency. The President of the United States has sole prerogative for determining when the EAS will be activated at the national level but has delegated this authority to the director of FEMA for non-presidential alerts. FEMA is responsible for the implementation of the national-level activation of the EAS, tests, and exercises. In addition, EAS may also be used by state and local authorities, in cooperation with the broadcast community, to deliver important emergency information, such as weather information, imminent threats, AMBER, SILVER, or BLUE alerts, and local incident information targeted to specific areas.

EAS transmits emergency information quickly and automatically, even when facilities are unattended. If one link in the emergency alert system is broken, the message is transmitted via other available pathways. Emergency messages sent to EAS can support a full message (up to 160 words) text for screen crawl/display, up to 60 seconds of pre-recorded audio, and additional language translations of the message which stations may optionally display/play. EAS equipment provides a method for automatic interruption of regular programming, but the interruption only occurs once, and the message is only repeated twice before regular programming is resumed.

EAS is an ideal alerting technology for the segment of the population actively watching television or listening to radio programs. It has the potential to reach non-English speaking subsets of the City's population in their own language and achieves widespread coverage in a reasonable amount of time. However, alert transmission precision is low as messages may be forwarded and broadcast to TV sets outside the emergency notification area. Moreover, given the recent increase in the popularity of on-demand Internet-based television (e.g., Hulu, Amazon Prime Video, CBS All-Access), video (e.g., YouTube), and music (e.g., Pandora, iTunes, Amazon Music) services, many people may never watch live television or listen to a radio program and would thus not be exposed to EAS messaging. Television is however still an effective tool for disseminating information, not only for those who were watching when the initial alert was received, but also for home or business owners who might turn on the TV for alert updates and further information after an initial warning notification was received via some other means.

Protocol: The OEM uses AlertSCC to transmit local incident information to be disseminated via EAS.

2.3.2 Wireless Emergency Alert (WEA)

WEA broadcasts alerts and warnings to cell phones and other mobile devices. WEA messages look like text messages but are designed to get one's attention with unique sound and vibration patterns, both repeated twice. WEA messages are currently no more than 90 characters and must include the type and time of the alert, any action one should take, as well as the agency issuing the alert. WEA transmission is not affected by network congestion and will not disrupt texts, calls, or data sessions that are in progress.

WEA can be used to broadcast three different types of messages: (1) extreme weather alerts (e.g., tsunami, tornado, hurricane, blizzard, or flash flood warnings) and civil emergencies (riots, state of emergency, etc.), (2) AMBER/SILVER/BLUE alerts (see Section 2.3.6), and (3) presidential alerts during a state of national emergency. After May 1, 2019, WEA will add an option for sending two additional types of messages, namely WEA Test Code and Public Safety Messages. Given the prevalence of cell phones today, with 95% of US adults owning a mobile device of some kind, WEA is the go-to system for alerting when the emergency may lead to loss of life or property. Currently, more than 100 wireless carriers participate in the program and will broadcast WEA messages to their subscribers.

A current limitation of WEA, however, is that messages can only use up to 90 UTF-8 characters, restricting the amount of information that can be shared with the public and the languages that can be used to compose the message. A recent upgrade in the system now makes it possible to send a short URL along with the 90-character message, which may be used to provide additional information about the alert and message translations in different languages. Additionally, a series of upgrades in 2019 are adding Spanish language support for alerts and increasing the 90-character message limit to 360 characters [9]. However, the longer messages will only be available on Long-Term Evolution (LTE) or newer cell phones and Unicode characters used by other foreign scripts are still not supported. Another limitation of the WEA system is its inability to reach the non-cellphone carrying population, including some elderly, children, and the homeless.

Protocol: The OEM uses AlertSCC to transmit alerts via the WEA system. WEA messaging will only be initiated if the emergency may lead to loss of life or significant property damage.

2.3.3 National Warning System (NAWAS)

NAWAS is a communications system originally designed and implemented in the 1950's as a means of notifying and preparing for a nuclear attack. The system, which was never used for its intended purpose, has proven invaluable to local emergency managers responding to or coping with natural disasters. Today, NAWAS is an automated telephone system used to convey warnings to United States-based federal, state and local governments, as well as the military and civilian population. The system consists of what is essentially a 2200+ telephone party line. The phone instruments are designed to provide protection from lightning strikes, enabling their use during storms. The interconnecting lines provide some protection by avoiding local telephone switches, which ensures they are available even when the local system is down or overloaded. NAWAS has major terminals at each state Emergency Operations Center and State Emergency Management Facility. Other secondary terminals include local emergency management agencies, National Weather Service (NWS) field offices and public-safety answering points (PSAPs).

The information disseminated via NAWAS may include acts of terrorism, earthquakes, floods, hurricanes, nuclear incidents/accidents, severe thunderstorms, tornadoes, tsunamis and winter storms/blizzards. NAWAS allows the issuance of warnings to all stations nationwide or to selected stations as dictated by the situation. When NAWAS is not being used for emergency traffic/tests, State and local government personnel are encouraged to use it for official business.

Protocol: The OEM does not have control over alert dissemination via NAWAS. Alerts are initiated at the county, state, or national levels.

2.3.4 National Oceanic and Atmospheric Administration Weather Radio (NWR)

Figure 3 NWR stations in California [8]

NWR broadcasts messages via a network of radio stations with more than 1,000 transmitters covering the entire territory of the USA, including adjacent coastal waters, Puerto Rico, the U.S. Virgin Islands, and the U.S. Pacific Territories. NWR requires a special radio receiver or scanner capable of picking up the signal, which is broadcast over the VHF public service band at seven pre-defined frequencies. The receivers can automatically turn on, even when turned off, in the event an alert is detected. NWR stations in California are displayed in Figure 3.

Protocol: The OEM does not have control over alert dissemination via NWR. Alerts are initiated at the state or national levels.

2.3.5 All-Hazards Emergency Message Collection System (HazCollect)

HazCollect automatically relays non-weather emergency messages over the Internet to applications that subscribe to receive such updates, including apps, websites, email lists, text message groups, social media, etc. In order to receive messages from HazCollect, the applications must understand the IPAWS-OPEN protocol and opt-in to the service.

Protocol: The OEM does not have control over alert dissemination via HazCollect. Alerts are initiated at the county, state, or national levels.

2.3.6 AMBER/SILVER/BLUE Alerts

The National Center for Missing and Exploited Children manages America's Missing Broadcast Emergency Response (AMBER) system. AMBER was named after Amber Hagerman, a 9-year-old abducted and murdered in Arlington, Texas in 1996. An AMBER alert is declared by a law enforcement organization when it has concluded that a child has been abducted. Public information in an AMBER alert usually consists of the name and description of the abductee, a description of the suspected abductor, and a description and license plate number of the abductor's vehicle, if available. Alerts are officially distributed through commercial radio stations, Internet radio, satellite radio, television stations, and cable TV using the federal EAS and NWR systems. AMBER alerts are also issued and posted via electronic traffic-condition signs, e-mail, commercial electronic billboards, and wireless device SMS text messages. In addition, AMBER alert has teamed up with Google, Bing, and Facebook to relay information regarding an AMBER alert to an ever-growing demographic of people using Web search and social media services. Like AMBER alerts, SILVER and BLUE alerts have recently been proposed for seeking the public's help in locating missing elderly (SILVER) or when a police officer is in danger or has been shot or killed and law enforcement agents are seeking to apprehend the aggressor (BLUE).

