Hurricane Science and Engineering: Research Needs in Emergency Preparedness and Response

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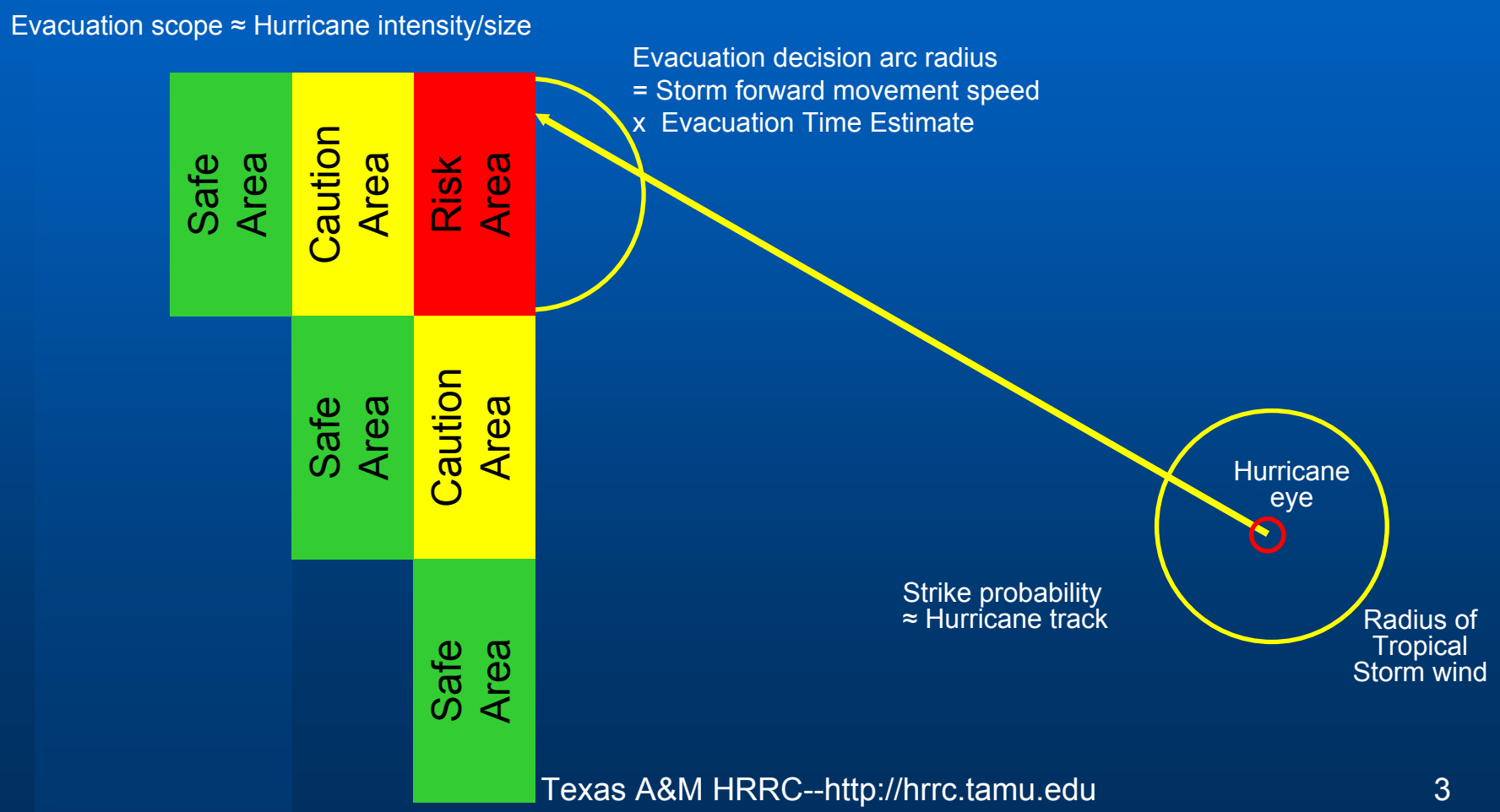
Why is evacuation research critical?

- Evacuation is a sign of policy failure (inadequate land use and building construction practices).
- Such failures are highly likely to persist, so research is needed to improve evacuation preparedness and response.
- Evacuation route system capacities will probably not increase significantly, so there is a need for better short-term (24-48) forecasting, evacuation decision making, and evacuation implementation.

