

**Federal Building and Fire Safety Investigation  
of the World Trade Center Disaster**

**World Trade Center Investigation Status  
Project 7: Occupant Behavior, Egress, and  
Emergency Communications**

October 20, 2004

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# Purpose and Outcomes

**Purpose:** To determine the behavior and fate of occupants and responders by collecting and analyzing information on:

- occupant behavior
- human factors
- egress
- emergency communications
- evacuation system

## Desired Outcomes

- Enhanced evacuation systems
- Enhanced safety of occupants

# Collection of Occupants First Person Accounts

- Face-to-face Interviews
  - Over 225 Occupants of WTC 1, 2, and 7
- Telephone Interviews
  - 803 Occupants of WTC 1 and 2
- Focus Group Interviews
  - 6 Focus Groups

# Other Activities

- Other Data Collection
  - 9-1-1 Records
  - Published Accounts
  - Written Communications, Protocols, and Procedures
  - Scientific Literature
- Causal Modeling
- Egress Modeling
- Observations of Fire, Smoke, and Damage

## Initial Building Population

- Total Building Population at 8:46 a.m. on September 11<sup>th</sup>:
  - WTC 1: 8,900 ± 750
  - WTC 2: 8,500 ± 900
  - Both Towers: 17,400 ± 1,200

# Decedent Analysis

## Sources of Information:

September11Victims.com: This site is dedicated to the victims of September 11, 2001 tragedy.

Portraits: 9/11/01: Published by the New York Times in 2003, this book includes short interviews with family members of many decedents.

CNN.com In-Depth Special (<http://www.cnn.com/SPECIALS/2001/memorial/index.html>): Tribute site for people to write remembrances of decedents.

Badge List maintained by Port Authority of New York and New Jersey: Includes name, employer, building, and floor for all occupants with badge-access to WTC 1 or WTC 2.

Numerous memorial sites maintained by companies which lost employees: Includes names and remembrances of decedents. Examples include the Port Authority, Fire and Police Departments, Marsh & McLennan Companies, EuroBrokers, Fiduciary Trust, and others.

Newsday.com: Includes short stories written about specific decedents.

NIST Interviews with occupants and family members

\* Where possible, we have used eyewitness accounts to place individuals. Where no specific accounts existed, we used employer and floor information to place individuals.

