ABSTRACT

Traditional hazard vulnerability analysis (HVA) looks at probability and impact to determine risk. The results are often graphically displayed in an XY chart, and mitigation priorities are determined by risk ranking alone. This model is not sufficient, because it does not consider the cost of mitigation. The updated HVA looks at value, in which the traditional XY chart is expanded to a cube model in which the Z axis reflects cost. In a typical hospital HVA, where there may be over 50 different potential events, determining proximity to the perfect value point (high probability, high impact, low cost) allows a better ranking system when allocating scarce mitigation dollars.

INTRODUCTION

Hazard vulnerability analysis (HVA) is “the identification of potential emergencies and the direct and indirect effects these emergencies may have on the health care organization’s operations and the demand for its services.”¹ HVA is the traditional method of assessing risk to fixed geographic assets and has been used in many settings to identify risk, define needed preparedness activities, and assign mitigation priorities.² However, mitigation in general, and HVAs specifically, were not the traditional focus of attention in healthcare-related emergency management.³ This changed in 2001, when the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) significantly revised EM standard EC 1.4 in their comprehensive accreditation manual.¹ The manual stated that the 4,500 JCAHO-accredited hospitals were required to conduct HVAs to identify potential emergencies that could affect the need for services or the ability to provide those services.

HOSPITALS AND DISASTERS

Most disasters involve some health component and affect normal hospital operations. Hospitals, society, and disasters interact in three distinct ways:

1. **A hospital-specific disaster (e.g., a fire).** The impact of a hospital reducing its operations may have a grave impact on the community’s health.⁴

2. **A community-wide disaster (e.g., Hurricane Katrina).** Hospitals are subject to the same conditions seen in the community, such as flooding, power failures, and structural damage.

3. **Isolated disasters (e.g., the Oklahoma City bombing).** Hospitals are not directly affected but need to be able to modify normal operations to handle additional patients in a short timeframe.

In almost any disaster, the impact on the hospital system will have significant ramifications for the community as a whole.

THE VALUE OF MITIGATION

Mitigation activities act to reduce the probability that an adverse event will occur or limit the event’s impact on the hospital. Hospitals are concerned with a number of facets of disaster impact: the impact of disasters on normal operations, unforeseen costs, and the total cost of recovery from a disaster. Factors that must be considered when determining if mitigation is the best strategy are the probability of the event.
occurring, event impact on the hospital, impact of performing the mitigation activity, discount rate of capital (money spent for prevention is more cost-effective than money spent for recovery), and other more pressing uses for the capital (e.g., other non-mitigation projects). When all factors are considered, mitigation is a high priority for hospitals given the strong internal and external focus on continuity of operations. This aspect alone drives mitigation projects.

THE GOALS OF HAZARD VULNERABILITY ANALYSIS

HVAs identify potential risks so that hospitals can better prepare for them and can mitigate their impact.

THE TRADITIONAL HAZARD-VULNERABILITY ANALYSIS MODEL

The first component of an HVA is to determine the likelihood of a particular event. There are a variety of sources hospitals can use to determine the probability of an event, such as Project Impact. The second component is to determine the impact of a particular event. The product of these two factors is the risk. The United Nations defines risk as “the expected losses from a given hazard to a given element of risk over a specified future time period,” where element of risk may be lives lost or property destroyed. Most HVA literature defines risk as the probability of occurrence multiplied by impact on the hospital.

Probability of occurrence

Probability of occurrence focuses on assessing the likelihood of an event occurring in a finite geographical area within a finite timeframe. There is no standard benchmark for assessment, although many hospitals define the finite geographical area as their service area, city, or county. Many natural hazard experts use 50 or 100 years as a standard timeframe.

Impact on the hospital

Many events will have a limited impact on a hospital. For example, a snowstorm in Buffalo, New York, may have no significant impact on hospital operations, while a comparable snowstorm in Raleigh, North Carolina, would cause significant disruption. Impact can be a multifaceted problem that includes increased numbers of injured or ill patients, potential injured or dead employees, property loss, and interruption of hospital services. Some analyses also include ability to respond to events, degree of planning, ability to mount an effective internal response, and availability of external resources.

