



High Rise Building Evacuation

Lessons Learned from the World Trade Center Disaster

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Lecture Outline

- **Introduction**
 - Human behavior in emergencies
 - High rise building emergencies-considerations
 - Background- recent high rise emergencies
- **World Trade Center Evacuation Study**
 - Preliminary quantitative results
 - Lessons identified
 - Lessons learned



Human Behaviors in Emergencies

What is Known:

1. Will generally not go towards smoke
2. Seek out groups and stay with group even if it is not the best option
3. Group size is important
4. Information serves as motivator



Human Behaviors in Emergencies

5. The faster groups form - the faster they evacuate
6. Individual and group panic dependent on several key factors
7. Familiarity helps groups to form and minimizes panic
8. Leadership is especially important in public spaces- both for shaping group behaviors and for guidance



High Rise Considerations

- Do occupants in high rise emergencies behave in ways that are similar to non-high rise occupants?
- Do emergency preparedness plans (other than evacuation plans) differ for high rise vs low rise buildings?
- How does high rise workplace occupancy differ from public use space in terms of evacuation behaviors? Lessons??



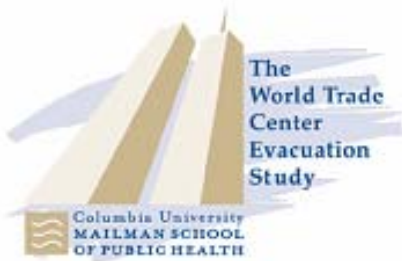
Implications

- If the behavior is the same as non-high rise emergencies, does it have utility in a high rise situation? If not, can the behavior be changed?
- If the planning is the same as for occupants of low-rise buildings, is it effective? If not, can it be changed?



Background

- **High Rise Emergencies**
 - WTC, 1993
 - Oklahoma City, Murrah Building, 1995
 - Chicago High Rise Fires, 2003, 2004
 - **WTC, 2001**



WTC Bombing, 1993

- February 26, 1993, 12:17 pm
- Explosion under plaza
- 1300 lbs of explosives
- 6 deaths
- 1,000 injuries
- 40,000 per building evacuated
- 6 hours after evacuation, people were found at their desks

WTC Bombing, 1993





Murrah Building Oklahoma City, 1995

- 9-story federal building
- 4,000 lbs of explosives
- Massive structural damage
- 168 deaths (46% fatality rate)
- >800 injuries (47%)
- Combined, 93% of occupants affected
- 800 other buildings in the area were damaged or destroyed

Murrah Building Oklahoma City, 1995





Chicago High Rise Fire, 2003

- October, 2003, 5:00pm
- Cook County administrative building, 35-story
- 6 deaths (trapped in stairwell)
- 8 hospitalized
- No sprinklers

Chicago High Rise Fire, 2033





Chicago High Rise Fire, 2004

- December, 2004, 6:30pm
- 29th floor of LaSalle Bank, 45-story
- Caused by electrical malfunctions
- No sprinklers
- 37 injuries

