ERGONOMICS & HUMAN FACTORS IN DISASTER MANAGEMENT

Pamela McCauley Bush, Ph.D. CPE
Department of Industrial Engineering & Management System
University of Central Florida

Collaborators & UCF Team

- Dr. Lewellyn Curling, College of the Bahamas
- Mr. Phillip Armbrister, College of the Bahamas
- Mr. Mohammad Jeelani, University of Central Florida
- Mr. Arturo Watlington, University of Central Florida
- Ms. Susan Gaines, University of Central Florida

Ergonomics & Human Factors in Disaster Management

- Disaster management and response is an inherently human intensive process with human interaction and decision making
- All phases of the disaster management continuum
  - Hierarchical human intensive decision making structure
 - First Responders
  - Victims

Prevalance & Impact

- From 1980–2009, there have been 96 weather–related disasters globally in which overall damages costs exceeded $1 billion per event.
- The number of deaths due to terrorism from 2005–2009 was 88,431 people.
- In 2007 alone, the losses due to fire in the US were over $14 billion

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Scientific Community Response

- Society has turned to science and technology for solutions:

  The National Academies of Science has defined a need for the scientific community …"to pursue research that addresses the application of information technology in various areas of disaster management."

Overview of Research
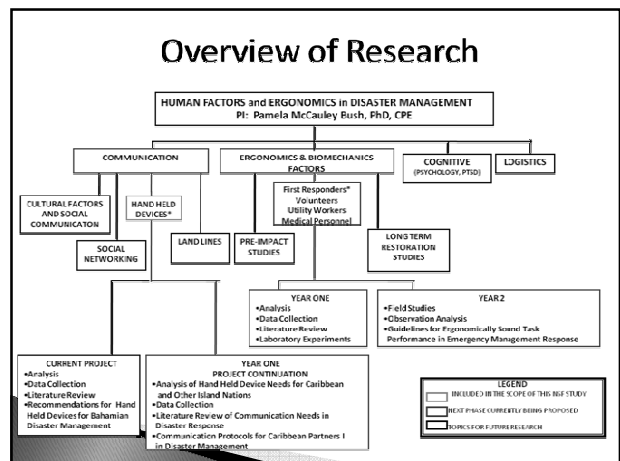
What Technologies?

▸ Research has shown that the technologies to be used in global high consequence disaster management must have the following characteristics:
  ◦ Reliable and Accurate
  ◦ Resilient
  ◦ Cost effective
  ◦ Compatible with the environment
  ◦ Globally or Regionally Accessible

  ◦ ...... *"Wireless and Mobile Technology!"*

Significance

• Wireless communication is used extensively in emergency management yet it has not been officially implemented in the emergency management policies of many counties, states and countries

Significance

• A methodology for assessing these devices specifically when used during emergencies does not exist.
• The human factors and usability issues associated have not fully evaluated
• Human factors compatibility will be a primary factor in usefulness

Mobile Communication

▸ Evaluate the use of hand-held communication devices among emergency management professionals and the general population

▸ Research the characteristics that impact usefulness of hand-held devices

▸ Develop a mathematical model to quantify the human factors compatibility of hand held communication devices in emergency management

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Background & Literature Review

▸ Literature Review Matrix

	Alexander and Klein	Arif	Department of Defense	Natl. Institute of Justice	Ide and Kaneta	Jones	Leventhal and Barnes	Meissner et al.	NEMA	Shankar	Souza and Kusolchu	Villagran et al.	WirelessGuide	Zingale et al.	Jeetani
Infrastructure needs								X							X
Organizational needs	X					X	X		X	X	X				X
Equipment needs		X	X	X			X	X					X	X	X
Civilian considerations					X				X	X					X
Response procedures									X						X
Information exchange				X			X					X			X
Human factors	X											X			X
Usability			X	X					X				X	X	