Results from probability and impact analyses are typically ranked on a numeric scale from lowest to highest, referred to as the risk rank. The results are then either summarized or plotted on an XY chart to visually display the information (Figure 1). While the numerical scale ranking does not have standard definitions, the probability of occurrence ranges from “no possibility of occurrence” to “will occur,” while impact on the hospital ranges from “no effect” to “total devastation.” For the purposes of analysis, this study uses a 0-10 scale for both probability and impact. The closer the event’s plotted point is to the upper right-hand corner (high risk, high impact) where the risk rank (X times Y) equals 100, the higher it ranks as a priority for mitigation.

AN UPDATED HAZARD VULNERABILITY ANALYSIS MODEL

Impact of cost on the mitigation process

A critical shortcoming of the current model is that, although it does identify the risk to the hospital, it does not identify value—the combination of cost, probability, and impact. With more than one-third of

Figure 1. Traditional hazard vulnerability analysis.
American hospitals operating at a loss, cost is a key factor in making choices about mitigation priorities.\textsuperscript{12} In a 2003 American Hospital Association survey, New York State hospitals, although anticipating spending over $110 million for mitigation and preparedness that year, indicated a shortfall of over $460 million.\textsuperscript{13} By introducing the concept of value to traditional HVA, hospitals will be better able to determine priorities given a wide variety of potential catastrophic events. Adding cost as a third factor (the Z axis) in the traditional XY chart of probability and impact will allow hospitals to better choose among equal risks (where the probability and impact are the same), equivalent risks (where the product of probability and impact is the same), and disparate risks (where there are multiple events with different risks). Cost is ranked on a scale of 0-10, where 0 = no cost and 10 = very high costs. There is no formal scale similar to the traditional HVA—it is up to each hospital to determine the metric. The closer the plotted point is to the upper right-hand corner of the front face of the cube (high risk, high impact, low cost = the perfect value point), the better the value and the higher it ranks as a priority for mitigation (Figure 2).

Using a formula, where $D = $ distance, the distance from the upper right corner/front face can be calculated by using this reasonably simple formula, where $X$ is the impact rank, $Y$ is the probability rank, and $Z$ is the cost rank. The lower the number, the shorter the distance, the closer it is to the perfect value point:

$$d = \sqrt{(x_1-10)^2 + (y_2-10)^2 + (z_3)^2}$$

As events are plotted toward the lower left rear corner (low probability, low impact, high cost = the worst value point), they provide less value and are less of a priority to mitigate. Looking at three different examples demonstrates the applicability and importance of using the Updated HVA model.

**Equal risks**

Hospital A has identified two events—fire and flood—that have the same probability and impact. Under traditional HVA analysis, they appear as equal mitigation priorities with a risk rank ($X \times Y$) of 16. This may not be true if mitigating the risk of fire costs $20,000 while mitigating the risk of flood costs $60,000. Only by using cost as the third axis is the value difference revealed. If, for example, each cost point is assigned a value of $10,000, then cost is ranked as a 2 for fire and 6 for flood (Figure 3).

Using the updated HVA, hospitals can prioritize risk not only by probability and impact but also by cost, allowing them to determine the priority that yields the best value. In this scenario, mitigation against fire is the best value, since it is closest to the perfect value point:

$$8.72 = \sqrt{(4-10)^2 + (4-10)^2 + (2)^2}$$

$$10.39 = \sqrt{(4-10)^2 + (4-10)^2 + (6)^2}$$

**Equivalent risks**

Hospital B has identified two events: building collapse and earthquake. Building collapse has a probability of 2 and an impact of 5, for a risk rank of 10.
Earthquake has a probability of 5 and an impact of 2, for a risk rank of 10. Both events have equivalent risk rank. Under the traditional HVA analysis, they appear as equivalent mitigation priorities. This may not be the case if mitigating the risk of building collapse is $20,000, while mitigating the risk of earthquake is $80,000. If each cost point is assigned a value of $10,000, cost is ranked as a 2 for building collapse and 8 for earthquake (Figure 4). In this case, building collapse should be the mitigation priority, since it is the best value:

\[ 9.64 = \sqrt{(2-10)^2 + (5-10)^2 + (2)^2} \]

\[ 12.37 = \sqrt{(5-10)^2 + (2-10)^2 + (8)^2} \]

