Consensus Study Report

November 2017

HIGHLIGHTS

Emergency Alert and Warning Systems:
Current Knowledge and Future Research Directions

Alerts and Warnings...

- Deliver information to populations at risk with the goal of maximizing the probability that people will take protective action with minimal delay.
- Are sent for natural hazards such as severe weather and manmade events such as terrorist attacks or active shooter emergencies.
- Can be sent by government agencies, colleges and school, or private organization.

Following a series of natural disasters, including Hurricane Katrina, that revealed shortcomings in the nation's ability to effectively warn populations at risk, Congress passed the Warning, Alert, and Response Network (WARN) Act in 2006. The resulting Integrated Public Alert and Warning System (IPAWS) would come to include the Wireless Emergency Alerts (WEA) system, which delivers short alert messages to cell phone subscribers. Today, new technologies such as smart phones and social media platforms offer new ways to communicate with the public, including through official channels, less official channels (such as mainstream media outlets and weather applications), and unofficial channels (such as first-person reports via social media). As a result, there are numerous opportunities to better deliver, target, and tailor emergency alerts. *Emergency Alert and Warning Systems: Current Knowledge and Future Research Directions*, a report from the National Academies of Sciences, Engineering, and Medicine, explores how a more effective national alert and warning system might be created, identifies some of the gaps in our present knowledge, and sets forth a research agenda to advance the nation's alert and warning capabilities.

THE FUTURE ALERT AND WARNING ECOSYSTEM

There are many opportunities to go beyond WEA to make use of the ability of mobile devices to decide which messages to present based on user needs or contextual information and to leverage other emerging technologies. Alerts and warnings that reach people through tools and communication devices they are using and present information in a way they are accustomed to will be the most effective. For an increasingly connected population using communication media

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and other technologies in diverse ways, any methodology that relies solely on the current cellular broadcast technology will not be sufficient for the primary alert and warning system.

FINDING: Alert and warning systems exist within a larger communication and technical ecosystem, and government-designed and maintained systems must fit within this larger ecosystem.

FINDING: A more cohesive and all-encompassing alert and warning system is needed that can better integrate public and private communications mechanisms and sources of information, continue to provide the necessary information for the purpose of preserving the health and safety of people, and have a technologically agnostic architecture that allows new technologies for alert and warnings to be adopted quickly.

FINDING: The nation's alerting capabilities, such as WEA and IPAWS, will need to evolve and progress as the capabilities of smart phones and other mobile broadband devices improve and newer technologies become available. This evolution will need to be informed by both technical research and social and behavioral science research.

THE EVOLUTION OF AN INTEGRATED ALERT AND WARNING ECOSYSTEM

The report envisions an alert and warning system that continually takes advantage of new technologies and reflects new knowledge that emerges from events and research. In the near term, this means working to increase the adoption of WEA and other existing alert and warning systems across the nation, and incorporate current knowledge about public response to craft more effective alert messages. Research focusing on testing technology implementation and adapting existing technologies—such as new technologies for delivering and geotargeting messages—will also be important. In the long term, progress will involve gaining a better understanding of existing technologies, exploring new technologies, and continuing socio-technical research to inform the design and operation of future alerting systems.

Near-Term Strategy: Adopt Existing Technologies for Alerts and Warnings. WEA was developed prior to the widespread use of smart phones and newer cellular network technologies. New technologies could address the shortcomings of WEA, including a host of accessibility, security, and functionality concerns. These advances should:

- Modernize delivery technologies. The immediate opportunity to modernize is to switch from second- or third-generation Short Message Service-based (Cell Broadcast) to fourth-generation long-term evolution (LTE) broadcast.
- Diversify communications technologies, such as Bluetooth and WiFi, in handsets to help distribute alert messages when cellular network congestion or failure occurs.
- Support the use of location information stored in handsets to improve the precision of geotargeting by determining if a device is located within the targeted area and whether an alert should be displayed.
- Incorporate more adaptability so that alert and warning capabilities can be upgraded more easily as understanding of public response and technology capabilities change(similar to the way in which phone applications are updated).
- Provide mechanisms for performance monitoring and user feedback.

Long-Term Strategy: Build an Integrated Alert and Warning Ecosystem. In the longer term, IPAWS could be augmented so that it draws on a wide variety of data sources, enhances public understanding of emergencies and public response, and uses a wider range of potential technologies and devices for delivering messages. Envisioning such an advanced system requires exploring questions around technical feasibility and implementation as well as an understanding of how these tools will affect public response. However, past technical, social, and behavioral research already informs us of some of the properties that an ecosystem should have. These desirable system properties and goals have the potential to inform research investments and to inform future system requirements:

- Using technologies that are privacy preserving.
- Assuring end-to-end service availability and the validity and integrity of messages.
- Giving users as much control as possible over what kinds of messages they receive, without limiting alerting control to simply on or off.
- Including metadata in alerting systems that can be used in combination with user preference to determine when and how to present alerts.
- Integrating messages across communication channels. For example, IPAWS messages could be made available as a data stream for private industry to use freely in weather applications,

navigation systems, social media streams, and the like.