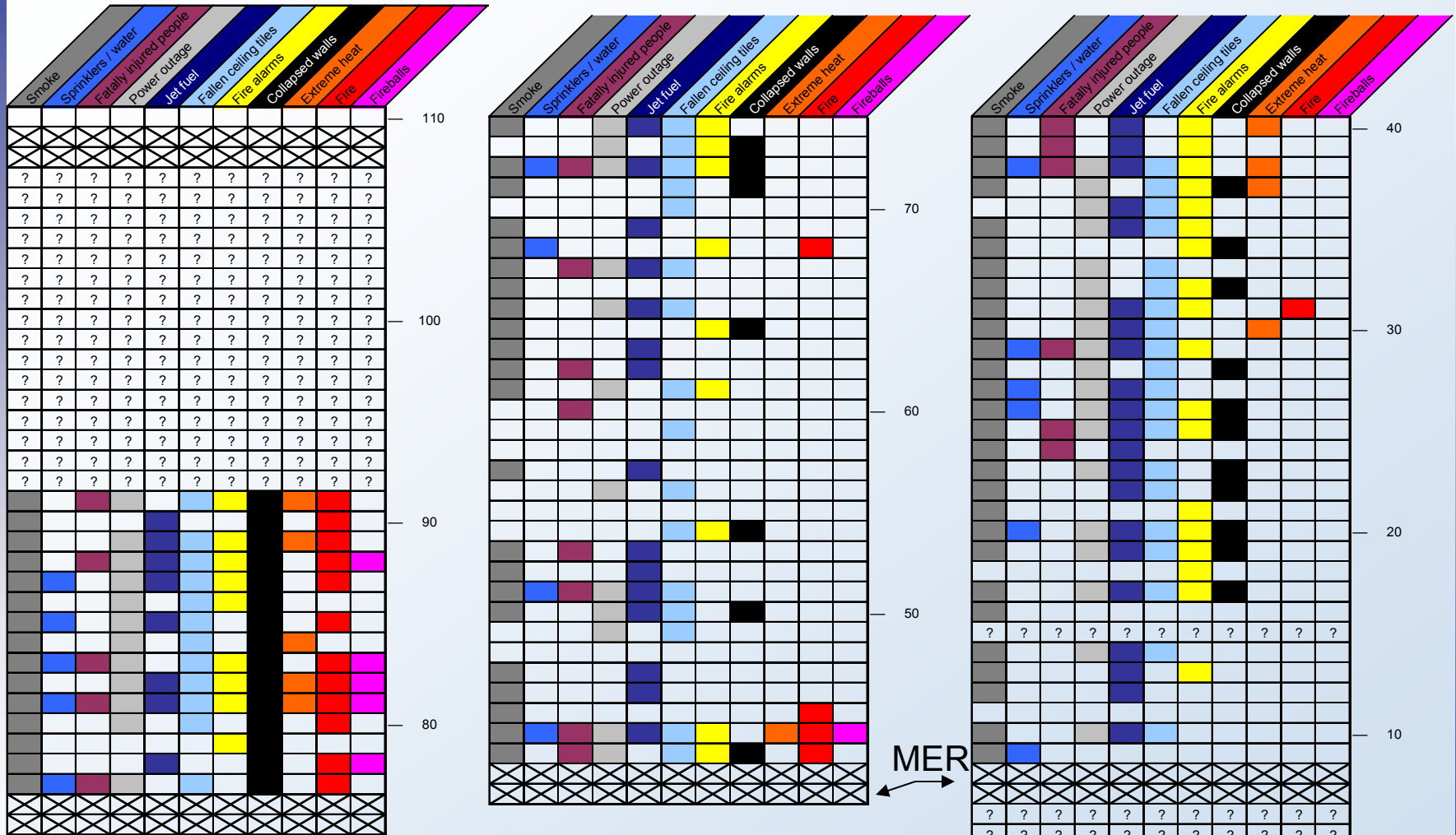
Likely Location at Time of Impact*		
<b>World Trade Center 1 Occupants</b>		<b>1,466</b>
	At or Above Impact	1,355
	Below Impact	111
<b>World Trade Center 2 Occupants</b>		<b>624</b>
	At or Above Impact	617
	Below Impact	7
<b>Confirmed Below Impact in WTC 1 or WTC 2</b>		<b>30</b>
<b>Unknown Location Inside WTC 1 or WTC 2</b>		<b>26</b>
<b>First Responders (Total)</b>		<b>421</b>
	FDNY	343
	NYPD	23
	PAPD	37
	Hospital/Paramedic	7
	Federal	2
	Volunteer Responders	9
<b>Bystander/Nearby Building Occupant</b>		<b>18</b>
<b>American Flight 11</b>		<b>87</b>
<b>United Flight 175</b>		<b>60</b>
<b>No Information</b>		<b>17</b>
<b>Total</b>		<b>2,749</b>

## Decedent Analysis, cont'd

- The majority of the below impact region deaths were accounted for by being trapped by debris on the starting floor, delayed evacuation initiation (of statistical outlier magnitude), or performing emergency response building responsibilities.
- While the mobility status of every decedent known to be below the impact region (111) in WTC 1 could not be determined, it does not appear that mobility challenged individuals were significantly overrepresented amongst the decedent population.
- Several civilians and first responders perished assisting mobility-challenged colleagues and many more risked their lives assisting mobility-challenged colleagues who successfully evacuated.