Chicago High Rise Fire, 2004



WTC, 2001

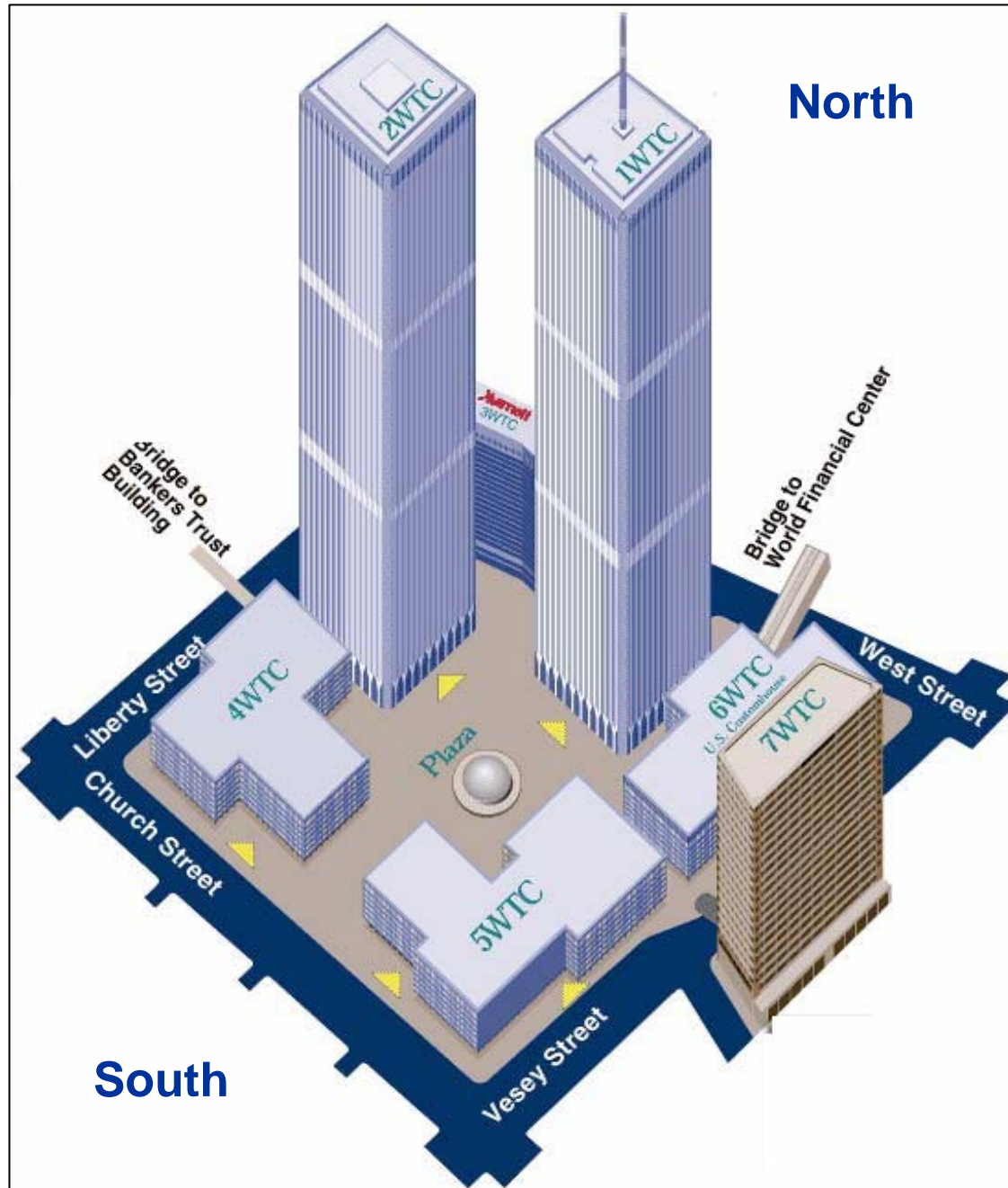
North Tower Impact

- 8:46am
- 767, 10K gallons
- Impact at 94-98th floors
- Collapsed 1 hour and 42 minutes after impact

South Tower Impact

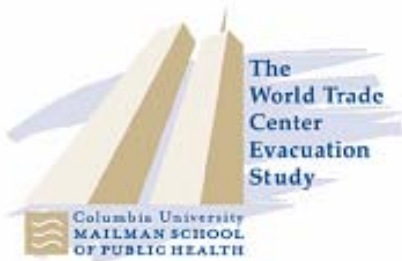
- 9:02am
- 767, 10K gallons
- Impact at 79-84th floors
- Collapsed 57 minutes after impact

WTC Complex



WTC, 2001

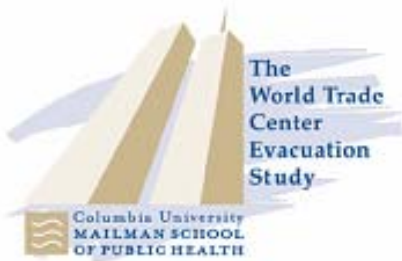




WTC, 2001

Fatalities

- 421 first responders
- 147 jetliner crew and passengers
- 1,466 in North Tower (1,356 above impact)
- 624 in South Tower (618 above impact)
- 18 bystanders (on the ground)
- 73 location unknown
- Total deaths: 2,749
- 11% of occupants died, most above point of impact