Structure of the Hurricane Evacuation Management Problem



Structure of the Hurricane Evacuation Management Problem

Emergency manager questions	Meteorologist information
Will the storm strike my jurisdiction?	Storm track
How soon must I make a decision?	Forward movement speed
How far inland must we evacuate?	Intensity/ size

Structure of the Hurricane Evacuation Management Problem

Emergency manager questions	Traffic engineer information
How fast will vehicles enter the evacuation route system (ERS)?	Demand, by time and location
How fast can they move inland to safety?	ERS capacity
How long will it take to evacuate?	Evacuation time estimate

Structure of the Hurricane Evacuation Management Problem

- With respect to probable behavior, local emergency managers receive
  - Nearly complete information about storm behavior, and
  - Relatively little information about evacuee behavior.
- With respect to behavioral uncertainties, local emergency managers receive
  - Limited information about storm behavior uncertainties, and
  - No information about evacuee behavior uncertainties.

Structure of the Hurricane Evacuation Management Problem

Local emergency managers receive virtually no information about decision error costs.

	Storm strikes	Storm misses
Early evacuation	No lives lost, large cost	No lives lost, large cost
Late evacuation	Some lives lost, large cost	No lives lost, large cost
No evacuation	Many lives lost, no cost	No lives lost, no cost

Emergency Response Functions

- To develop a comprehensive hurricane emergency response system, it is necessary to understand emergency response functions and their allocation.
  - *Emergency assessment*: diagnoses of past and present conditions and prognoses of future conditions to guide emergency personnel.
  - *Hazard operations*: activities preformed to limit magnitude of impact just prior to an event.
  - *Population protection*: actions taken to prevent or minimize people's hazard exposure.
  - *Incident management*: activities to activate, coordinate and maintain the human and physical resources needed for the response effort.

Emergency Response Function Allocation Across Social Units

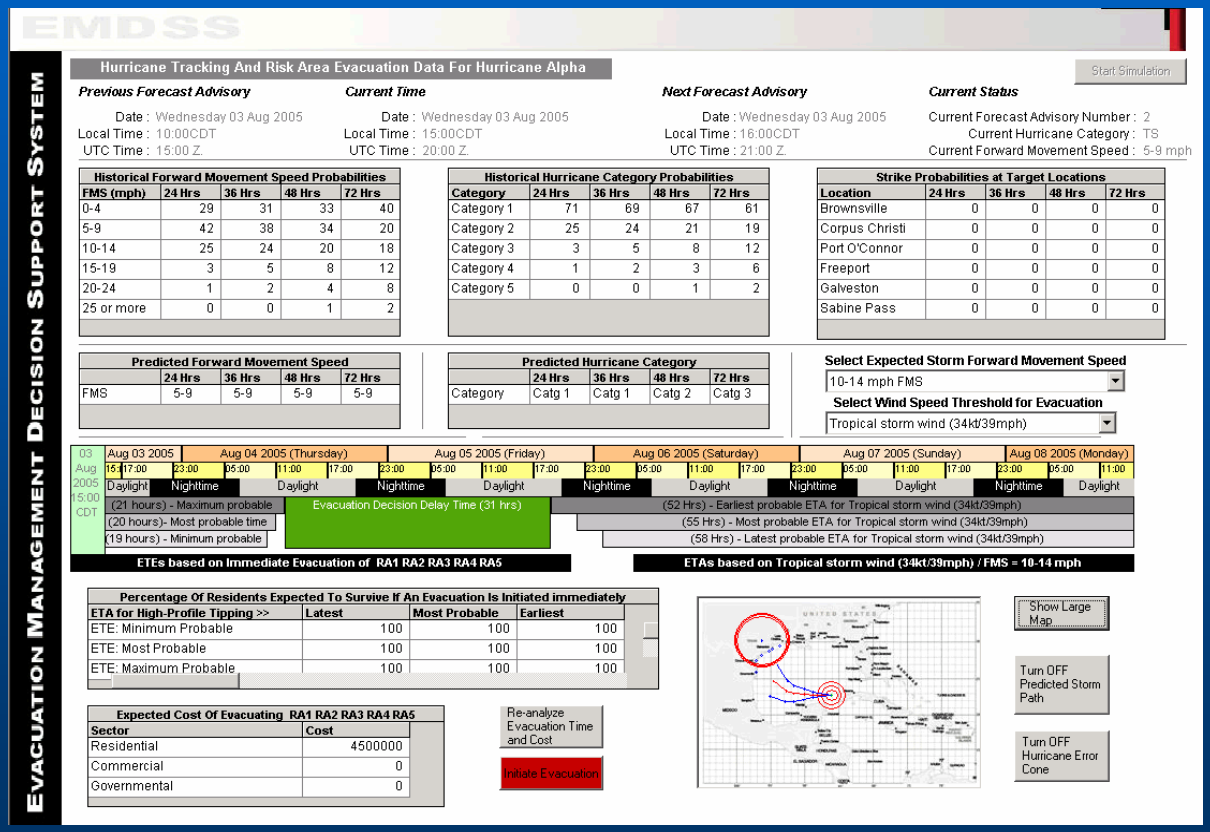
Social Units	Emergency Assessment	Hazard operations	Population protection	Incident management
National Hurricane Center/Tropical Prediction Center/Weather Forecast Offices	• Threat detection • Impact protection • Emergency classification		• Warning	• Activation • Notification • Internal and external coordination • Public information
State Emergency Management Agencies	• Emergency classification		• Protective action selection (some states) • Warning • Protective action implementation	• Activation • Notification • Internal and external coordination • Public information
Local Emergency Management Agencies	• Emergency classification		• Protective action selection (some states) • Warning • Protective action implementation	• Activation • Notification • Internal and external coordination • Public information
News Media	• (Risk perception)		• Warning	• Activation • Notification • Public information
Households, Businesses, Special facilities and other organizations	• (Risk perception)	• Area protection • Debris control • Structural protection • Contents protection	• Warning • Protective action implementation	• Activation • Internal and external coordination