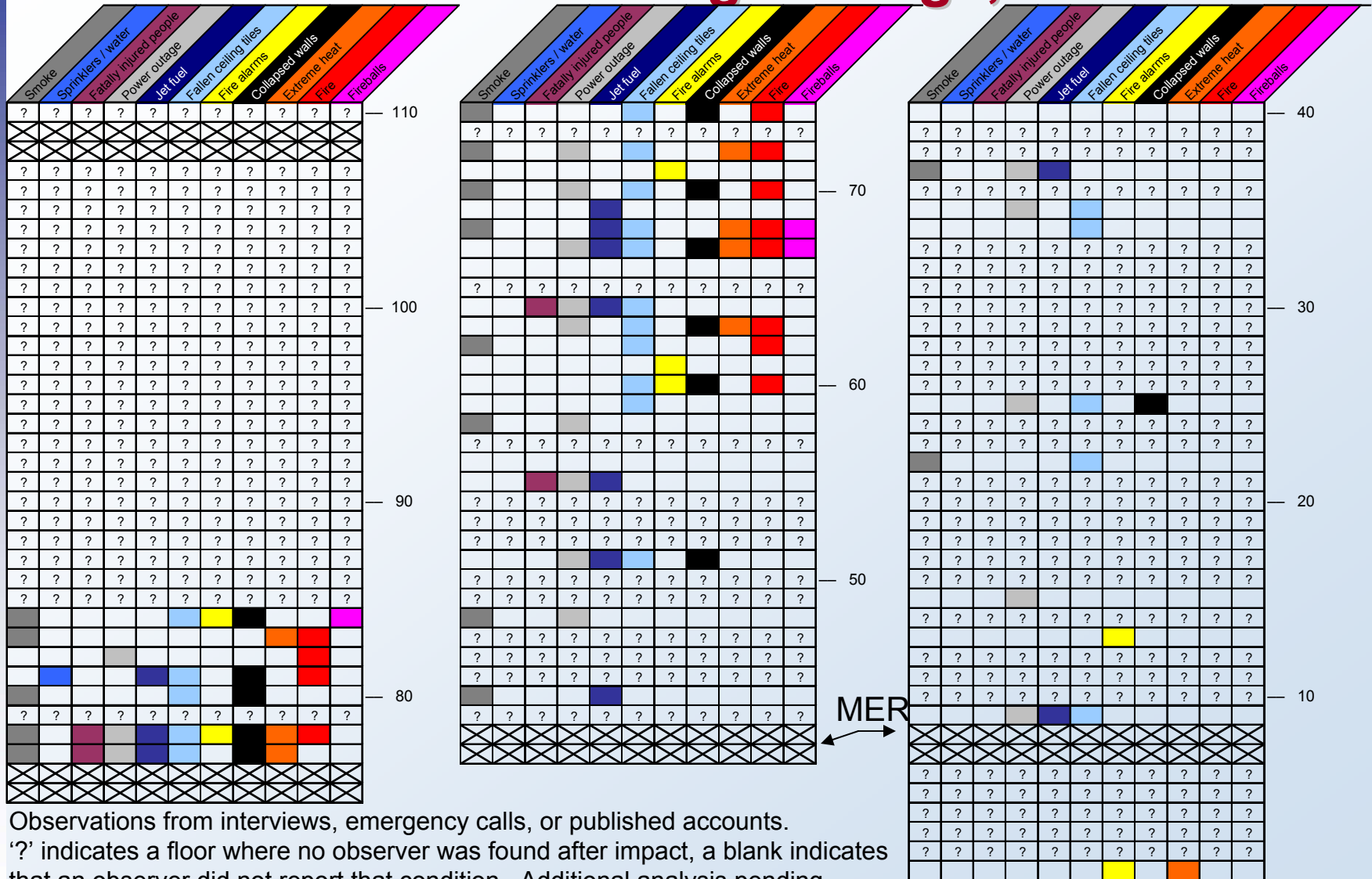


# Observations of Building Damage, WTC 1



Observations from interviews, emergency calls, or published accounts. '?' indicates a floor where no observer was found after impact, a blank indicates that an observer did not report that condition. Additional analysis pending.

# Observations of Building Damage, WTC 2



## Above the Floors of Impact, WTC 2

Stairwell A was passable for a period of time after WTC 2 was attacked. NIST identified 18 individuals who used this path, although one died from 9/11 related injuries. At least two people from below the impact region went up to help and did not successfully evacuate.