Design Features of High Rises

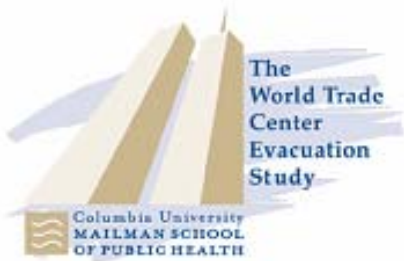
- Not designed to withstand impact of fuel laden large aircraft
- Most high rise buildings are not designed for emergency full building evacuation at magnitude required by WTC Disaster
- Rescue of occupants located in inaccessible areas of high rises above the point of impact is not possible



WTC Evacuation Study

Study Objectives

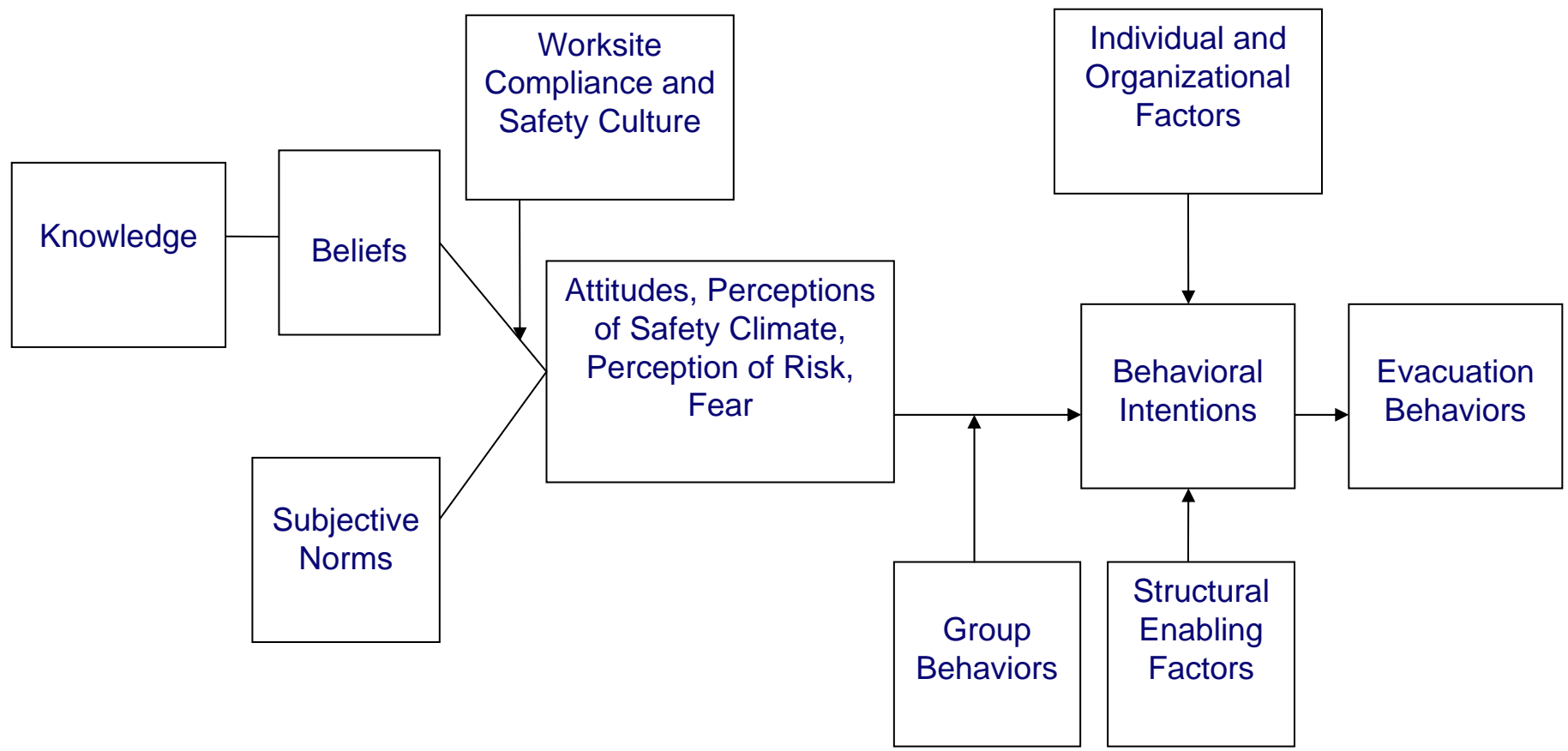
- To identify the individual, organizational, and environmental structural (building) factors that affected evacuation from the WTC on 9/11/01
- To inform policy and practice that support safe evacuation of high rise structures
- To inform preparedness for other mass evacuations



