Local Health Department Planning for a Radiological Emergency: An Application of the AHP\(^2\) Tool to Emergency Preparedness Prioritization

**ABSTRACT**

**Objective.** We tested the Analytical Hierarchy Process tool for its use in public health to identify potential gaps in emergency preparedness by local health departments (LHDs) in California and Hawaii during a radiological emergency.

**Methods.** We developed a dedicated tool called All-Hazards Preparedness Squared (AHP\(^2\)) that can be used by those who are responsible for all-hazards preparedness planning and response to guide them while making strategic decisions both in preparing for and responding to a slow-moving incident while it is unfolding. The tool is an Internet-based survey that can be distributed among teams responsible for emergency preparedness and response. Twenty-eight participants from 16 LHDs in California and Hawaii responsible for coordinating preparedness and response in a radiological emergency participated in using the tool in 2013. We used the data to compare the perceived importance of different elements of preparedness among participants and identify gaps in preparedness of their organizations for meeting the challenges presented by a radiological incident.

**Results.** Clarity of information and transfer of information (to and from agency to public, state, and federal partners) were public health officials’ dominant concerns while responding to an emergency. Participants also found that there were gaps in the adequacy of training and awareness of the chain of command during a radiological emergency.

**Conclusion.** This preliminary study indicates that the AHP\(^2\) tool could be used for decision making in all-hazards preparedness planning and response.
Every team responsible for managing an emergency might wish for the ability to predict the future, which would be based on situational awareness, past experience, and training under assumptions related to an emergency’s complex situation and environment. Yet, situational awareness during an emergency is usually limited by a lack of resources for responding to an emergency and by the diversity of the stakeholders involved. As Danielsson and Ohlsson state: “An emergency is by definition a unique and unpredictable event, and it is seldom possible, even in retrospect, to assess what the outcome of an emergency response would have been if alternative measures had been followed. The only kind of normative models available to emergency response teams are tactical doctrines codified in manuals and guidelines.” Even these guidelines may lack adequate guidance for making good decisions, including a lack of resources and tools on how to make them.

The U.S. Department of Homeland Security Target Capabilities List includes only “seven references to decision making, most of which involve planning for and coordinating the decision-making processes, and none of which involve elements for evaluating the ability to actually make decisions.” Also, the National Incident Management System focuses on planning for and coordinating decision making, but gives no explicit guidance on how to make a decision, especially by a team comprising people with varied priorities.

Clearly, tools to help public health professionals undertake collaborative efforts to make effective decisions while responding to a complex emergency would be welcome.

In fact, decision-making techniques do exist. The simplest technique and most broadly applied in government and industry is the Analytical Hierarchy Process (AHP), developed by Tomás Saaty at the University of Pittsburgh in the 1970s. The AHP is a multi-element decision analysis technique that involves structuring complex problems into a hierarchy of elements that influence the problem. Saaty compares the elements in pairs and employs an algorithm to sort them in order of importance in influencing the problem, then prioritizes the data to determine the best decision to solve the problem. The AHP technique is clear, methodical, nonpartisan, and transparent—characteristics that are suitable for high-stress, high-accountability fields such as emergency preparedness and response in public health.

We developed an Internet-based, collaborative tool that we call All-Hazards Preparedness Squared (AHP2), which is especially designed for use in public health. It facilitates AHP-type analyses for a variety of stakeholders and provides a basis for analyzing their responses in ways that help prioritize key elements for preparedness and response to a public health emergency. It can also help a team evaluate specific potential actions and collaboratively determine the best decisions to meet the challenges of an emergency. Furthermore, it can be customized for each team member and distributed to all team members. For emergency preparedness and response, AHP2 can be used by a team to respond appropriately to a slow-moving emergency by prioritizing elements and resources in preparation for responding effectively to particular emergency scenarios. An example of an application of AHP2 for response might be the decision of when to close schools during an H1N1 epidemic, which involves the consideration of many elements and approaches to avoid unintended consequences (Personal communication, Harvey Kayman, University of California, Berkeley, June 2012).