Location at 8:46 a.m. (WTC 1 Impact)	Location at 9:03 a.m. (WTC 2 Impact)
Floor 103	Floor 78
Floor 103	Floor 78
Floor 102	Floor 78
Floor 101	Floor 78
Floor 100	Floor 82 (Stairs)
Floor 100	Floor 78 (Elevator)
Floor 100	Floor 78
Floor 97	Floor 78
Floor 97	Floor 78 †
Floor 86	Floor 78
Floor 86	Floor 78
Floor 84	Floor 84
Floor 84	Floor 84 *
Floor 84	Floor 84 (Elevator)
Floor 81	Floor 81
Floor 81	Floor 81
Floor 79	Floor 78
Floor 78	Floor 78

\* After impact, ascended to floor 91 for a period of time before finally making it below the impact zone.

† While this individual did evacuate the building, they died several days later as a result of injuries sustained on September 11, 2001.

## WTC 2 Evacuation

- Minutes or seconds prior to collapse of WTC 2, an NYPD ESU officer reported from the 20s that his team was having trouble ascending the stairwell because of the volume of people in the stairs.
- Two individuals (at least) were aware of the tenability of Stairwell A and were above the 78<sup>th</sup> floor at some point after 9:03 a.m.
- Several callers from above the floors of impact were on telephone as WTC 2 collapsed.

These facts suggest that **among several possibilities** a group of occupants from above the impact floors had identified a way through the impact region and were making their way **down the stairwell some minutes** before building collapse.

## WTC 2 Evacuation

9/11 Commission Report came to similar conclusion.  
Page 296:

“But just before the tower collapsed, a team of NYPD ESU officers encountered a stream of civilians descending an unidentified stairwell in the 20s. These civilians may have been descending from at or above the impact zone.”

# Emergency Communications

- Occupants called 9-1-1 and Port Authority seeking assistance and advice.
  - Opportunities to improve occupants situational awareness were often lost. Specific knowledge about location of fires and impact damage was only occasionally communicated to occupants who requested the information and was without apparent coordination.
  - Some operators advised sheltering (e.g., many at 9-1-1), while others advised evacuation (e.g., many at PA Police Desk); some permitted window breaking while others instructed occupants not to break windows.
    - The “right” advice with respect to a particular action, however, is highly sensitive to the caller’s particular situation and may be clear only in hindsight.

# Public Address System Announcements

## WTC 1

Many announcement attempts were made from the Fire Command Station in the lobby, initially to selected floors and then, within approximately ten minutes, to the entire building. However, only two face-to-face interviewees in WTC 1 reported hearing any announcements, and the source is unclear.

## Conclusion:

**Damage to the 22<sup>nd</sup> floor communication closet likely disabled building-wide announcement capability.**

# Public Address System Announcements

## WTC 2, Prior to 9:03 a.m.

~ 9:00 a.m. - *There is a fire condition in WTC 1. WTC 2 is secure. Please return to your offices.*

9:02 a.m. – “May I have your attention please. The situation is in Building 1. However, if conditions on your floor warrant, you may wish to start an orderly evacuation.”



# Public Address System Announcements

## WTC 2, After 9:03 a.m.

9:12 a.m. – (Fire Command Station in WTC 2 over Radio Channel 22) “310-B to any units: Be advised that Building Two (inaudible) only (inaudible) warden phones. We can't pick up warden phones. We are just making straight announcements telling the people not to stay at the warden phones, because we can't pick them up.”  
(PANYNJ 2003)

# Public Address System Announcements

## **WTC 2, After 9:03 a.m., cont'd**

~9:20 a.m. – Announcement made updating occupants on the condition of the building and progress of the evacuation.