Protocol: Distribution of AMBER, SILVER, and BLUE alerts is done via WEA and controlled by the California Highway Patrol (CHP). The OEM does not have direct access to transmitting messages via this system. In the event of an AMBER, SILVER, or BLUE emergency, the OEM would contact CHP via the 911 Dispatch.

2.4 Public Media Broadcast

Local TV and radio stations can be used to broadcast warnings and alerts prior to a disaster or emergency, and pertinent rescue information during the event. Television and radio messages may need to be recorded by OEM personnel, TV station announcers, or as an interview with a qualified OEM communication specialist. Stations may receive alerts through the EAS system and relay the information either automatically, through a set of tones and alert ticker at the bottom of the screen, or by interrupting regular programming with a news alert.

Protocol: The OEM communicates alerts to local radio and TV stations through IPAWS. Additionally, when the EOC is activated, a qualified City Emergency Public Information Officer may give interviews for local stations. Spanish and Vietnamese translations of the alerts will be sent to the local Spanish and Vietnamese media stations, respectively.

2.5 Loudspeakers

The San José OEM currently has 4 LRAD systems available for use during emergencies, 3 of which are LRAD 100X portable mobile communication devices with focused, directional broadcast up to 600 m in ideal conditions. The remaining system is a trailer-based LRAD 360XT rapidly deployable mobile mass notification system which provides 360-degree uniform sound coverage up to 850 m away. The LRAD systems are invaluable alerting tools during emergencies, especially for reaching people in the middle of the night or those who cannot be reached by other means of notification. However, the current LRAD systems are insufficient to cover at least 90% of the City area and are best used for localized small-scale emergency responses, not for overall City-wide emergency warnings.

Protocol: The OEM may deploy LRAD devices during local emergencies and evacuation scenarios. Two additional 100X portable devices are owned by the Police department but can be used by the OEM when needed. OEM personnel or police officers may be dispatched with LRAD units in the field.

2.6 Sirens and Public Address Systems

Sirens can be used to get the population’s attention, alert them of an impending emergency and potentially direct them to an alternate channel for additional information. For sirens to be an effective tool, the population must be trained to understand the code/tone of the siren and take action when it is activated. In addition to producing tonal-based alerts, broadcast sirens can also play back a short pre-recorded audio message that may direct the population to sources for additional information.

Protocol: The City does not currently have any deployed sirens in the City of San José.

2.7 Disaster Service Worker Volunteers

The OEM enlists the help of a dedicated network of volunteers to support preparedness activities and augment emergency response. These include:

- San José Radio Amateur Civil Emergency Services (RACES)
- San José Community Emergency Response Team (CERT)

In the event of an emergency, RACES operators can help transmit alerts and coordinate communication with emergency responders if other communication channels are not available. The alerting capabilities for this notification channel is limited to people that have and are actively using citizen's band (CB) or amateur radios. Transmission of messages using amateur radios may take several minutes, as most radios have a transmission range of 1-5 miles without the use of repeaters, which means messages may need to be relayed multiple times to reach someone on the outskirts of the City.

Protocol: The OEM activates volunteer support as necessary when the EOC is activated. EOC personnel directs volunteers to facilitate communication or assist with in-person notifications.

2.8 In-Person Notifications

For those segments of the population that may not be able to be reached via other channels, the OEM partners with volunteers and emergency responders ("boots-on-the-ground", e.g., Police, Fire) to knock on doors and inform people of impending danger and the actions they should take in response. While this channel is slow and ineffective for quickly alerting a large percentage of the population, it is crucial for reaching at-risk elements of the population, such as the homeless and the elderly, or when addressing quickly changing situations.

Protocol: The OEM uses in-person notifications when other notification channels may not be available or appropriate, often when the EOC is activated. In-person notifications are especially needed to reach the homeless and other vulnerable segments of the population in San José. The OEM deploys both Police patrols and disaster service worker volunteers to sequentially cover the areas of the City in need of alerting.

2.9 Emergency Notification for the Blind, Deaf, and Visually- or Hearing-Impaired

The San José OEM makes a concerted effort to reach the blind, deaf, and visually- or hearing-impaired segment of the City's population. The variety of channels used to simultaneously transmit alerts ensures people will receive some alerts in a means they can understand. For example, TTY devices can display alerts on a screen and cell phone-based alerts are preceded by a special haptic/vibration pattern in addition to auditory tones. Additionally, visually-impaired people can use cell phones and personal computers to read text messages via text-to-voice software or can be reached through voice calls. However, the number of channels that can be used to reach this sub-segment of the population is limited. For example, deaf people may not hear sirens or public safety announcements, and blind people may not see an alert on a message board. To maximize the probability that they receive timely alerts, visually- and hearing-impaired people should be encouraged to sign up for AlertSCC alerts and register available cell phones and TTY devices.

Part 3: Findings and Recommendations

Upon analyzing the San José emergency response architecture and processes, after a comparison with available and upcoming alert technologies across the globe, we note that the current OEM processes and systems are well designed in general, but contain several limitations. We will first discuss those limitations and then provide recommendations for improving the mass warning system and processes in both the short-term (1-2 years) and the long-term (5-10 years).

3.1 General Limitations of the San José Alert Infrastructure

3.1.1 Limited Efficiency and Effectiveness Evaluation Capabilities

Most alert channels used by the San José OEM do not currently capture alert transmission success rates. Currently, only recipients of Everbridge text, email, and phone call messages may acknowledge receipt. When Everbridge receives this confirmation, it has the capability to stop transmitting additional duplicate alerts to the recipient via other Everbridge controlled channels. However, radio, television, EAS, WEA, and weather radio broadcasts are inherently one-way, and broadcast reception coverage cannot be easily measured. Moreover, there are no mechanism in place for these one-way methods to have end-to-end systems testing that can reliably capture transmission efficiency (speed) and effectiveness (reachability success rate) metrics.

3.1.2 Limited Coverage of Traditional Alert Devices (LRAD, sirens)

For some segments of the population, or during emergencies with extended wide-scale loss of power, the best means of alert may be traditional approaches, such as acoustic devices (LRAD) and sirens. San José lacks permanent acoustic devices, such as sirens, that cover the surface area of the City, and the OEM office does not have enough LRAD units to transmit messages across the entire City.