Our study, which was conducted in 2013, had two aims: (1) to test the AHP2 tool for its use in public health and (2) to present the results from an application of the tool to identify potential gaps in emergency preparedness by local health departments (LHDs) in California and Hawaii during a radiological emergency scenario resembling the Fukushima catastrophe. The participants revealed the challenges they might experience during a radiological emergency systematically through the use of the AHP2 tool. The specific radiological scenario we developed was the movement of a radioactive plume that was carried by wind across counties in California and Hawaii and that was tracked by local citizens’ network of radiation monitors, whose members posted data on Facebook. Through this process, survey participants had the opportunity to reflect on the consequences of radiological contamination affecting their home counties and cities.

**MATERIALS AND METHODS**

**Application of AHP2 for planning a radiological scenario**

The AHP2 tool is hosted at the James Martin Center for Nonproliferation Studies at the Monterey Institute of International Studies in Monterey, California. It can be used for many other applications and is easy to customize.

The first step in using the AHP2 tool was to determine underlying elements that influence the level of LHDs’ preparedness for meeting the challenges posed by a radiological event. We used seven past radiological events to identify elements of preparedness that influenced outcomes, and collaborated with subject-matter experts to group them into four factors (Unpublished report. CNS: 14 historical radiological and chemical
case studies. Monterey [CA]: James Martin Center for Nonproliferation Studies; 2013). For example, the elements of human assets, financial aid, and mutual aid agreements were included as the factor “Critical Resources.” Factors (e.g., Information Tools, Resources, Communication, and Organizational Strength) that were logically related to the elements were entered into the AHP² tool. The factors are defined in Figure 1 and the elements are defined in Table 1. Participants could hover the mouse cursor above any of the terms to reveal the definition of any factor/element in a pop-up window at any time while completing the survey. This step in configuring AHP² with appropriate definitions of factors and elements that are understandable by all participants was the most challenging aspect of configuring the tool.

Next, participants who were employed in senior positions in LHDs in California and Hawaii and responsible for coordinating preparedness and response in a radiological emergency were identified and invited to participate in the survey. Each letter invitation contained a Web address for the AHP² survey tailored specifically to the individual. All health officers of LHDs in California were invited to participate in the survey; however, only one or two representatives from 16 counties completed the survey. The diverse group of counties included half the population of California, but neither of the two counties with nuclear power plants participated. In total, 28 respondents completed the AHP² survey for a 26% response rate (16 of 61 counties in total). Several subject-matter experts affiliated with state organizations responsible for emergency planning and response, as well as from academic institutions, also participated in the survey. The survey took place from September 2012 to May 2013.

**Measurement 1: importance of weight distribution of preparedness components**

The participants were prompted to choose specific elements that they felt fit most logically with the four factors (Figure 2) by dragging and dropping the element to the appropriate factor using their mouse. The AHP² tool then generated an individualized Web-based survey so that participants could respond to specific questions comparing their selected elements in the same family in pairs on a 10-point bipolar, semantic differential (SD) scale (Figure 3). For example, the component Supplies was compared in terms of importance with Finances. The AHP² program then calculated the importance weights of the components according to the data for each participant using the AHP technique. The weights are considered to be a measure of the components’ importance and can vary for every participant.

**Measurement 2: potential gaps in preparedness for radiological scenario**

The weights determine the importance of the elements to the response, but they do not measure any perceived gap in preparedness. The difference in the interpretation of the weight is because it is possible to have a perceived weakness in an element rated as less important, so that the actual impact during an emergency will be minimal. For this reason, particular components logically related to each element (49 in total) were ranked on a bipolar SD scale in terms of the degree of preparedness for the particular radiological scenario. For example, one of the elements, Human Assets, includes components that may be significant during an emergency (e.g., Medical First Responders, Doctors, Firefighters, and Translators).