Research Needs: Behavior of Social Units

- Social/behavioral research on state/local government is virtually nonexistent.
- New research is needed to address
  - Inter- and intra-organizational information collection, retention, retrieval, and distribution; and
  - Individual decision makers' cognitive processing of information about storm behavior and evacuee behavior.

Hurricane Evacuation Management Decision Support System (EMDSS)

- Research using EMDSS is beginning to study hurricane tracking exercises
  - Situational awareness,
  - Mental workload, and
  - Evacuation decision making



EMDSS Research

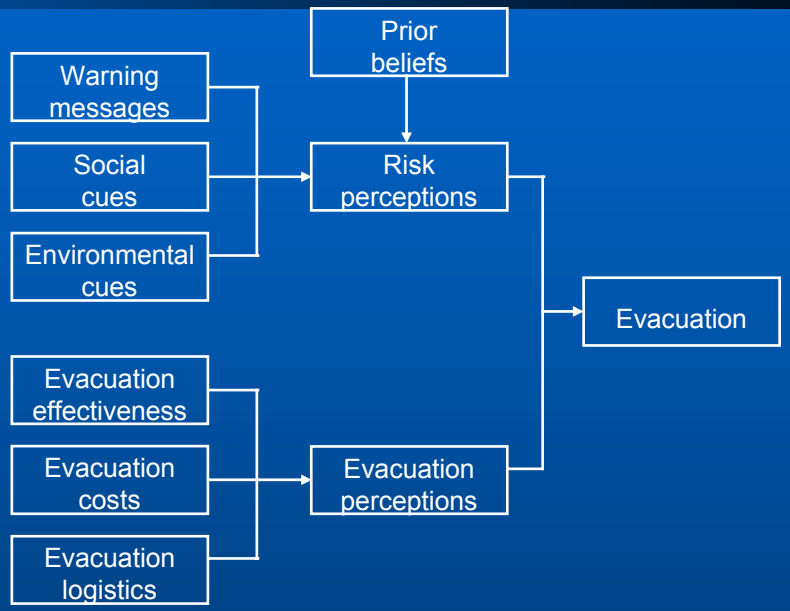
- Studies are examining the effects of
  - *Community conditions*: Population size/distribution and evacuation route system capacity
  - *Situational characteristics*: Time of day/week/season
  - *Storm characteristics*: Track, forward movement speed, intensity, size
  - *Information displays*: Current/forecast/uncertainty data for storm and evacuee behavior
  - *Decision team composition*: Individuals, groups with varying levels of knowledge

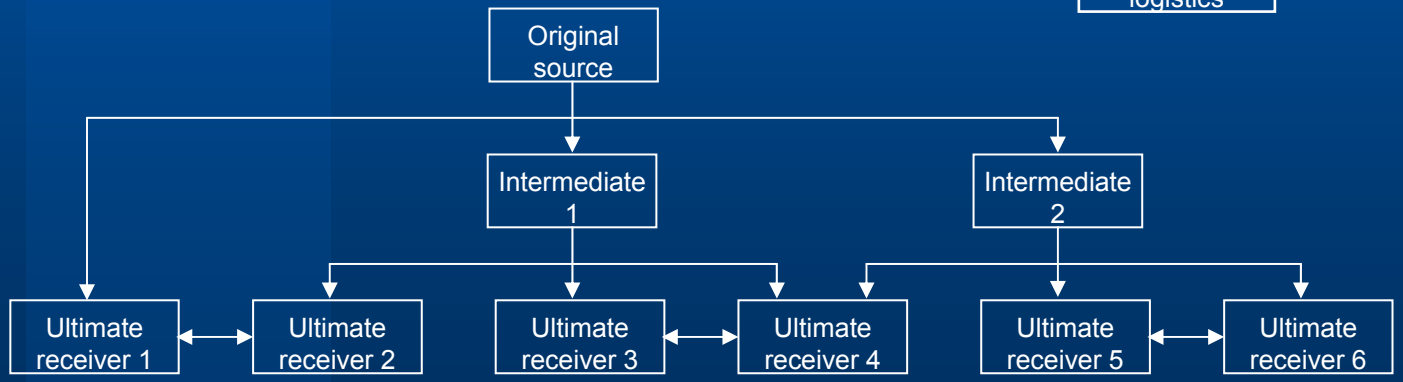
Research Needs: Behavior of Social Units