3.1.3 Limited Support for Non-English Speakers

Most current systems only allow use of English or Spanish characters in messages, yet the 2010 U.S. census indicated that 34.8% of San José residents are Asian [10]. Across the Bay Area, 7.3% of the residents speak Chinese at home, 6.5% Vietnamese, and 3.2% Tagalog [11]. Some of these residents may not speak or read English and require alerts in their primary language.

3.1.4 Alert Prioritization and Systems Integration

Current alert systems transmit messages following lists of residents that are not coordinated between alert systems. For example, John Doe may receive an SMS denoting the emergency, and a minute later may also receive a phone call and an email. Jane Doe may not be notified until several minutes later, even though John Doe has already received three alert notifications. Internally, Everbridge has the capability to coordinate message transmission to individuals via the different channels it manages. However, contact information must be disambiguated among multiple lists to ensure different contact details are associated with the correct persons/entities. Moreover, Everbridge cannot currently integrate external message-receipt feedback into the priority scheme. For example, if John Doe hears an alert in progress via radio and confirms message receipt via a tweet or text message, we may consider that he has successfully received the alert. In this case, it would be beneficial to lower messaging priority for John Doe and focus on notifying the other residents we have not yet reached.

3.1.5 Manual Alert Initiation and Transmission

The City of San Jose first response organizations and the OEM Duty Officer follow a set of proscribed protocols for alerting the public. Following these protocols, decisions are made at the appropriate level depending on the circumstances regarding life safety or impacts on the community. On-scene response agencies or members of the public routinely initiate communications related to perceived emergency events in the community by contacting the 9-1-1 Dispatch Center. Once contacted, the Dispatcher may contact the OEM Duty Officer with a request to activate the Emergency Operations Center and to initiate crisis communications protocols. This process is recognized for its applicability since Incident Commanders are charged with immediate life safety decision making. In evolving events this process routinely engages leadership at several levels and can protract initiation of messages to the public by any amount of time deemed appropriate. This manual validation process may take from minutes to hours, delaying public notification.

3.1.6 Lack of Support for IoT Sensor Networks

Real-time sensor data may be used to gauge the severity of an on-going emergency and even predict with some level of certainty when an emergency may occur. For example, data from depth and volume sensors along river beds may be used to develop prediction models for when a river would crest and lead to flooding. Air quality sensors throughout the City could detect the spread of a smoke plume resulting from an oil tanker derailment or the presence of some pathogens released as part of a biological terrorism incident. Earthquake detection sensors throughout the West Coast may be used to predict earthquakes before they arrive. When the prediction level of certainty is high enough and the time to the predicted emergency incident is short, algorithms could then be used to trigger automatic alerts using pre-defined message templates augmented with details specific to the predicted incident. While current systems (e.g., Everbridge) do have limited capabilities to integrate input from external sensors and alert triggering based on automatic analytics from those data, no such sensors or analytics are currently being used by the San José OEM. This denotes a missed opportunity to make earlier informed decisions based on real-time situational awareness rather than second-hand reports.

3.2 Short-Term Alert System Improvement Recommendations

Given the limitations of AlertSCC and IPAWS-related alert mechanism detailed in Section 2, the OEM could consider complementing these systems with City-wide direct field-based alerting.

Recommendations:

3.2.1 Infrastructure Development

- ➔ <u>Acquire and Use Tonal Alerting Devices</u>. The City may consider installing broadcast sirens with audio transmission capabilities throughout the entire City. These sirens transmit an alert tone followed by a recorded audio message that may be easier to understand by the residents. The City could execute a study to identify the optimal placement of sirens in the City, given the hilly terrain, so that siren-based alerts can be heard by all residents. Existing decommissioned civil defense towers, which the City currently owns, may be used as a subset of the siren locations in the alert network.
- ➔ <u>Acquire Additional Long-Range Acoustic Devices</u>. The City may consider purchasing additional portable LRADs to improve potential coverage to at least 30% of the City area. Employees and

volunteer teams could be trained to use and be equipped with portable LRAD devices when they are sent in the field during an emergency.

3.2.2 Protocol Implementation and Testing

- ➔ Implement Scenario-Based Emergency Response Protocols. Although the federal National Incident Management System (NIMS), the state Standardized Emergency Management System (SEMS), and the field Incident Command System (ICS) all establish standardized protocols related to response, additional steps could be taken to develop standardized operating procedures (SOPs) for public notification in the event once of the 6 scenarios occurs. Understanding that resources may be impacted or not exist at the time of the emergency, the OEM could develop pre-defined alert message templates in multiple languages (at the minimum, in English, Spanish, Chinese, Vietnamese, and Tagalog), and pre-defined alert sequences and priorities in Everbridge, for example. To be most effective during an emergency, protocols must be specific and include detailed information for each step and for each functional group involved in the response.
- ➔ Test Scenario-Based Emergency Response. The City needs to plan and execute tests of the pre-defined protocols and EOC activations to ensure smooth operation and staff awareness of protocols and of their responsibilities during an emergency. Tests need to be repeated at regular intervals.

3.2.3 Public Education and Outreach

- ➔ Educate the Public About Emergency Alerts and Response. The public needs to be trained on emergency procedures, the significance of alerts received via cell phones, SMS, voice calls, or sirens, and how to respond to alerts. Sufficient public education is needed to overcome their initial complacency and take immediate action when so instructed by the San José Public Information Officers. The OEM currently organizes a number of public education events throughout the year. It may consider developing new ways to reach out to and educate residents. For example, they may partner with area schools and offer to give talks at assemblies or ask local movie theaters to include 30 second PSAs before certain movies (especially theme-appropriate movies, such as “disaster movie” block-busters). They may also consider partnering with technology and social media companies (e.g., Facebook, Google, Twitter) to leverage their extensive advertising expertise for the purpose of targeting specific segments of the population with PSAs specifically designed for them.
- ➔ Measure Public Education Effectiveness. The OEM must regularly survey a representative sample of the San José residents to determine the effectiveness of their education efforts. The survey must ascertain the percent of the population that is aware of how they may receive emergency alerts and, in general, what they should do in response to an emergency.

3.3 Long-Term Alert System Improvement Recommendations

A major limitation of the current City of San José mass warning system is its lack of connectivity with and support for state-of-art IoT sensor networks and corresponding system infrastructures. Ray et al. [12] survey the state-of-the-art of IoT system use in disaster management and future trends in the space. They note that the use of IoT technology, coupled with advanced analytics, holds great promise in improving our ability to provide early disaster warning in various scenarios. As an example, Figure 5 shows several examples where IoT sensors could be used to improve flood-related monitoring and alerting. Sensors installed at the edge of retention ponds and in drainage canals can provide a data stream which can be analyzed via Machine Learning techniques to predict when flooding may occur.