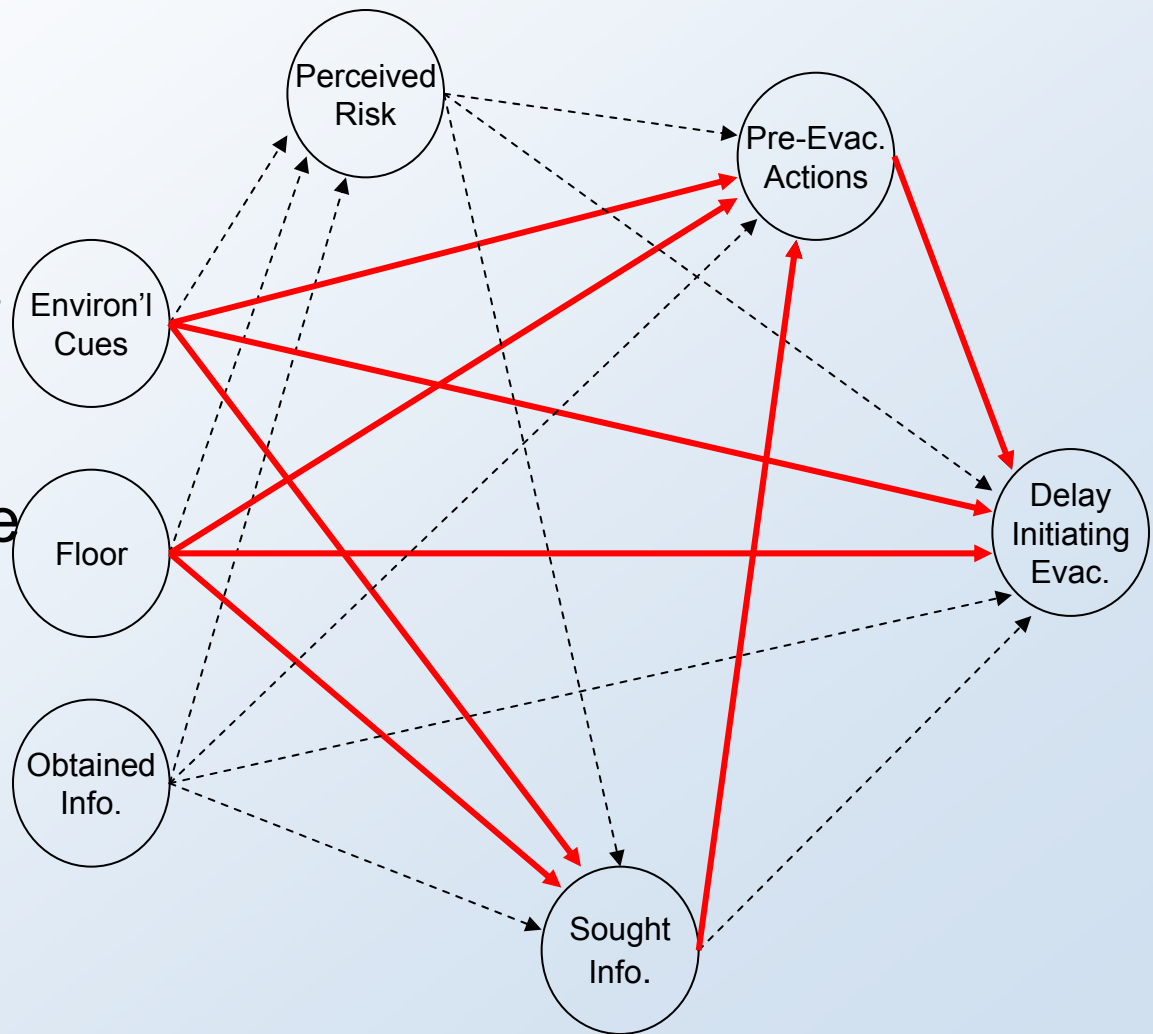
Prior to approximately 9:40 a.m. – Building-wide announcement instructing occupants to go down the stairs.

## **Conclusion:**

**Announcements in WTC 2 were heard by occupants building-wide before 9:03 a.m. and were heard in at least the upper regions (including above the impact area) of WTC 2 after 9:03 a.m.**