Research Methodology

▸ Background & literature review
  ◦ Academic publications
  ◦ Review manuals, instructions and guidebooks for hand held devices
  ◦ Emergency management standard operating procedures,
  ◦ Emergency Support Functions
▸ Data Collection
  ◦ Community Survey
  ◦ Emergency Management Professionals Survey
▸ Determination of Device Selection Factors
  ◦ Determine levels of existence for factors
▸ Ergonomic Equipment Evaluation
▸ Develop aggregate mathematical model
▸ Laboratory Test
▸ Model Validation

Data Collection

- Survey: experts and community
- An ergonomic and physical evaluation of devices
- Laboratory Study
- Model Development
  - Subject Matter Expert Interviews
    - Factor weighting
      - Obtain relative significance using analytic hierarchy processing
    - Quantification of factors
    - Development of aggregate model

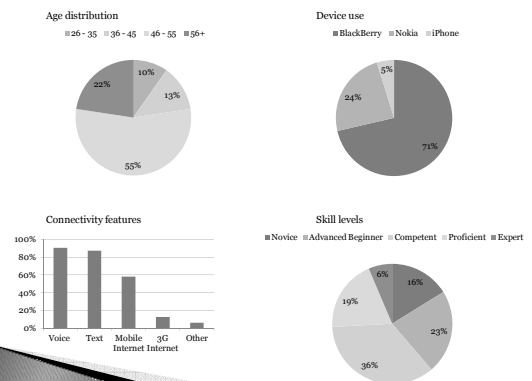## Survey of Emergency Management Officials

- A survey conducted involving 31 Bahamian emergency management officials
- The survey consisted of 29 multiple choice questions and 4 free response questions
- Questions were grouped under the associated topics of:
  - Background
  - Hand-held communication experience
  - Device performance
  - Usability
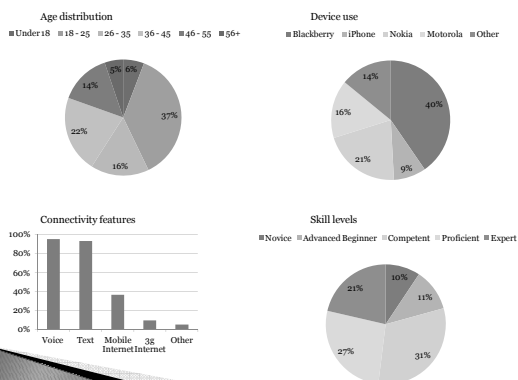 - Other communication devices
  - Suggestions

Survey of Bahamian Civilians

- A similar survey was conducted involving 155 randomly selected Bahamian civilians living in Nassau.

- The survey consisted of 14 multiple choice questions as well as 3 free response questions regarding use of hand-held communication devices in emergency situations

Survey Responses for E.M. Officials

Age distribution
26 - 35   36 - 45   46 - 55   56+
10%
13%
22%
55%

Device use
BlackBerry   Nokia   iPhone
5%
24%
71%

Connectivity features
100%
80%
60%
40%
20%
0%
Voice   Text   Mobile Internet   3G Internet   Other

Skill levels
Novice   Advanced Beginner   Competent   Proficient   Expert
6%
16%
19%
23%
36%

Survey Responses for Civilians

Age distribution
Under 18   18 - 25   26 - 35   36 - 45   46 - 55   56+
5%   6%
14%
22%
16%
37%

Device use
Blackberry   iPhone   Nokia   Motorola   Other
14%
16%
21%
9%
40%

Connectivity features
100%
80%
60%
40%
20%
0%
Voice   Text   Mobile Internet   3G Internet   Other

Skill levels
Novice   Advanced Beginner   Competent   Proficient   Expert
10%
11%
21%
27%
31%

Hand Held Devices Identified

- The following devices were determined to be the most popular among SME's and citizens
  - BlackBerry Torch
  - BlackBerry Curve
  - Motorola Bravo
  - Nokia 2330
  - iPhone 3GS

Infrastructure Needs

- High availability of connectivity features
- Fast data access
- Access to 3G mobile internet
- Access to picture and video messaging
- Better wireless signals
- More reliable service