Colleagues

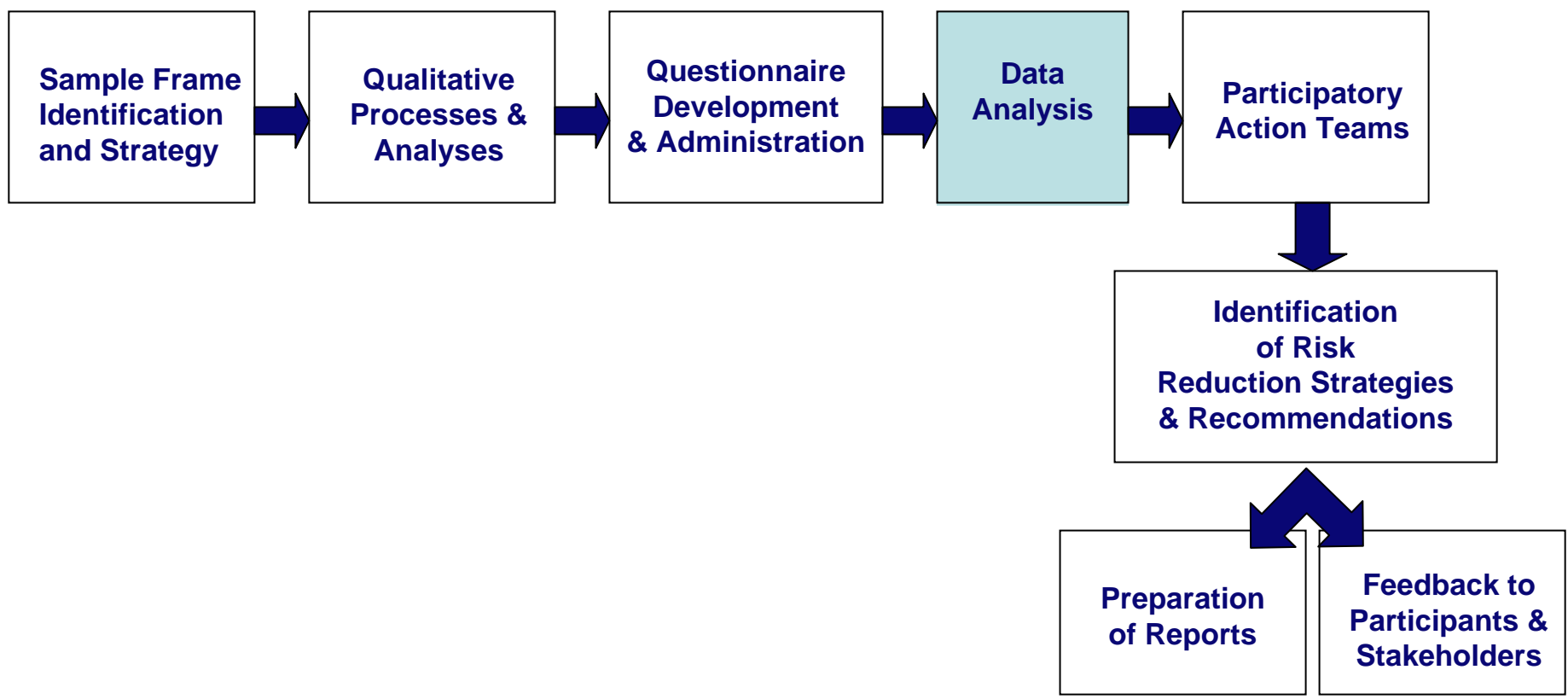
- Kristine Qureshi, RN, DNSc
- Martin Sherman, PhD
- Marcie Rubin, MPH, MPA

WTC Evacuation Study Model





WTC Evacuation Study: Overview





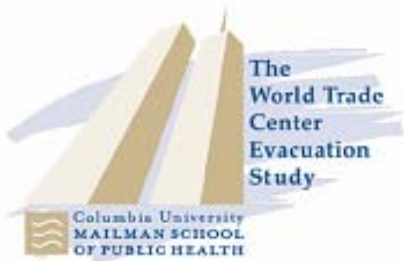
Outcome Variables

- Decision to evacuate
- Began to evacuate
- Reached the street level (Rate of evacuation= minutes per floor)
- Injuries (physical and psychological)
- Long term health impact