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**Figure 1. The four factors used in an AHP² survey of local health department officials in California and Hawaii involved in planning for a radiological scenario: September 2012–May 2013**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Definition (appeared in pop-up window)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources</td>
<td>Equipment, supplies, facilities, and human capital potentially available for deployment to incident or emergency operations</td>
</tr>
<tr>
<td>Information tools</td>
<td>Competence related to the collection and analysis of information and intelligence relevant to risks and threats that may affect the response</td>
</tr>
<tr>
<td>Organizational strength</td>
<td>Established modes of operation and competence encompassing accountability, professionalism, flexibility, and leadership necessary for incident management</td>
</tr>
<tr>
<td>Communication</td>
<td>Activity of successfully transferring meaningful information in coordination with established protocols, within and between agencies, jurisdictions, and to the public</td>
</tr>
</tbody>
</table>

*These definitions appear as pop-up windows throughout the program whenever the mouse hovers over the terms. Note that for a different application, these factors can be easily changed.

AHP² = All-Hazards Preparedness Squared
Table 1. Partial scores and elemental importance weights used in an AHP\(^2\) survey of local health department officials in California and Hawaii involved in planning for a radiological scenario: September 2012–May 2013

<table>
<thead>
<tr>
<th>Element</th>
<th>Definition</th>
<th>Element weight(^a)</th>
<th>Partial weight(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information clarity</td>
<td>Clear and coherent, using common language</td>
<td>15.7</td>
<td>17.7</td>
</tr>
<tr>
<td>Information transfer</td>
<td>Presentation of data or facts within an agency, among agencies, and to the public</td>
<td>8.9</td>
<td>10.3</td>
</tr>
<tr>
<td>Human assets</td>
<td>Personnel and volunteers available for incident response</td>
<td>7.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Training</td>
<td>All preparatory exercises and certifications to ensure competency for response</td>
<td>8.8</td>
<td>7.6</td>
</tr>
<tr>
<td>Risk assessment</td>
<td>Tools for predicting vulnerabilities and analyzing the potential consequences of threats, taking into account population demographics, infrastructure, and the physical environment</td>
<td>6.7</td>
<td>7.2</td>
</tr>
<tr>
<td>Chain of command</td>
<td>Knowledge of the integrated line of authority within the ranks of collaborating incident management organizations</td>
<td>7.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Hazard identification</td>
<td>Standardized tools for gathering, measuring, organizing, and sharing information about the threat and recognizing potential dangers and coincident hazards (e.g., geospatial modeling)</td>
<td>6.1</td>
<td>6.8</td>
</tr>
<tr>
<td>Management</td>
<td>Control of resources and personnel, and the coordination of activities</td>
<td>5.7</td>
<td>6.8</td>
</tr>
<tr>
<td>Documentation</td>
<td>Compiled record of information, actions, and occurrences that is accurate and complete to ensure situational awareness and access to critical information</td>
<td>5.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Procedures and protocols</td>
<td>Established guidelines for action, and the basic obligations of responders, incident management personnel, and others</td>
<td>7.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Hazard mitigation</td>
<td>Prevention measures and policies for minimizing vulnerability and injury (e.g., relocation and evacuation, educational outreach efforts, and lessons learned)</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Equipment</td>
<td>Tools necessary for immediate response (e.g., personal protective equipment, transport vehicles, rescue and construction machinery, and communication devices)</td>
<td>3.4</td>
<td>3.6</td>
</tr>
<tr>
<td>Mutual aid agreements</td>
<td>Existing agreements for external support from other jurisdictions or sectors in the form of equipment, supplies, facilities, and human capital</td>
<td>3.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Supplies</td>
<td>Long-term stock of essential provisions (e.g., food, water, and public health stock)</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Facilities</td>
<td>Establishments that fulfill a particular function or service (e.g., emergency operations center, alternate care sites, hospitals, publicly owned buildings, and public works)</td>
<td>3.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Finances</td>
<td>The ability to fiscally prepare for and respond to emergencies</td>
<td>2.5</td>
<td>1.9</td>
</tr>
</tbody>
</table>

\(^a\)The element importance weight distribution averaged across all individuals who participated in the survey expressed as a percentage of the total weight. This weight is interpreted as a measure of the perception of the importance of elements that influence the level of the local health department's preparedness. The higher the value, the higher the level of the element.