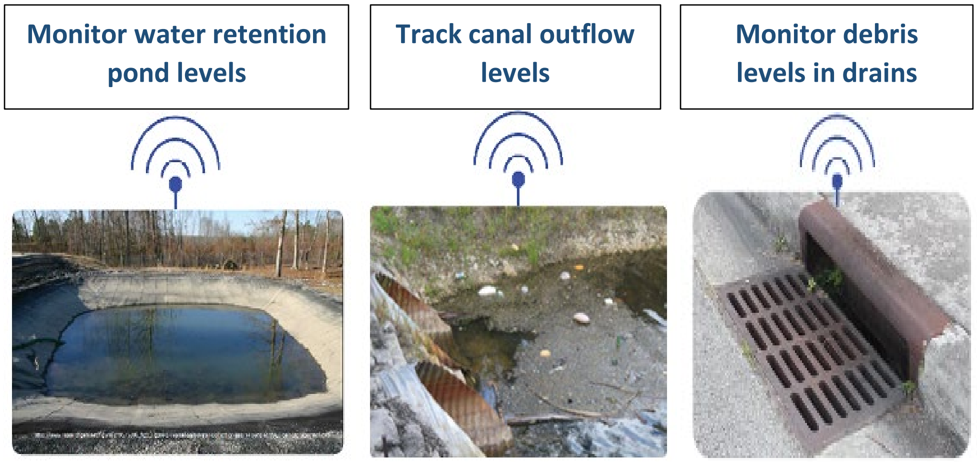

Figure 4 Example IoT sensors for flood monitoring

In most cases, the City may be able to partner with other agencies that have direct access to and responsibility over the systems being monitored (e.g., the SCVWD for monitoring dams). Agreements could be defined that would provide the OEM with automatic alerting from IoT devices and, if possible, raw sensor data which can be used to develop independent analyses and prediction models.

The City of San José has started a number of pilot IoT development projects centered around transportation management, community Internet access, smart waste management, and environmental monitoring. For example, the City currently has cameras and other traffic-related sensors at 950 signaled intersections. The sensor data may be useful for emergency-related analyses that they were not originally intended for. For example, computer vision algorithms can be used to detect traffic congestion, accidents, or flooded roadways by analyzing the raw video feed [13, 14]. If some IoT pilot programs prove useful, the City may consider scaling and multiplying these programs to provide overall coverage of San José.

Recommendations:

3.3.1 Smart Emergency Warning System Infrastructure

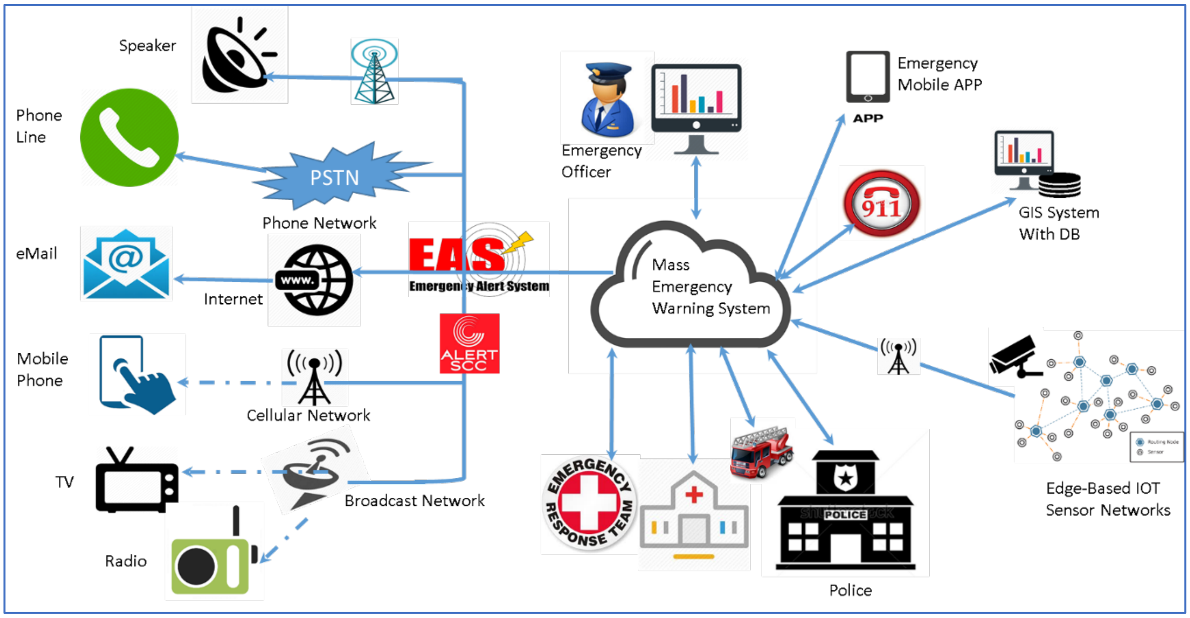

Figure 5 Smart emergency warning system infrastructure for San José

➔ Develop an Integrated Emergency Warning System Infrastructure. Figure 5 presents a proposed smart emergency warning system infrastructure for the City of San José. It extends existing integrated mass warning systems (such as IPAWS and AlertSCC) to support various functions, including integrated communication with all stakeholders and the public via diverse channels and automatic response based on edge-based IoT sensor network data analytics. The system must be cloud-based to ensure resiliency to local destructive events and connected to the OEM and other stakeholders via multiple redundant communication networks. The system aggregates emergency related data from sensors, first responders, and the public and disseminates curated information via a smart emergency mobile app, a smart emergency dashboard, and various alert systems discussed in Part 2.

➔ Institute Comprehensive Alert Dissemination Efficiency and Effectiveness Tracking. A smart emergency warning system infrastructure would allow better integration of alert dissemination and population response, which would help both with prioritizing alert messaging and measuring the efficiency and effectiveness of transmissions. A representative sample of recruited volunteers from all areas of San José could participate in regular emergency alert system validation and testing. During a test, they would record the exact time (e.g., via an app) when they first received and acknowledged the alert and send the information back to the OEM for analysis. Goals could be set for continuous improvement of alert and notification delivery until at least 90% of the population can be reached within 10 minutes of the alert initiation.

3.3.2 Emergency Support Teams

➔ Further Develop Support Team Capabilities. As new technologies and capabilities are added to the San José emergency warning system infrastructure, appropriate personnel must be added to develop and support these resources. For example, as exemplified in Figure 6, an emergency monitoring team may be responsible for maintaining IoT sensors and ensuring accurate data capture and storage, while an emergency analysis and forecasting team may use Machine Learning to develop prediction models for potential disasters or develop data-driven strategies for improving alert notifications and reducing evacuation times. The added personnel complement existing members who focus their efforts on emergency process development, planning, warning, response, and recovery.