Organizational Needs

- More effective intra-organizational and inter-organizational coordination
- Integrated communication and information system for disaster management
- Integration and linkage of information
- Timeliness and updating of information
- Standardization of information
- Phased information release
- *Utilization of mobile technology in order to promote civilian awareness*

Equipment Needs (primary)

- Devices that require little physical and cognitive effort
- Devices that are portable
- Appropriate human-computer interface
- Devices that are durable
- Ergonomically designed devices
- Devices with adequate grip
- Devices that consider user capability
- Devices that are cost effective
- Devices that consider usability
- Weather resistant
- Alternative methods for powering devices

Usability Factors Identified

- Ease of learning,
- Efficiency of use,
- Ease of remembering,
- Frequency of errors, and
- Subjective pleasure

‣ * Nielson's model of usability

Device Selection Factors & Ratings

	3	2	1
Durability	Designed for rugged use and is submersible in water	Designed for rugged use, but is not submersible in water	Designed for standard use only
Battery life and type			
Talk time	Equal to or greater than 8h	Greater than 4h but less than 8h	Less than 4h
Standby time	400h+	200h-400h	Less than 200h
Battery type	Li-Ion	NiMH	NiCad
*Accommodation to environmental lighting	Extremely well	Well	Poorly
Text Entry	Mini-Qwerty physical text entry with large buttons	Mini-Qwerty physical text entry with small buttons	Mini-Qwerty soft text entry or limited key physical text entry
*Grip	Highly Adequate	Adequate	Inadequate
Screen size	320x480 or larger	176x220 to 320x480	176x220 or smaller
Portability			
Weight	Under 3.0 oz	3.0-6.0 oz	Over 6.0 oz
Volume	Under 5.0 in³	5.0-6.0 in³	Over 6.0 in³
*Audio clarity	Extremely clear	Clear	Unclear
Usability			
*Ease of learning	Extremely easy	Easy	Difficult
*Efficiency of use	Under $(\bar{x}-5z)$ task time	$(\bar{x}-5z)-(\bar{x}+5z)$ task time	Over $(\bar{x}+5z)$ task time
*Ease of remembering	Extremely easy	Easy	Difficult
*Frequency of errors	Less than $(\bar{x}-5z)$	$(\bar{x}-5z)-(\bar{x}+5z)$	More than $(\bar{x}+5z)$
*Subjective pleasure	High	Medium	Low
Unit Cost	Over $300	$100-$300	Under $100

Fuzzy Mathematical Model

‣ Sources of input
  ◦ Background and literature
  ◦ Subject Matter Experts: Emergency Management Officials survey
  ◦ Community survey

Subject Matter Expert Interviews

- Interviewed Bahamian emergency managers "again"
  - AHP analysis to obtain relative significance of factors
  - Range of existence for factors to establish universe of discourse and fuzzy membership functions

AHP Results for Usability

Ranking (k)	Factor	Relative Weight (b_k)
1	Ease of remembering	.306
2	Ease of learning	.202
3	Efficiency of use	.177
4	Frequency of errors	.166
5	Subjective pleasure	.148

AHP Results for Device Selection

Ranking (j)	Factor	Relative Weight (a_j)
1	Audio clarity	.163
2	Usability	.162
3	Portability	.126
4	Accommodation to environmental lighting	.093
5	Battery life and type	.085
6	Unit cost	.083
7	Text entry method	.081
8	Grip	.072
9	Screen size	.069
10	Durability	.065

AHP Results for Portability Factors

Ranking (l)	Factor	Relative Weight (c_l)
1	Weight	.677
2	Volume	.323

Usability Rating (U)

- $U = g_1b_1 + g_2b_2 + g_3b_3 + \ldots + g_nb_n$

- Where:

  - U = Usability rating
    - g_o = rating of existence for each usability factor
    - b_k = weighted priority for each usability factor

Device Selection Rating (DS)

- $DS = j_1d_1 + j_2d_2 + j_3d_3 + \ldots + j_nd_n$

  - j_n = Rating for each device selection factor
  - d_n = Weighted importance of each device selection factor

  -

Portability Rating (P)