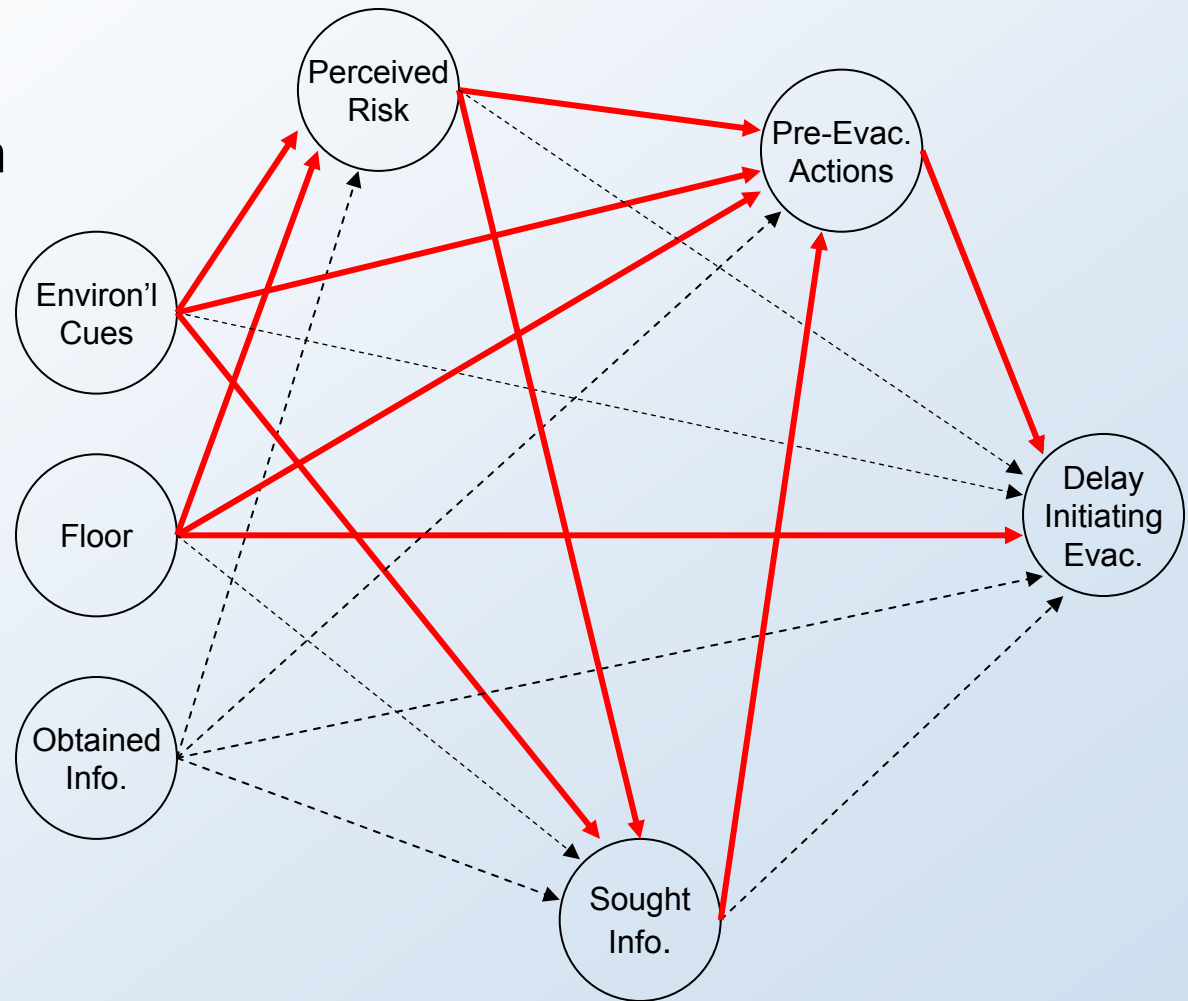
# Causal Modeling: Evacuation Delay in WTC 1

The main process that led to evacuation delay: Environmental cues and floor led people to seek additional information and take actions which delayed the start of evacuation.