- Making alerting systems device agnostic and able to support more than one modality of information presentation.
- Reflecting a better understanding of the information needs of emergency managers to quickly analyze data generated via social media.
- Using Internet of Things devices and other embedded sensors to detect, analyze, and categorize potential events, send alerts, and potentially automate certain protective actions.
- Incorporating available communications technologies to increase our ability to deliver information in the event that primary communication networks fail.
- Adapting message content and format to the needs of the end user

RESEARCH AGENDA

To realize an integrated alert and warning system, additional research questions will need to be answered. Given that alerts and warning are inherently interdisciplinary, this research agenda includes a wide range of socio-technical questions and highlights the need for social and behavioral scientists and technologists to interact frequently with each other.

Public Response. Although much has been learned about the public response to alerts and warnings from years of research, many long-standing questions remain, and new technologies have introduced new questions. Key open topics include the following:

- ***Message characteristics.*** How message length and the inclusion of protective guidance as hyperlinks affect public response, how to best express lead-time to a hazard, and how to best to manage opt-in and opt-out preferences.
- ***Accessibility.*** How to most effectively provide messages in languages and dialects other than English, how to adapt to differing physical abilities, and how to account in emergency planning for disparities in access to technologies.
- ***Geotargeting.*** How to best use the improved geotargeting capabilities afforded by WEA and the Common Alerting Protocol (CAP), determine locations of interest, make use of improving indoor location capabilities, and communicate protective action based on location.
- ***Community engagement.*** New tools and technologies support communications among members of a community.
- ***Hazard and Alerting Education.*** More research is needed to determine how to motivate behavior change as well as what other factors contribute to successful public disaster education campaigns.

Post Alert Feedback and Monitoring. More direct feedback mechanisms could be built into alerting applications on mobile devices, and these tools will need to be more readily available. Perhaps more importantly, research is needed to understand what information would be most helpful to emergency managers. Tools, including those that employ machine learning and other artificial intelligence techniques, are also needed to quickly understand and process feedback to ensure emergency managers are not overwhelmed with information.

A future alerts and warnings ecosystem that includes consistent, well-understood, and insightful measurements could improve response to future hazards. By building measurements into the alerts and warning system itself, researchers could gain supporting evidence for findings made in lab studies. Feedback during the lifecycle of a hazard could also be integrated into future responses within the same incident.

Technical Challenges and Their Impact. Delivering alerts via mobile devices was a leap forward; however, technical research could further improve capabilities. These research questions include:

- ***Incorporating other wireless communication technologies beyond standard cellular communications.*** WEA is designed to only use cellular communications. During hazards, some cellular networks may not function properly, so other technologies are needed to deliver messages.
- ***Role of connected devices***. More devices in homes and throughout the environment will be available to use as alerting channels and to detect emergencies or potential risk. Machine learning and other artificial intelligence techniques will play a role in automating alerts for short-fuse events and providing responders with information during and after events.
- ***Security, trust, and privacy.*** A system that instructs large populations to take a particular action may represent a significant target for spoofing or attacks on service availability. As emergency managers begin harnessing information—including personal and geographically relevant infor-

mation—from social media, security and privacy concerns will increase.

Challenges to Building Better Alerting Systems. Beyond the specific research topics listed above, the committee noted several challenges to building a better alert and warning systems:

- ***Slow adoption of new systems.*** As of August 8, 2016, just under a third of U.S. counties had registered to use the Integrated Public Alert and Warning System gateway, the system that allows message originators to send WEA messages. An increased use of WEA by local emergency officials would not only reach additional populations, but also increased use would improve familiarity with the systems.
- ***Limitations on weather forecasts and other information about natural hazards.*** Agencies that distribute weather-related messages at the state, local, regional or federal levels must ultimately rely on accurate forecasts and weather information from the National Weather Service and National Oceanic and Atmospheric Administration and information provided by the US Geological Survey, meaning these services are integral to any alert and warning systems.
- ***Ever-changing technology.*** Technology and communications tools used by the public are quite dynamic. However, adding to this challenge is that old and new technologies coexist for long periods of time. To reach the majority of individuals, systems must not only evolve but also continue to be compatible with legacy technologies.
- ***Difficulty of interdisciplinary research and converting research to practice.*** Technologists, social science researchers, and emergency managers have had few opportunities for ongoing interactions to consider how to apply current knowledge or fill gaps in our understanding.
- ***Incentives to participate.*** Sharing information about how the system is working across numerous official sources, social media companies, navigation companies, local media, and hardware makers will be an increasing challenge.

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This Consensus Study Report Highlights was prepared by the Computer Science and Telecommunications Board based on the report *Emergency Alert and Warning Systems: Current Knowledge and Future Research Directions* (2017). The study was sponsored by the Department of Homeland Security Science and Technology Directorate, with assistance from the Department of Health and Human Services. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of the sponsors. Download the report at **nap.edu** and learn more about the board at **nas.edu/cstb**.

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