\(^b\)The median of the individual partial score distribution for all participants expressed as a percentage of the total score (sum of the partial scores). The values can be seen as a measure of the challenges in preparedness as perceived by participants in the study because they take into account both the importance of the element and the challenge that the element poses for the present scenario.

AHP\(^2\) = All-Hazards Preparedness Squared

The questions were phrased so that the higher the rank on the scale, the more serious a challenge its degree of preparedness will pose for the response to the emergency. For example, one component was Clear and Concise Message Formatting, which belonged to the element Information Clarity. The question to be rated on the SD scale that corresponded to Clear and Concise Message Formatting was: “Insufficient clarity of information will pose significant challenges during this emergency. To what extent do you agree with this statement concerning clear, concise message formatting?” The respondent could dial a slider along 10 gradations from 1 (100% disagree) to 10 (100% agree) in response to the question. Completely agreeing that
Concise Message Formatting could pose a serious challenge corresponded to a high SD scale ranking that was considered to be a measure of the component’s adequacy for this emergency. However, a high rank did not reveal if the component corresponded to a gap in preparedness compared with other components that had equal rank. To distinguish components that may rank high in the SD ranking but may not be as important as other components with equal scale rank, the rank was scaled in magnitude by the weight of the element to which the component logically belonged.

RESULTS

Determination of partial scores for elements

We sought to determine potential gaps in emergency preparedness and highlight aspects of preparedness (elements and components) that are not only considered to be important as measured by their importance weighting, but are also considered to be problematic under the scenario.

As described in the previous section, the AHP² tool calculated a distribution of weights for each participant as a measure of how he/she prioritized elements that influence emergency preparedness. To aggregate the data across all participants, the median of the weight distribution was calculated for each element and expressed as a percentage of the sum over all element weights. The percentage measures the degree to which respondents prioritized elements that influence emergency preparedness. Table 1 shows the element, definition, and percentage of the total weight to which the element contributes (column 3). We found that among the most important were Information Clarity, Information Transfer, Human Assets, Training, and Procedures and Protocols, which contributed to more than 50% of the total score.

Nevertheless, elements of preparedness with a high importance weight (Measurement 1) may not have components that pose a challenge during this particular emergency. For this reason, the participants separately ranked components logically associated with each element on a 10-point SD scale in terms of the degree of preparedness of that component for the scenario (Measurement 2). The questions were phrased in such a way that the higher the rank on the scale, the more serious the challenge posed by that component’s preparedness. Box plots for a subset of the elements are shown in Figure 4. Because the distributions were asymmetric, with large tails to lower SD values and with different sample sizes (as different individuals chose...
different components), it was appropriate to use the median rather than the mean of the distribution to measure the central tendency across all participants.

The final step was to scale the magnitude of individual weights associated with the elements by the SD rank for each component. For example, the weight associated with the element Human Assets was scaled by the SD scale rank for each of the associated components (e.g., Medical First Responders or Doctors) for each participant, which we call the partial score. The median of this distribution measures how challenging participants collectively considered each aspect of preparedness for the scenario. The last column in Table 1 is the median of the partial score distribution for all participants expressed as the percentage of the total score (sum of the partial scores). We suggest that the variation in the partial score is a measure of the degree to which the component might pose a challenge for a radiological emergency, averaged across all participants. Finally, in Table 2, we list the partial scores expressed as a percentage of the total score for the first 15 elements.