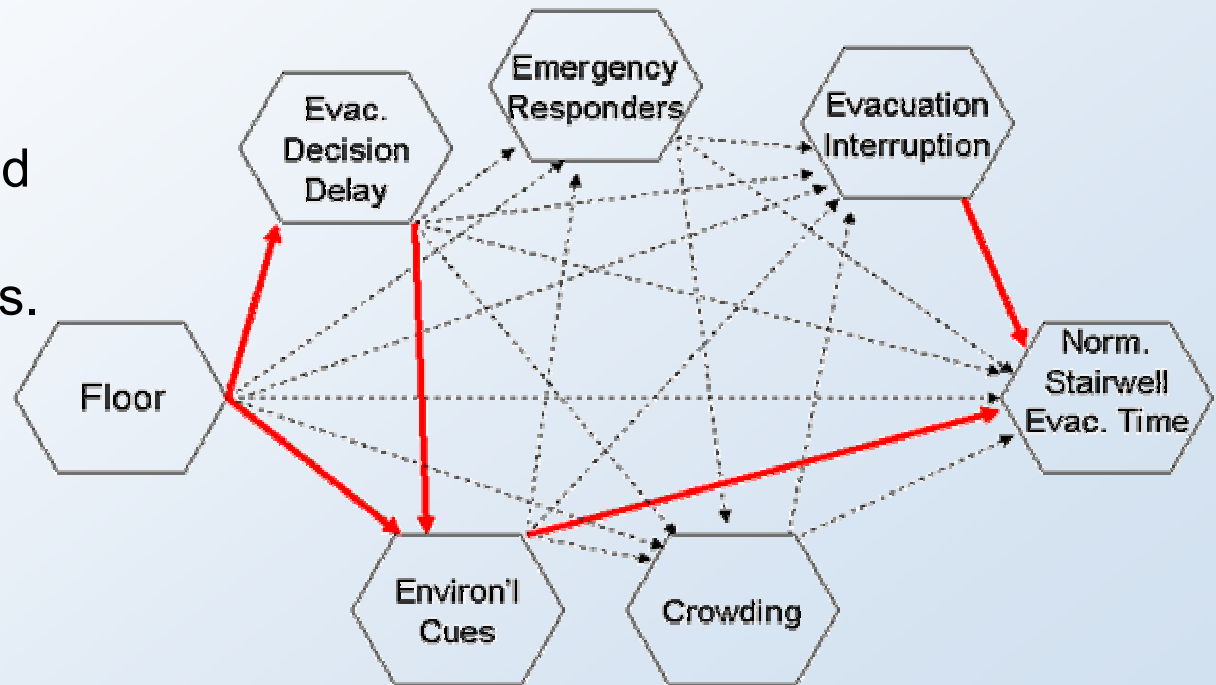
# Causal Modeling: Evacuation Delay in WTC 2

The main process that led to evacuation delay: Environmental cues and floor led people to perceive risk and these three factors led people to seek additional information and take actions which delayed the start of evacuation.



# Causal Model for Stairwell Evacuation Time\*

Starting floor led to encountering environmental cues; floor also predicted delay starting evacuation (discussed previously) which led to environmental cues. This predicted stairwell evacuation time. Additionally, interrupting evacuation led to higher stairwell evacuation time.



\* Tower 1 Data Only

# Evacuation Findings

- Even though a percentage of evacuees reported that they perceived counterflow to be a problem, it was found not to be a significant predictor in the variation of total evacuation time of occupants in WTC 1 when compared to other factors, including evacuation initiation delay, evacuation interruption, and encountering obstacles in the evacuation path (environmental cues) such as smoke, water, or debris.
- In WTC 1, the average surviving occupant spent 48 seconds per floor descending the stairwell. This translates to approximately 0.2 m/s (0.65 ft/s), which is about 50% of the slowest speed measurement presented in the SFPE Handbook of Fire Protection Engineering for non-emergency evacuation.
- In WTC 1, each stairwell door exited approximately 37 people per minute per meter of effective width, averaged over 100 minutes, which is consistent with the slowest measurement presented in the SFPE Handbook of Fire Protection Engineering for non-emergency evacuation.

# Evacuation Findings

- Most of the emergency communication system in WTC 1 was disabled on September 11, 2001.
- All three stairwells in WTC 1 were rendered impassable in the area of impact. Two of three were rendered impassable in the area of impact in WTC 2.
- The PANYNJ reports that it never advised tenants to evacuate upwards. Standard occupant evacuation procedures and drills required the use of stairwells to exit at the bottom of the WTC towers. WTC evacuation procedures did not include a plan to provide roof rescue for occupants trapped in a building incident. Emergency response helicopters, however, made numerous, unsuccessful attempts on September 11, 2001 to access the roof.