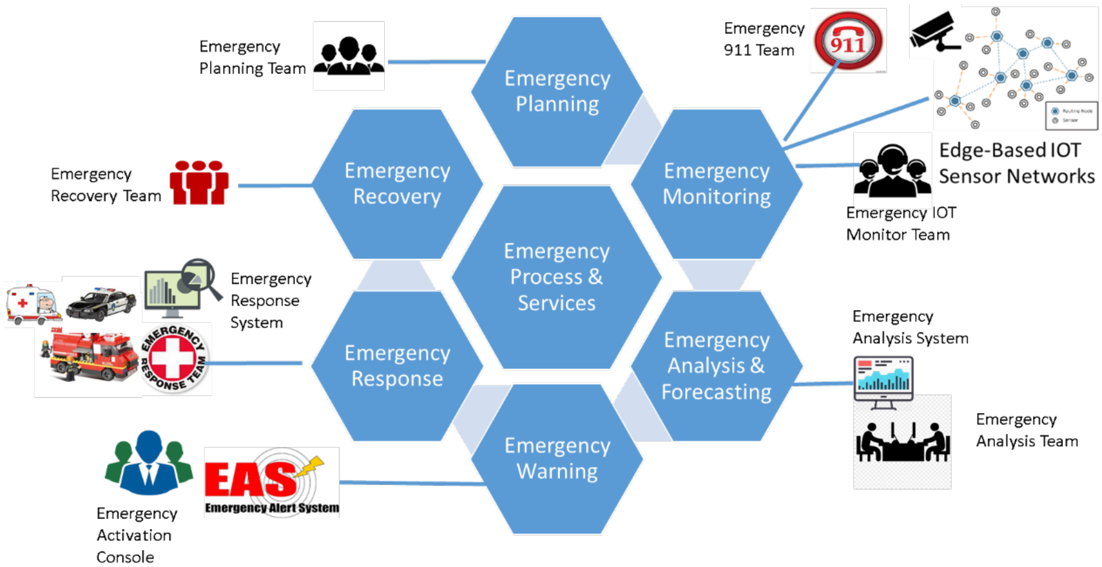

Figure 6 Necessary support teams for emergency response

3.3.3 Agreements and Technology Integration with Relevant Agencies

➔ Develop Data Sharing Agreements with Relevant Agencies. Agreements may be obtained to allow the OEM to receive automatic alerts and sensor data feeds from other agencies when those sensors may help prevent or mitigate emergences. Examples include dam and water retention pond sensor data, highway camera and inductive loop detector feeds, and data from railroad scanners.

3.3.4 Technology Investment: Internet-of-Things and Cloud-Based Analytics

➔ Identify and Deploy IoT Sensors for Emergency Monitoring and Management. Sensors and IoT can help improve emergency response times and potentially save lives by drastically reducing the time between the onset of the emergency and public notification. The City could develop a comprehensive long-term strategy for incorporating these technologies in emergency notifications. Additionally, it could consider using IoT technologies for emergency management. For example, drones equipped with IoT sensors can be used to assess damage, locate people in danger, deliver life-saving equipment, etc.

- Develop an OEM Data Science Team. The multitude of data available from sensors and notification systems must be carefully analyzed to develop and improve prediction models, automatic notification algorithms, and overall emergency response efficiency and effectiveness testing. While some prediction models may be available from state or federal agencies (e.g., weather predictions), local models could be developed that utilize additional IoT sensor data and optimize local prediction accuracy. When local model effectiveness consistently exceeds that of other agencies, they may be relied on in automatic or manual alert decisions. The City would need to hire appropriate personnel to fill this void.

3.3.5 Smart Emergency Dashboard and Mobile App

- Develop an Integrated Emergency Management Dashboard. The City may investigate developing a Web-based dashboard application that would integrate alerts, response coordination, and status information, both for emergency responders and the public. In the course of an emergency, responders and the public alike would not have to hunt down information in multiple places or miss communications that were sent via a different channel than the one checked. Given proper training, both responders and the community could turn to the dashboard for a coordinated response strategy as soon as an emergency was declared.
- Develop an Integrated Emergency Management Mobile App. Given the prevalence of smart phones in today's society, a mobile app could be developed that would provide similar functionality as the dashboard. Figure 7 shows an example of the services that such an app could provide. The functionality could be included in the recently released *My San José* app, which allows residents a convenient way to request City services [15]. The dashboard and app could have pre-defined scenario-based emergency procedures, including message templates in multiple local languages [16, 17], that can be quickly activated or looked up in the event one of the scenarios develops.

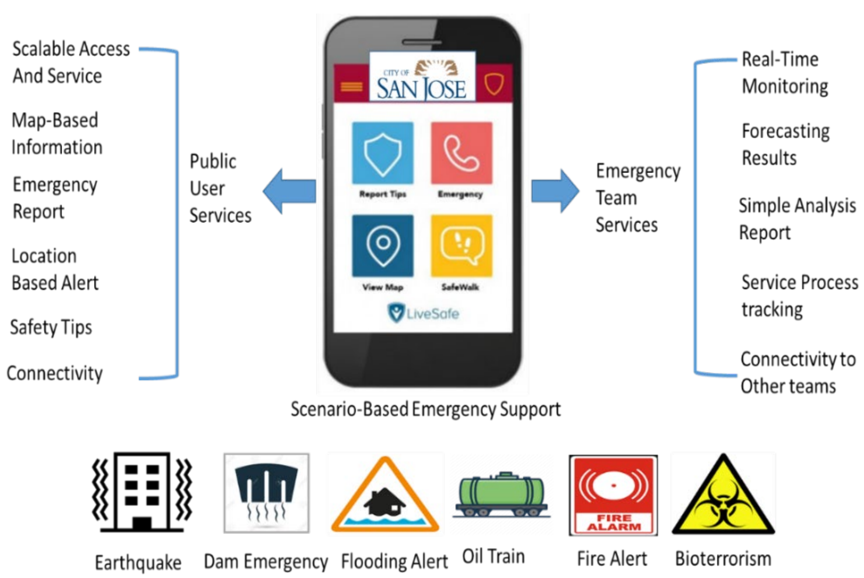

Figure 7 Smart emergency mobile app for San Jose

Part 4: Scenario Communication Protocols

Table 2 details the current OEM communication protocols for the 6 identified scenarios of interest. The "How OEM Staff Notified" column indicates the process by which the San José OEM is alerted that an incident has occurred. The "Affected Public" column denotes the potential number of people that may be affected and damages that may be incurred during the scenario. Finally, the "How Public Notified" column notes alert channels that may be used to notify the population during and after the event.