**DISCUSSION**

Examining Tables 1 and 2, it is not surprising that Clarity of Information and Transfer of Information (to and from agency to public, state, and federal partners) were dominant concerns for participating public health officials, as receiving technical information during a time of duress may be very challenging. This finding is consistent with the findings of a 2012 survey by the Inspector General of Health and Human Services of 40 of the most populous LHDs in the U.S., which found that “localities also varied in the extent to which they coordinated with federal, state, and local partners for RN (radiological and nuclear)-specific public health planning. Most state and local officials were aware of federal guidance sources available to aid RN-specific public health planning, but requested more comprehensive and specific planning tools.” The same study also found that only half of the counties surveyed conducted public health emergency preparedness planning in one of the five areas suggested in the Nuclear/Radiological Incident Annex to the National

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**Figure 3.** Screenshot of the AHP² tool during the pairwise comparison step, where each factor and element is compared in pairs in terms of their relative importance, in a survey of local health department officials in California and Hawaii involved in planning for a radiological scenario: September 2012–May 2013

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AHP² = All-Hazards Preparedness Squared
In addition, of the counties that conducted a public health preparedness plan, only one-third established a communication strategy. Human Assets and Training were also perceived as concerns, which may indicate that public health professionals do not consider themselves well prepared for a radiological event in terms of technical knowledge and training. For example, a high score for Human Assets may express concern that these public health professionals will have different responsibilities and priorities during an emergency and/or require specialized dose monitoring and equipment. A response to a radiological incident is different from other types of hazard responses, especially if it is an intentional event. Training should focus on “increasing the understanding of and ‘demystifying’ radiation and its effects in the public health and emergency response communities and among the public at large...” as well as preparing “public health workers to focus on their roles and responsibilities.”

Other elements considered significant were Risk Assessment and Hazard Identification, indicating a concern for the ability to monitor and predict how the threat will evolve. There was also a perception of inadequate knowledge of the Chain of Command during a radiological emergency.

Practical implications
There is much discussion in the public health and emergency preparedness fields about the responsibilities of decision makers and the characteristics of inappropriate decision makers, but little specific information and few tools are available to guide decision makers either to prepare for future events (i.e., allocation of preparedness resources) or to help them make decisions for slow-moving emergencies (e.g., a disease outbreak). The purpose of our study was to test the AHP tool for public health applications and to present the results to identify potential gaps in emergency preparedness for LHDs in California and Hawaii during a radiological emergency scenario. Based on our assessment, the partial scores indicate a need for a clear, coherent communication strategy, using common language, understandable by all response teams, in addition to a well-planned communication plan to and from the relevant agencies. Previous studies indicated that many of the most populous counties did not even have a communication strategy in case of a radiological incident despite the fact that the 2010 National Security Strategy determined that the most severe threat facing the American population is a “terrorist attack with a nuclear weapon.”

The emphasis on Training, Information Clarity, and Communication Systems as concerns suggests that counties must conduct further training for the communications strategy of a radiological incident, as well as all aspects of Hazard Identification and knowledge of the Chain of Command. Because these recommendations are not unexpected, they demonstrate that the AHP tool may
be used to prioritize emergency preparedness elements and identify possible problem areas.

Limitations
This study was subject to several limitations. One finding from this study was that some participants found the AHP² tool time consuming to use. This finding is an artifact of the AHP technique, when the problems are complex with many elements to a problem, as with the scenario we considered. There are methods to concentrate only on important elements that may be implemented in the next version of the tool. Also, because the study involved 28 respondents and only one scenario, the AHP² tool would benefit from being applied to a situation that involves more participants and testing it in other applications to fully identify its potential usefulness for the public health community.

CONCLUSION
Based on our assessment, the partial scores indicate the need for a clear, coherent communication strategy that uses a common language and is understandable by all response teams, in addition to a well-planned communication plan to and from the relevant agencies. While these results are expected, they indicate that the AHP² tool can be used to prioritize complex emergency preparedness elements and identify areas of concern. The AHP² tool can be easily configured for specific applications through a Web-based interface.

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REFERENCES