**Disparate risks**

The two previous examples were simple—either equal probability and impact or an equivalent risk rank. Adding the cost axis for equal or equivalent choices could easily be done in a list format. The problem becomes significantly more complex when considering multiple events that are not equivalent. In many hospital HVAs, there may be as many as 53 different events to consider, and ranking events for mitigation becomes significantly more difficult.10

For simplicity, the following example contains only five events. Hospital C has identified five events during their hazard vulnerability analysis. Once identified, hazards must be assessed for frequency and impact, which is plotted on the traditional XY axis (Figure 5). Each cost point is assigned a value of $10,000 (Table 1).

Adding the Z axis for the cost of the same events (Figure 6) changes their ranking dramatically. In the traditional model, the risks could be ranked from lower left to upper right as they get closer to 100 (the upper right corner of the chart). When cost is included as a factor, the rankings change as rank is based on proximity to the perfect value point (the upper right-hand corner of the front face of the cube). When

<table>
<thead>
<tr>
<th>Event</th>
<th>Traditional XY value</th>
<th>Cost ($US)</th>
<th>Adding Z axis value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hailstorm</td>
<td>1,1</td>
<td>20,000.00</td>
<td>2</td>
</tr>
<tr>
<td>HAZMAT event</td>
<td>3,3</td>
<td>40,000.00</td>
<td>4</td>
</tr>
<tr>
<td>Bomb</td>
<td>5,5</td>
<td>20,000.00</td>
<td>2</td>
</tr>
<tr>
<td>Labor unrest</td>
<td>7,7</td>
<td>60,000.00</td>
<td>6</td>
</tr>
<tr>
<td>Tornado</td>
<td>9,9</td>
<td>80,000.00</td>
<td>8</td>
</tr>
</tbody>
</table>
cost is included, even though tornado is high probability and high impact, a hospital concerned with value will address bomb and labor unrest first (Table 2).

### Table 2. Traditional HVA mitigation priority compared with updated HVA mitigation priority

<table>
<thead>
<tr>
<th>Event</th>
<th>Traditional*</th>
<th>Updated**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hailstorm</td>
<td>5 (1)</td>
<td>5 (12.88)</td>
</tr>
<tr>
<td>HAZMAT event</td>
<td>4 (9)</td>
<td>4 (10.68)</td>
</tr>
<tr>
<td>Bomb</td>
<td>3 (25)</td>
<td>1 (tied) (7.35)</td>
</tr>
<tr>
<td>Labor unrest</td>
<td>2 (49)</td>
<td>1 (tied) (7.35)</td>
</tr>
<tr>
<td>Tornado</td>
<td>1 (81)</td>
<td>3 (9.06)</td>
</tr>
</tbody>
</table>

*Risk rank (100 = best); ** distance from ‘perfect’ (lower = better).

**Figure 6. Multiple events (updated HVA).**

By adding a cost variable to the traditional hazard vulnerability analysis, hospital emergency managers can move toward implementing the concept of value. Including value as a key determinant in ranking mitigation priorities, scarce hospital resources can be directed to address risks in a clear and consistent manner.

### Conclusion

By adding a cost variable to the traditional hazard vulnerability analysis, hospital emergency managers can move toward implementing the concept of value. Including value as a key determinant in ranking mitigation priorities, scarce hospital resources can be directed to address risks in a clear and consistent manner.

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### References