Independent Variables

- **Individual**
 - Pre-event health status, peri-event sensory input, familiarity with building, prior experiences, knowledge, subjective norm, delaying activities, post-event experiences and treatment
- **Organizational**
 - Preplanning, emergency preparedness climate, leadership
 - Risk communication
- **Structural**
 - Egress factors
 - Communication infrastructure



Preliminary Quantitative Data

- Responses: 1767 total;
- Of these, **1444** (82%) evacuated on 9/11/01
- Demographics (N=1444):
 - Gender: 58% male
 - Age, mean yrs: 44 yrs
 - Age, range: 22-80 yrs
 - Tenure, mean: 6 yrs
 - Tenure, range: 0-37 yrs
 - Marital status: 70% married/partner
 - Children: 48%
 - Race: 80% Caucasian
 - Education: 66% college+
 - Employment: 84% private company
 - Union membership: 7%



Preliminary Quantitative Data

Individual Factors

- Health Status:
 - Disability or medical condition: **23%**
 - Including...
 - Asthma: 28%
 - Mobility: 21%
 - Mental Health: 15%
 - Heart Condition: 12%
 - Other (pregnancies, illness): 15%
 - Vision: 5%
 - Hearing: 3%
 - Smoking: 19%
- **16% said their disability affected their ability to walk down large number of stairs**



Preliminary Quantitative Data

Individual Factors-Knowledge

- Building Participants **DID NOT KNOW:**
 - 49%: 3 stairwells
 - 20%: Exit locations
 - 45%: Doors on certain floors were locked
 - 86%: Where stairs would lead
 - 73%: Where sky lobbies were located
 - 26%: Thought roof might be means of escape
 - 25%: Not sure about roof



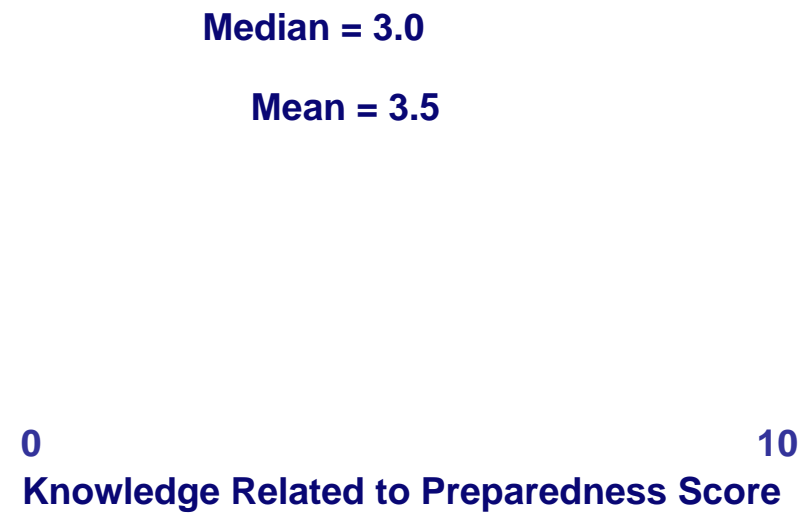
Preliminary Quantitative Data

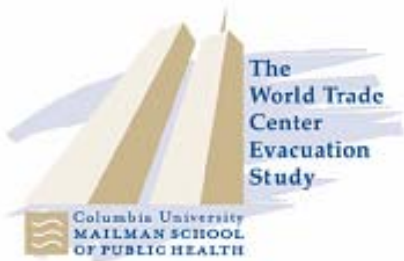
Individual Factors-Knowledge

- **Knowledge Related to Preparedness (10 Questions)**

- Mean 3.5
- Range 0-10
- Median 3.0
- Mode 2.0

Number of Participants





Preliminary Quantitative Data

Individual Factors-Knowledge

- **Knowledge on Disability Preparedness:**
 - 28% reported having a disabled person on their floor
 - 11% said a plan for disabled evacuation was in place
 - 10% said co-workers were assigned to assist disabled individuals
 - 8% said there was special equipment for disability evacuation



Preliminary Quantitative Data

Organizational Factors-Preparedness

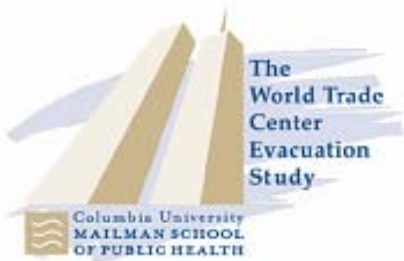
- 39% were **never** provided with written fire safety instructions
- 41% **never** provided with evacuation plans
- 67% reported **no plans** regarding where to gather after evacuating
- 47% **no plans** for head count
- **Only 21% were familiar** with their building.