Table 2: Current Notification Paths for the Considered Scenarios

Scenario	How OEM Staff Notified	Affected Public	How Public Notified
Anderson Dam Failure at Full Capacity	SCVWD → 911 Dispatch → CAD Page to OEM Duty Officer	300K residents $30 billion loss	AlertSCC, social media, LRAD, sirens / PA systems
No Notice Oil Train Derailment in Central San José	Union Pacific → 911 Dispatch → CAD Page to OEM Duty Officer	Immediate evac. of 1M 20-minute evac. of 3M	AlertSCC, WEA, social media, news, LRAD, sirens / PA systems, in-person notifications
Gradual Onset Severe Weather Forecast with Expected 100-Year Flooding	National Weather Conference call 72+ hours in advance	250K residents 30K businesses	AlertSCC, WEA (if imminent threat to life or safety), NWR, in-person notifications
Delayed Onset and No-Notice Biological Terrorism Incident	Hospitals → County Public Health → OEM; Social Media; Fire Dispatch increased call volume → OEM	1M residents 60K businesses	AlertSCC, WEA, social media, news, LRAD, PA Systems
Severe Earthquake	Berkeley Seismological Lab → OEM; Magnitude 6.5+ earthquake triggers full EOC activation	$16B loss for 100y event $41B loss for 500y event	Self-notified, AlertSCC, WEA, social media, news, Sirens / PA Systems
Complex Coordinated Terrorism Attack	Police Command Center or 911 Dispatch → CAD Page to OEM Duty Officer; Social Media; News	Variable, depending on population density of targeted area	AlertSCC, WEA, News, Social Media, Sirens / PA Systems

4.1 Anderson Dam Failure at Full Capacity

Many large dams integrate sensor systems and Machine Learning prediction models in their dam monitoring systems. For example, the Enguri Dam is the second highest concrete arch hydroelectric dam in the world. It once provided more than 40% of the electricity needs for the entire country of Georgia, a small Eurasian nation at the intersection of Eastern Europe and Western Asia. Georgia uses DAMWATCH, a real-time telemetric monitoring system of dams that integrates sensor data and predictions for all the country's dams, which account for 92% of its overall internal energy production.

The Puerto Rico Automated Dam Data Acquisition and Alarm Reporting System (ADDAARS) [18] provides tools to monitor conditions of Puerto Rico dams and reservoirs in real-time. Data can be transmitted via both satellite and radio to ensure communication redundancy. The system aggregates information from a multitude of sensors, including water level sensors, radar-based sensors, submersible pressure gauges, pluviometers, rain gauges, and others. Data is gathered every 5 minutes, stored in a database, and can be visualized in real-time by operators.

Artificial Intelligence (AI) or Machine Learning can be used to predict the water level of a dam and trigger an alert if the level passes a pre-defined threshold [19]. While these types of tools may reside with the dam owners or the SCVWD, it would be beneficial to receive real-time sensor feeds from nearby dams that may cause disasters in San José. The OEM can then monitor these feeds via AI-based algorithms and initiate preparedness for emergency response even prior to receiving a call from SCVWD.

Table 3 provides a list of recommended alert channels to consider for use during an Anderson Dam failure at full capacity. The failure would lead to heavy flooding in a large portion of San José within hours of the event. The OEM must use all available notification channels to coordinate the swift evacuation of potentially affected areas of the City.

Table 3: Recommended Notifications for Anderson Dam Failure at Full Capacity

Dissemination Channels	Speed (minutes)[1]	Coverage[1]	Concentration[1]	Comments
Wireless emergency alerts (WEA)	< 10	Widespread	Dispersed	
Wireless communications (SMS)	< 10	Widespread	Dispersed	
Dedicated tone alert radios	< 10	Limited	Concentrated	
Text telephone (TDD/TTY)	10-30	Widespread	Dispersed	
Internet apps	10-30	Widespread	Dispersed	
Social media	10-30	Widespread	Dispersed	
Reverse telephone distribution systems	10-30	Limited	Dispersed	
Loudspeakers and public address (PA) systems	10-30	Limited	Concentrated	In evacuation area.
Audio sirens and alarms	10-30	Limited	Concentrated	In evacuation area.
Broadcast sirens	10-30	Limited	Concentrated	In evacuation area.
Message boards	10-30	Limited	Concentrated	
Radio	30-60	Widespread	Dispersed	
Television broadcast	30-60	Widespread	Dispersed	
Television message scrolls	30-60	Widespread	Dispersed	
In-person notification	> 60	Limited	Concentrated	If safe to patrol. Use boats.

1. *Attribute definitions can be found in Table 1.*

4.2 No-Notice Oil Train Derailment in Central San José

Large quantities of oil pass through the country each year by ship, pipeline, rail, and roadway. Beyond its role in refineries for gasoline production, many companies use oil in manufacturing processes. Accidents, human mistakes, and equipment failure can all lead to disastrous consequences. It is thus necessary to monitor oil transports and be able to send out mass warning alerts in the event of an unforeseen spill.

The Federal Railroad Administration (FRA) has jurisdiction over railroad safety. The FRA has about 500 federal inspectors throughout the country along with 180 state railroad safety inspectors. The FRA uses past incident data to determine where its inspection activity should be targeted. Rail incidents are investigated by the National Transportation Safety Board (NTSB), an independent federal agency. The NTSB makes recommendations for preventing future incidents based on its findings. After the Lac-Mégantic derailment in Canada, the FRA initiated a comprehensive review of safety requirements [20].

They observed that three areas required attention – tank car design, prevention of derailments, and railroad operations. Preventing these types of accidents thus must involve a coordinated effort between federal agencies regulating rail car manufacturing and transportation authorities at all levels of government that regulate their operation on California railways.

Table 4 provides a list of recommended alert channels to consider for use during a no-notice oil train derailment in central San José. When a rail incident results in an oil spill, the state, territorial, or local officials are typically the first government representatives who are informed about the situation. Depending on the severity of the accident (e.g., based on the number of train cars that rupture and the amount of oil they carried), the City may need to evacuate everyone in 1-mile radius of the accident site within 10 minutes, including 35,000 students, faculty, and staff at San José State University. A wider area covering the entire City may need to be subsequently evacuated within 1 hour. All available notification channels should be used to expedite the City's evacuation.

Table 4: Recommended Notifications for No-Notice Oil Train Derailment in Central San José

Dissemination Channels	Speed (minutes)[1]	Coverage[1]	Concentration[1]	Comments
Dedicated tone alert radios	< 10	Limited	Concentrated	
Wireless emergency alerts (WEA)	< 10	Widespread	Dispersed	
Wireless communications (SMS)	< 10	Widespread	Dispersed	
Loudspeakers and public address (PA) systems	10-30	Limited	Concentrated	In evacuation area.
Audio sirens and alarms	10-30	Limited	Concentrated	In evacuation area.
Broadcast sirens	10-30	Limited	Concentrated	In evacuation area.
Message boards	10-30	Limited	Concentrated	
Reverse telephone distribution systems	10-30	Limited	Dispersed	
Text telephone (TDD/TTY)	10-30	Widespread	Dispersed	
Internet apps	10-30	Widespread	Dispersed	
Social media	10-30	Widespread	Dispersed	
Radio	30-60	Widespread	Dispersed	
Television broadcast	30-60	Widespread	Dispersed	
Television message scrolls	30-60	Widespread	Dispersed	
In-person notification	> 60	Limited	Concentrated	If safe to patrol.