- Social/behavioral research on the news media is extremely limited
- New research is needed to address news media organizations' processing of hurricane information
  - Electronic (radio and television) vs. print (newspapers)
  - Local vs. national media
  - New technologies (e.g. cell phone and internet) that can either be used by the news media or by authorities to bypass the newsmedia.

Research Needs: Behavior of Social Units

- Social/behavioral research on households and businesses has focused
  - Mostly on warnings and compliance,



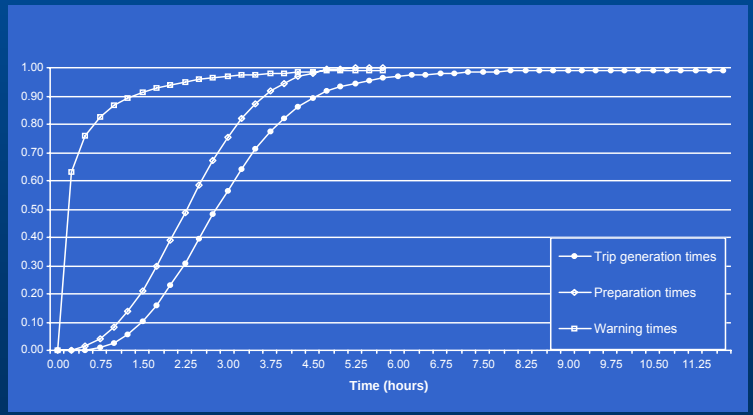


Research Needs: Behavior of Social Units

- Social/behavioral research on households and businesses has focused
  - Mostly on warnings and compliance,
  - Less on spontaneous evacuation, and
  - Little on response timing
  - Almost none on transient and transit dependent populations

Table 1: Smoothed percentages of households expecting to evacuate for hurricanes in Category One through Category Five, by Risk Area.

Risk Area	Category One	Category Two	Category Three	Category Four	Category Five
1	45.9	63.7	87.8	98.2	100.0
2	35.9	53.7	77.8	88.2	91.4
3	31.1	48.9	73.0	83.4	86.6
4	28.2	46.0	70.1	80.5	83.7
5	26.5	44.3	68.4	78.8	82.0



Research Needs: Behavior of Social Units

- Further research is needed to extend existing lines of research on
  - Prior beliefs about hurricanes and evacuations,
  - Social and environmental cues,
  - Warning source perceptions,
  - Communications channels used,
  - Risk perception processes,
  - Evacuation perception processes, and
  - Warning compliance/spontaneous evacuation.

Research Needs: Behavior of Social Units

- New research is needed to
  - Examine evacuation by transit dependent and transient population segments,
  - Expand linkages with traffic engineers' models of traffic flows,
    - Types of vehicles taken
    - Route and destination selection
    - Driving behavior in dense traffic flows
  - Assess the economic costs of evacuation incurred by households, businesses, and government agencies,
  - Assess expected fatality rates in a late evacuation.

Evacuation Parameters Identified by EMDSS

1. Size and distribution of the risk area resident population
2. Transit dependent resident population
3. Number of persons per residential household
4. Number of evacuating vehicles per residential household
5. Number of evacuating trailers per residential household
6. Number of hotel rooms
7. Hotel occupancy rate (number of transients)
8. Number of vehicles per evacuating hotel room
9. Percentage of early evacuating residential households
10. Percentage of early evacuating transients
11. Percentage of residents' PAR compliance/spontaneous evacuation
12. Percentage of transients' PAR compliance/spontaneous evacuation
13. Residential households' trip generation time distribution
14. Transients' trip generation time distribution
15. Evacuees' utilization of the primary evacuation route system
16. Evacuees' utilization of routes within the primary evacuation route system
17. Evacuation destinations
18. Residential households' evacuation costs
19. Commercial evacuation costs
20. Governmental evacuation costs
21. Survival rates in structures, by surge depth and wind speed
22. Survival rates in vehicles, by surge depth and wind speed

Questions?