Preliminary Quantitative Data

Organizational Factors-Preparedness

- 20% **were not** familiar with who was in charge
- 94% had never exited the building as part of a drill
- 27% had evacuated the building prior to 9/11 at least once (1993)
- 81% had participated in fire drills, but of these, **only 10% had ever entered a stairwell**
- 50% were knowledgeable to **evacuate on own**



Preliminary Quantitative Data

Structural Factors

- **Communication**

- 39% could not hear or recall ANY PA system announcements
- 26% reported false alarms once a month or more

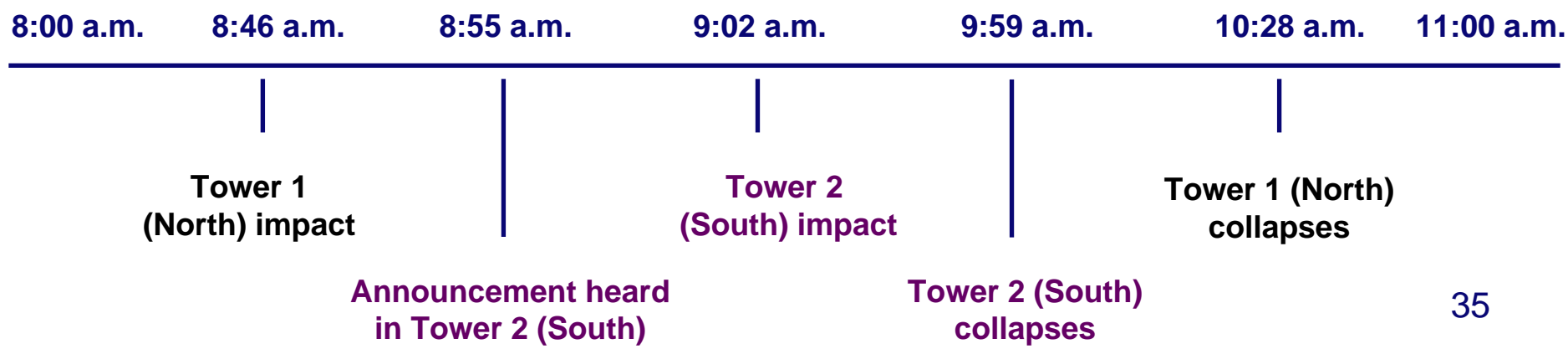


Preliminary Quantitative Data

Key Time Periods

- First became aware
- Made decision to leave
- Began to leave
- Reached street level

	WTC1		WTC2	
	mean	range	mean	range
First became aware	8:46	8:46- 9:20	8:47	8:46-9:02
Made decision to leave	8:51	8:46- 9:30	8:52	8:46-9:30
Began to leave	8:52	8:46- 9:30	8:53	8:46-9:30
Reached street level	9:32	8:46-10:28	9:15	8:46-9:58



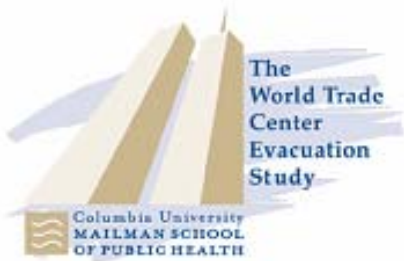
Preliminary Quantitative Data

- **Decision to evacuate**
 - Individual level
 - sensory input
 - calls from outside
 - influence of subjective norm
 - Organizational level
 - leadership decision-making
- **Began to evacuate**
 - Individual level:
 - delaying activities - two or more led to statistically significant delays in initiation
 - Disabilities: twice as likely to delay initiation



Peri-Event Experiences

- 60% overcrowding
- 26% smoke/dust
- 30% water
- 9% locked doors
- 9% light
- 5% fire/intense heat



Preliminary Quantitative Data

Individual Factors

Delaying Activities...

