Evaluating the Hurricane Decision Simulator

Cameron MacKenzie, Sophia Hetherington, Anna Prisacari, Sarat Sivaprasad
Industrial and Manufacturing Systems Engineering, Iowa State University

Eva Regnier
Graduate School of Business and Public Policy, Naval Postgraduate School
U.S. Marine Forces Reserve (MFR)
## MFR Decision Support Matrix

### Hours before arrival of 39-mph winds

1. **96 hours**: Send advance emergency relocation staff (ERS) to alternate headquarters
2. **96 hours**: Send liaison officers to local municipal emergency operations centers
3. **72 hours**: Send rest of ERS to alternate headquarters
4. **72 hours**: Activate remain behind element to stay if evacuation ordered
5. **60 hours**: Evacuate or shelter in place
6. **48 hours**: Transfer command and control to alternate headquarters
Hurricane Decision Simulator

• Training tool to make hurricane preparation decisions

• Key characteristics
  • Simulated storms (storm and forecasts)
  • User decisions
  • Actions of other entities
  • Consequences of storm plus decisions

Hurricane Decision Simulator

Simulated storms...with forecasts

Six key decisions

and follow-on actions
Results:
The storm made landfall at 30.0°N and 90.3°W as a Category 2 hurricane. The storm made landfall on 11 Aug 0800, 246 hours after the NHC’s first forecast of this storm. NOLA experienced 104 mph winds, 12 hours before the storm made landfall. Landfall occurs when the center of the storm reaches the coastline, but high winds often reach land much earlier, especially for large or intense storms. Tropical storm force winds (39 mph or greater) reached NOLA about 24 hours before the storm made landfall.

The storm surge was 4.0 feet and occurred at low tide.

You deployed the ADVON 54 hours before NOLA experienced 39 mph winds.
You deployed liaison officers to local municipal EOCs 48 hours before NOLA experienced 39 mph winds.
You deployed the rest of the ERS to the alternate HQ 42 hours before NOLA experienced 39 mph winds.
Use by the Marines

- Individual training by crisis action team and emergency relocation team (almost 200 people) since Fall 2015
- Used in developing annual (team) specialized hurricane exercises
- Expanded to Hialeah Reserve Training in Florida in June for command turnover
Research question

• Does the Hurricane Decision Simulator help people make better decisions?

• How does the Hurricane Decision Simulator impact or change people’s decision making?
Subjects

- Engineering economy class in Spring 2017
- 157 undergraduate students, engineering majors
- Mostly juniors and seniors
You are the Commander of U.S. Marine Forces Reserves (MARFORRES) whose headquarters are located in New Orleans, Louisiana. …

Tropical cyclone

- Probability of tropical force winds
- Probability of hurricane winds
- Expected time to landfall

Evacuation costs

Marines timeline

Evacuate, shelter in place, neither?
Three scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Probability wind speed &gt; 39 mph</th>
<th>Probability wind speed &gt; 74 mph</th>
<th>Expected hours to landfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>77</td>
<td>31</td>
<td>58</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>84</td>
<td>22</td>
<td>59</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>100</td>
<td>52</td>
<td>58</td>
</tr>
</tbody>
</table>

- Costs of evacuation = $300,000 per day for 1-2 weeks
- Marines’ timeline recommends evacuating 60 hours before arrival of winds
Experiment

- Introduction to the Hurricane Decision Simulator (HDS)
- Subjects practiced with HDS (~15 minutes)

Day 2
- Each subject made decisions for the exact same 5 storms in HDS
- Subjects recorded information
  - Details of the storm
  - Riskiness of storm
  - Subjective evaluation of decision-making processes
- Final 3 storms in HDS equivalent to text description on day 1
Simulated storms...with forecasts

Six key decisions

and follow-on actions
Subjective evaluation of decision-making process

- Tropical Cyclone 1
- Tropical Cyclone 2
- Tropical Cyclone 3
- Tropical Cyclone 4
- Tropical Cyclone 5

Legend:
- Very Bad
- Quite Bad
- Neither Good or Bad
- Quite Good
- Very Good
- Not Sure
Comparison of decisions (pre vs post)

Proportion of subjects

Decision on day 1 (no simulation)

Scenario 1 (85 subjects)

Scenario 2 (106 subjects)

Scenario 3 (124 subjects)
Hypothesis 1

• Subject is more likely to make a different decision when using the Hurricane Decision Simulator

• Null: probability of making same decision on days 1 and 2 equals probability of making different decision
Hypothesis 1

Proportion of subjects

Scenario 1 (85 subjects)

Scenario 2 (106 subjects)

Scenario 3 (124 subjects)

Decision on day 1 (no simulation)
Hypothesis 1

- Subject is more likely to make a different decision when using the Hurricane Decision Simulator
- Null: probability of making same decision on days 1 and 2 equals probability of making different decision)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>4E-06</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>3E-06</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>4E-10</td>
</tr>
</tbody>
</table>

Reject null
Hypothesis 2

- Subject more likely to switch than what random chance would predict
- Null: probability of “Evacuate” equals probability of “Shelter” equals probability of “Wait”
Hypothesis 2

Decision on day 1 (no simulation)

Scenario 1 (85 subjects)
Scenario 2 (106 subjects)
Scenario 3 (124 subjects)

Proportion of subjects

Evacuate Shelter Wait

Evacuate Shelter Wait

Evacuate Shelter Wait

Evacuate Shelter Wait

Evacuate Shelter Wait

Evacuate Shelter Wait

Evacuate Shelter Wait

Evacuate Shelter Wait

Evacuate Shelter Wait
Hypothesis 2 using Bayesian analysis

- Jeffrey’s prior, $p \sim Dirichlet(0.5)$
- Posterior, $p \sim Dirichlet(0.5 + \text{number of subjects})$

### Given day 1 decision, probability 3 decisions on day 2 are equally likely

<table>
<thead>
<tr>
<th>Day 1 decision</th>
<th>Evacuate</th>
<th>Shelter</th>
<th>Wait</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>0</td>
<td>4E-4</td>
<td>0</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>2E-5</td>
<td>0</td>
<td>9E-4</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>0.01</td>
<td>0.11</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Based on 200,000 simulations of posterior distribution
Hypothesis 3

• Given that a subject switches between days 1 and 2, more likely that a subject switches to “Wait”

• Null: probability of switching from “Evacuate” to “Shelter” or from “Shelter” to “Evacuate” equals probability of switching to “Wait”
Hypothesis 3

Decision on day 1 (no simulation)

- Scenario 1 (85 subjects)
- Scenario 2 (106 subjects)
- Scenario 3 (124 subjects)
Hypothesis 3 using Bayesian analysis

- Jeffrey’s prior, $p \sim \text{Dirichlet}(0.5)$
- Posterior, $p \sim \text{Dirichlet}(0.5 + \text{number of subjects})$

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Given evacuate on day 1, $P(\text{shelter} &gt; \text{wait})$ on day 2</th>
<th>Given shelter on day 1, $P(\text{evacuate} &gt; \text{wait})$ on day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>1E-4</td>
<td>0.03</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>5E-4</td>
<td>8E-5</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>0.15</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Based on 200,000 simulations of posterior distribution
Conclusions

- People that practice with the Hurricane Decision Simulator (HDS) feel more comfortable making decisions in that context
- Impact of practicing with HDS
  - People seem more likely to switch their decisions after practicing with HDS
  - Choosing decision with HDS seems more than just random chance
  - HDS seems to influence people to wait to evacuate or shelter, especially for difficult decisions
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camacken@iastate.edu