1. *Attribute definitions can be found in Table 1.*

4.3 Gradual Onset Severe Weather Forecast with Expected 100-Year Flooding

Much research has been conducted towards developing IoT devices that can automatically detect flooding and alert appropriate parties. For example, a flash-flood alert system was designed that can automatically detect flooding conditions and transmit alerts to downstream towns via SMS messaging [21]. A Neural Network-based Machine Learning model was developed that can be used to accurately predict flooding 3 hours before it happens [22]. Moreover, cloud-based systems can be used to monitor water levels and provide real-time flood information and predictive analytics to monitoring personnel.

Table 5 provides a list of recommended alert channels to consider for use during a gradual onset severe weather forecast with expected 100-year flooding. WEA and auditory alert channels should be employed once an evacuation is deemed necessary. Prior to that, other channels may be used to inform the residents of current weather conditions and the possibility of necessary evacuations.

Table 5: Recommended Notifications for Gradual Onset Severe Weather Forecast with Expected 100-Year Flooding

Dissemination Channels	Speed (minutes)[1]	Coverage[1]	Concentration[1]	Comments
Wireless emergency alerts (WEA)	< 10	Widespread	Dispersed	If evacuation is necessary.
Wireless communications (SMS)	< 10	Widespread	Dispersed	
Dedicated tone alert radios	< 10	Limited	Concentrated	In evacuation area.
Loudspeakers and public address (PA) systems	10-30	Limited	Concentrated	In evacuation area.
Audio sirens and alarms	10-30	Limited	Concentrated	In evacuation area.
Broadcast sirens	10-30	Limited	Concentrated	In evacuation area.
Message boards	10-30	Limited	Concentrated	In evacuation area.
Reverse telephone distribution systems	10-30	Limited	Dispersed	
Tone alert and NOAA weather radio	10-30	Widespread	Dispersed	
Text telephone (TDD/TTY)	10-30	Widespread	Dispersed	
Internet apps	10-30	Widespread	Dispersed	
Social media	10-30	Widespread	Dispersed	
Radio	30-60	Widespread	Dispersed	
Television broadcast	30-60	Widespread	Dispersed	
Television message scrolls	30-60	Widespread	Dispersed	
In-person notification	> 60	Limited	Concentrated	

1. *Attribute definitions can be found in Table 1.*

4.4 Delayed Onset and No-Notice Biological Terrorism Incident

Biological terrorism prediction is beyond the prevue of the City of San José. The OEM may be alerted of likely incidents by federal or state agencies that are focused on this task. Alternatively, the OEM will be alerted by 911 Dispatch, social media, or though other channels that an incident has already occurred or is in progress. To properly respond to these types of incidents, the City or Santa Clara County need to create an anti-bioterrorism team, a point of contact for bio-terrorism related events, and an alternate/backup point of contact. The name and emergency contact information of the designated points of contact need to be made available to all public and private organizations: hotels, offices, schools, residential communities and hospitals. Studying responses to previous biological terrorism incidents around the world, such as the 1984 Salmonella Typhimurium virus attack in the Dales, Oregon [23], the 1995 Tokyo subway sarin attacks [24, 25], or the post 9/11 2001 U.S. Anthrax attacks [26, 27] may provide invaluable lessons for biological terrorism response preparedness.

Once an attack has commenced, the OEM must immediately activate the EOC and coordinate response with Police, Fire, the Federal Bureau of Investigations (FBI), the Center for Disease Control (CDC), and area hospitals. Table 6 provides a list of recommended alert channels to consider for use during a biological terrorism incident. Residents must be given clear information on quarantine procedures, signs of infection, and recommended action (e.g., shelter in place).

Table 6: Recommended Notifications for Delayed Onset and No-Notice Biological Terrorism Incident

Dissemination Channels	Speed (minutes)[1]	Coverage[1]	Concentration[1]	Comments
Wireless emergency alerts (WEA)	< 10	Widespread	Dispersed	
Wireless communications (SMS)	< 10	Widespread	Dispersed	
Dedicated tone alert radios	< 10	Limited	Concentrated	
Text telephone (TDD/TTY)	10-30	Widespread	Dispersed	
Internet apps	10-30	Widespread	Dispersed	
Social media	10-30	Widespread	Dispersed	
Reverse telephone distribution systems	10-30	Limited	Dispersed	
Loudspeakers and public address (PA) systems	10-30	Limited	Concentrated	Provide response information.
Audio sirens and alarms	10-30	Limited	Concentrated	
Broadcast sirens	10-30	Limited	Concentrated	
Message boards	10-30	Limited	Concentrated	
Radio	30-60	Widespread	Dispersed	
Television broadcast	30-60	Widespread	Dispersed	
Television message scrolls	30-60	Widespread	Dispersed	
In-person notification	> 60	Limited	Concentrated	If safe to patrol.

1. *Attribute definitions can be found in Table 1.*

4.5 Severe Earthquake

There are 7 significant fault zones in the Bay Area that can produce emergency incidents in San José: San Andreas, Calaveras, Concord-Green Valley, Greenville, Hayward, Rodgers Creek, and San Gregorio. In 2007, the United States Geological Society (USGS) and other agencies warned that the probability of a 6.7+ magnitude earthquake in the Bay Area likely to occur in the next 30 years was estimated to be at least 63%. Both the Hayward-Rogers Creek (31%) and the San Andreas (21%) Faults have non-negligible chances of developing a damage-producing earthquake during this time [28]. An updated model in 2014 puts the overall 30-year likelihood of a Bay Area 6.7+ earthquake at 72% [29]. Therefore, it is crucial that the City have emergency alert and response procedures in place for earthquake-related emergencies.

The current processes followed by the OEM are focused on dealing with the effects of the earthquake once shaking has stopped. A large enough earthquake will automatically trigger the activation of the EOC, and emergency-related communications will advise residents to move away from unsafe structures and head towards emergency shelters.

ShakeAlert [30] is a system being designed by USGS, along with University of California at Berkeley and other partner organizations, as an earthquake early warning system for the United States. The system is intended to reduce the impact that earthquakes have on the population and save lives by providing automatic advance warning through mass public notification technologies. In the event of an earthquake, heavy equipment, like trains, elevators, and cranes, can be automatically stopped in safe positions. People can quickly find a safe covered position, drop to the ground, and hold on while the earthquake passes. Similar active automatic earthquake early warning systems are already operational in Mexico, Japan, Taiwan, Turkey, Romania, and other countries [31].

Earthquake detection systems work by detecting earthquake primary waves (P-waves), which travel much faster than the much more destructive sheer waves (S-waves) that follow them from the earthquake epicenter [32]. The farther the epicenter is located, the more lead time exists between the P-waves and the imminent S-waves. If the epicenter is more than 100 km away, the lead time may be 50-100 seconds, which may translate into 20-50 seconds of warning after allowing time for detection and automatic warning transmission.