▸ $P = h_1 c_1 + h_2 c_2 + h_3 c_3 + \ldots + h_n c_n$

- h_n = Rating for each portability factor
- c_2 = Weighted importance of each portability factor

Overall Mathematical Equation

▸ $HFER = U_1 a_1 + DS_3 a_3 + P_4 a_4$

▸ Where:
- HFER = overall human factors and ergonomics rating for device use in emergency management

- U_1 = Usability rating
- a_1 = Relative significance of Usability

- DS_3 = Device Selection Factors Rating
- a_3 = Relative significance of Device Selection Factors

- P_4 = Portability Rating
- a_4 = Relative significance of Portability

Model Validation:
Laboratory Experiment

- Laboratory experiment utilized 17 subjects:
  - Performed standard emergency response activities
    - Place an emergency call
    - Take a picture and send it
    - Compose a text

Ratings of Currently Used Devices

	Audio clarity	Power/ transmitting	Rate of Learning	Efficiency of use	Frequency of Errors	Subjective Human	Stability	Weight	Volume	Portability	Accomodation to environmental Lighting	Battery Life(talk)	Battery Life (standby)	Battery Type	Military	Unit Cost	Text entry method	Help	Screen Size	Durability	Weighted Score
	.163	.906	.202	.177	.166	.148	.162	.677	.323	.126	.093	.514	.323	.161	.085	.083	.031	.072	.069	.065	1.00
BlackBerry Torch	2.3	2.1	2.2	1.9	2.2	2.0	2.1	2.0	1.0	1.7	2.7	2.0	2.0	3.0	2.2	1.0	2.0	2.3	3	1.0	2.05
Blackberry Curve	2.0	1.9	1.4	1.6	1.9	1.1	1.7	2.0	1.0	2.0	2.0	2.0	3.0	2.2	1.6	2.0	2.1	3	1.0	1.88
Motorola Bravo	2.2	2.5	2.4	2.3	2.0	2.0	2.3	2.0	2.0	2.0	2.5	2.0	2.0	3.0	2.2	1.6	1.0	2.3	3	1.0	2.00
Nokia 2330	2.1	2.1	1.5	1.9	1.8	1.1	1.5	3.0	3.0	3.0	1.8	1.0	2.0	3.0	1.7	3.0	1.0	1.9	1	1.0	1.92
iPhone 3GS	2.5	2.5	2.5	2.2	2.2	2.1	2.3	2.0	1.0	2.0	2.7	1.0	2.0	3.0	2.2	2.0	1.0	2.4	3	1.0	2.16

- Preliminary Outcomes:
  - *The iPhone 3GS was the most appropriate device for use during emergencies*

Conclusion

- Preliminary model has been developed and validated
- Research is ongoing to further refine, validate, and expand the mathematical model
- Additional HFE research is needed in the areas identified in SME and civilian interaction

Next Steps

▸ Additional validation and expansion of model
▸ International application in other nations
▸ Sustainability in Disaster Management

Sustainability in Disaster Management

‣ How do we implement disaster management processes, equipment and methods the accomplish the required goals and yet support sustainability?

Why does Sustainability Matter

‣ The human impact is primarily considered but often not focused on demographics
‣ Economic impact of global disasters is staggering
‣ The response and restoration activities can dramatically impact the environment, natural resources, infrastructure and communities

…Theoretically speaking:

"Effective integration of systematic sustainability methods in disaster response can save lives, the reduce negative environmental impact and minimize the economic impact of a natural or man-made disaster"

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A Few Research Questions?

‣ Is the necessary knowledge applied?
‣ Can the system model be defined?
‣ Can system factors be quantified, qualified measured and aggregated?
‣ Can the model be validated?

Disaster Management Sustainability: A Proposal

‣ Interdisciplinary approach
‣ Global perspective
‣ Collaborative approach
‣ Expected Outcomes:
  ◦ Validated outcomes that address this gap in the body of knowledge
  ◦ Processes, training and equipment in all Emergency Support Functions (ESF) used by counties, states and nations that consider sustainability in
    · Human resources
    · Environment
    · Economics

There is work to be done….

Thank You