Once they decided to leave, but BEFORE they began...

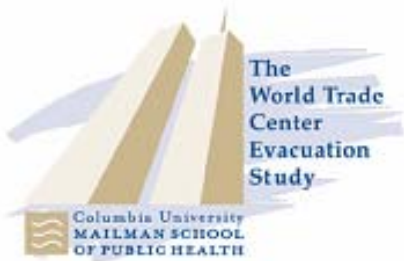
- Gathered items (40%)
- Sought out friends/co-workers (33%)
- Searched for others (26%)
- Phone calls (18%)
- Shut down/PC-related (8%)
- Waited for direction (7%)
- Gathered safety equip. (5%)
- Changed shoes (3%)
- Tried to obtain permission to leave (1%)



Preliminary Quantitative Data

Rate of Descent

- **Reached the street (stairs only)**
 - Rate ~ 1 min/floor
 - Rate was affected by:
 - Age
 - Gender
 - Disability
 - Knowledge
 - Leadership



Preliminary Quantitative Data

- **Physical Injuries: 37% (n=518)**
 - Inhalation Injury 11% (n=156)
 - Bruises 9% (n=126)
 - Cuts 6% (n=87)
 - Eye injury 4% (n=57)
 - Miscellaneous 12% (n=167)
- **Psychological Injuries: 24% (n=345)**
- **Severity:**
 - 63% sought medical care
 - 7% were hospitalized
 - 17% have long term health problems



Preliminary Quantitative Data

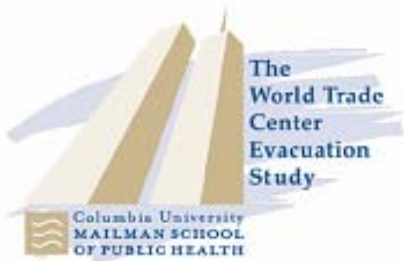
- **Reached the street (min/per floor)**
 - Organizational: Lack of leaders, poor preparedness
 - Structural: Blocked egress, crowding, lack of communication systems



Group Leader Characteristics

Characteristics of Leaders They Followed

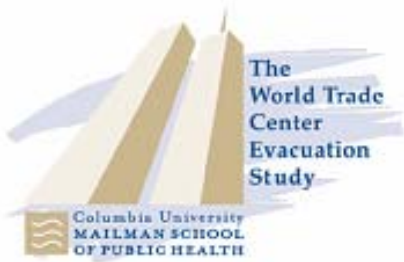
1. Calm
2. Authoritative Voice
3. Directive
4. Knowledgeable



Preliminary Quantitative Data

Leaving the Immediate Vicinity

- **Delaying Behaviors: Street Level**
 - 50% did not immediately leave the area
 - 36% stopped to see what was happening
 - 26% looked for friends/co-workers
 - 15% looked for a phone
 - 14% did not know where to go



Most Important Factors That Helped The Evacuation

- Staying calm (“Acting”)
- Instincts
- Mutual support
- Directions of first responders/NY/NJ Port Authority
- Integrity and condition of stairwells
- Lack of overcrowding on stairwells



Preliminary Recommendations

- Delineation of responsibilities
- Coordination/pre-planning with local agencies
- Communication systems
- Written plans, policies that target full evacuation if necessary
- Training, mandatory, new, annual, and orientation
- Specific preplanning for people with disabilities
- Drills to include stairwells, especially transfer hallways
- Evacuation drills - at least partial, leaders chosen with experience



Preliminary Recommendations

- **Inform:**
 - Building owners, leaseholders, employees
 - Code development
 - Building design
 - Regulatory compliance
 - Emergency planners
 - Other stakeholders



Next Steps

- Develop and evaluate model evacuation plans, focus on the building's safety leadership [NYC Code: Evacuation Action Plan Directors]
- Foster familiarity with stairwell environment-building occupants
- Widespread dissemination to reach all stakeholders
 - Spring meeting for all WTC employees and family members
 - Fall 2006 NYC meeting for all stakeholders



Next Steps

- Stakeholders
 - Building owners, managers, leaseholders, employees
 - Code developers
 - Building designers
 - Emergency planner



WTC Evacuation Study

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