The area located within 100 km radius of the earthquake epicenter is known as the *blind zone*, because it is too close to the epicenter to receive any meaningful warnings. However, inexpensive detectors can be locally installed in factories and schools that can provide a 5-10 second lead-time before the shaking starts [33], which can be enough time to move away from dangerous equipment, drop, and take cover. Moreover, ongoing research and development of fast transmission and broadcast technologies promises to reduce the time from detection to alert to less than a second [30, 34].

ShakeAlert has not been fully integrated with mass notification systems like IPAWS and WEA due to concerns that alerts would not be able to be delivered in time to all residents and due to worry of the system triggering false alert notifications that may lead to alert notification fatigue (people may not pay attention to a real alert in the future if they received several false alerts in the past). However, recent proposed changes in the WEA delivery protocols will bypass this obstacle, allowing full ShakeAlert integration as soon as wireless companies implement the changes [9, 30]. In the meantime, some private companies such as BART and Pacific Gas and Electric Company (PG&E) are already integrating automatic earthquake early warning into their emergency management [35].

We recommend that the San José OEM prepare for swift adoption of ShakeAlert automatic alert forwarding as soon as the system is fully operational. In the meantime, the OEM must begin the process of identifying public utilities and systems that may benefit from automatic earthquake advanced warning, such as Light Rail trains, natural gas distribution pipelines, and water processing facilities. The OEM could provide support for and encourage the owners of these utilities to install automatic response systems that can help mitigate disasters when very big earthquakes are detected.

Since ShakeAlert may only provide enough advance warning for earthquakes originating at least 100 km away from San José, it is important that automatic earthquake mass warning be complemented with local systems installed at key locations in the City. These IoT systems can rely both on local sensors (e.g., accelerometer), and on feedback from similar systems installed in other sections of the building or in nearby buildings. The larger the size of the IoT mesh sensor network and of the covered surface area are, the higher the accuracy of the overall system detections will be, which would allow it to respond to lower magnitude earthquakes while avoiding false alerts. Following the example of Los Angeles, whose City Hall was the first building to be equipped with earthquake early warning in October 2018, the San José OEM could coordinate efforts to equip public buildings with similar systems. Lessons learned from these efforts can be used in training the public, in equipping other public spaces and schools with similar local earthquake alert systems, and in developing future City Ordinances that may require the technology in certain buildings.

Finally, once an automatic earthquake early warning system is implemented, the San José OEM must develop public training programs to acquaint the population with the types of messages they may receive from the system and the actions they should take in response. Like the Great California Shakeout, which has been a yearly tradition since 2008, the OEM PSAs must provide concrete steps to follow and instill in the population a sense of urgency when earthquake-related alerts are received that may save their lives.

Table 7 provides a list of recommended alert channels to consider for use during a severe earthquake event. If possible, automatic alerts should be sent from ShakeAlert via WEA and SMS to the entire affected region, urging residents to stop, drop, cover, and hold on. Heavy-duty machinery should be stopped, and workers should quickly move away from them to find cover. Trains, planes on the ground, and busses should safely come to a complete stop and passengers should bend down in their seats and cover their heads or drop to the floor and hold on. After the earthquake subsides, alert channels need to be used to inform residents of potential aftershocks, ways to check whether their residence is safe to inhabit, potential evacuation orders, and the location of available shelters for those in need of help.

Table 7: Recommended Notifications for Severe Earthquake

Dissemination Channels	Speed (minutes)[1]	Coverage[1]	Concentration[1]	Comments
Wireless emergency alerts (WEA)	< 10	Widespread	Dispersed	
Wireless communications (SMS)	< 10	Widespread	Dispersed	
Tone alert and NOAA weather radio	10-30	Widespread	Dispersed	Provide response information.
Text telephone (TDD/TTY)	10-30	Widespread	Dispersed	Provide response information.
Internet apps	10-30	Widespread	Dispersed	Provide response information.
Social media	10-30	Widespread	Dispersed	Provide response information.
Message boards	10-30	Limited	Concentrated	Provide response information.
Radio	30-60	Widespread	Dispersed	Provide response information.
Television broadcast	30-60	Widespread	Dispersed	Provide response information.
Television message scrolls	30-60	Widespread	Dispersed	Provide response information.

1. *Attribute definitions can be found in Table 1.*

4.6 Complex Coordinated Terrorism Attack

A great deal of research is being conducted to identify potential terrorist activities prior to an attack. Fu and Chai [36], for example, developed a method for identifying terrorist cells by analyzing social media activities. While performing such analyses may be beyond its purview, the City of San José is encouraged to continue partnering with federal agencies and research labs that work in the space (e.g., Lawrence Livermore National Laboratory) to be informed in real-time of probable threats. Protocols need to be in place for rapid deployment of necessary resources and coordination of the emergency response.

Once an attack has commenced, the City would immediately activate the EOC and coordinate response with Police, the Federal Bureau of Investigations (FBI), and county and state emergency services. Table 8 provides a list of recommended alert channels to consider for use during a complex coordinated terrorism attack. The channel priorities may be dependent on the situation at hand, which may be quickly changing. For example, the City may choose not to use sirens and auditory signals to direct an evaluation effort if the relevant authorities believe the onset of a mass evacuation may trigger terrorists to detonate a large explosive device.

Table 8: Recommended Notifications for Complex Coordinated Terrorism Attack

Dissemination Channels	Speed (minutes)[1]	Coverage[1]	Concentration[1]	Comments
Wireless emergency alerts (WEA)	< 10	Widespread	Dispersed	
Wireless communications (SMS)	< 10	Widespread	Dispersed	
Dedicated tone alert radios	< 10	Limited	Concentrated	
Loudspeakers and public address (PA) systems	10-30	Limited	Concentrated	
Audio sirens and alarms	10-30	Limited	Concentrated	
Broadcast sirens	10-30	Limited	Concentrated	
Message boards	10-30	Limited	Concentrated	
Reverse telephone distribution systems	10-30	Limited	Dispersed	
Text telephone (TDD/TTY)	10-30	Widespread	Dispersed	
Internet apps	10-30	Widespread	Dispersed	
Social media	10-30	Widespread	Dispersed	
Radio	30-60	Widespread	Dispersed	
Television broadcast	30-60	Widespread	Dispersed	
Television message scrolls	30-60	Widespread	Dispersed	
In-person notification	> 60	Limited	Concentrated	If safe to patrol.

1. *Attribute definitions can be found in Table 1.*

Conclusion

The City of San José has worked hard to develop emergency response systems and processes it can rely on when disaster strikes. Yet, current technologies and past experiences do not offer any guarantees of being able to reach 90% of the population within 10 minutes of alert initiation. To meet this goal, the City must make significant long-term investments to improve the initiation time of alerts via automation and integrated communication via cloud-based IoT-driven dashboards, develop overall alert receipt response capabilities and periodic efficiency and effectiveness testing, and ramp-up their efforts to encourage pro-active alert notification sign-up on the part of the public. These added capabilities will allow for continuous measurement and improvement of OEM operations, ensuring the City is prepared to deal with future natural or man-made disasters.

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