# Evacuation Findings

- The decision to establish the primary evacuation route underground through the concourse (mall) and out up to street level by WTC 5 (commonly recalled as being by the Borders Bookstore) prevented a significant number of injuries and/or deaths.
- The first “first responders” were colleagues and regular building occupants. Acts of everyday heroism saved many people whom traditional first responders would have been unable to reach in time.



# Evacuation Findings

- In WTC 2, approximately 75 percent of the occupants above the 78th floor at 8:46 a.m. had successfully descended below the 78th floor prior to the impact of Flight 175 at 9:03 a.m. This occurred despite conflicting announcements, first urging people to return to their offices around 9:00 a.m., and then informing them that they may initiate an evacuation if conditions warranted around 9:02 a.m.
- Mobility challenged occupants were not universally identified or prepared for full building evacuation. One occupant, for example, reported being 'left' on their floor by colleagues, called authorities for assistance, and was eventually assisted by strangers (occupants).

## Evacuation Findings

- Occupants were often unprepared for the physical challenge of full building evacuation. Numerous occupants required one or more periods of rest during stairwell descent or turned to elevators after finding the stairwells strenuous.
- Occupants were often unprepared to encounter transfer hallways during the stairwell descent. Groups of evacuees occasionally hesitated or debated a course of action upon encountering a transfer hallway. (Note, however, that NYCLL 5 prohibits requiring occupants to practice stairwell evacuation.)
- Phased evacuation (defend-in-place) would not have been appropriate strategy for responding to the events of September 11, 2001 and does not appear to have been implemented except briefly on selected floors, after which it was abandoned in favor of full building evacuation.

# Evacuation Findings

- Approximately 87% of WTC occupants, and over 99% of those below the floors of impact, were able to successfully evacuate.
- At 9:03 a.m., when WTC 2 was hit, 21% of survivors had exited WTC 1 and 41% of survivors had exited WTC 2.
- By 9:37 a.m., 22 minutes before collapse, 95% of survivors had exited WTC 2.
- At 9:59 a.m., when WTC 2 collapsed, 88% of survivors had exited WTC 1.
- By 10:12 a.m., 16 minutes before collapse, 95% of survivors had exited WTC 1.

## Evacuation Findings

- Self-evacuation, use of elevators for 16 minutes in WTC 2 saved roughly 3,000 lives. This estimate assumed no occupant left their floor until 9:03 a.m., elevators were not usable, no occupants above the 78<sup>th</sup> floor survived, evacuation rate was similar to that observed in WTC 1, and the building collapsed at 9:59 a.m.
- During the last 20 minutes before each building collapsed, the evacuation rate in both buildings had slowed to about one-fifth the immediately prior evacuation rate. This suggests that *for those seeking and able to reach and use the undamaged exits and stairways*, the egress capacity (the number and width of exits and stairways) was adequate to accommodate survivors.

# Issue 1: Egress System Design

- The egress path (e.g., stairwell and elevator enclosures) may become compromised prior to evacuation of the affected population, due to a variety of scenarios (wind deflection, impact, fire, other). There are no minimum structural integrity requirements
- Building egress systems are not designed to accommodate full building evacuation. Full building evacuation is foreseeable under conditions of widespread power outage, earthquake, fire, or terrorist attack.
- Stairwells can be physically proximate yet considered remote by a "walking path" measurement; does not adequately meet separation requirements under non-fire conditions (e.g., overpressure).

# Issue 1: Egress System Design, cont'd

- Mobility Challenged Occupants
  - Areas of refuge create a delay in evacuation for mobility challenged occupants.
  - Procedures for identifying and assisting mobility challenged occupants may be insufficient. Some mobility challenged occupants are not currently capable of effecting their own escape.
- Egress system designers (often architects) are not currently required to have any professional training or accreditation in designing egress systems.

## Issue 2: Emergency Communications

- Missed opportunities to better communicate information between the occupants, 9-1-1 operator dispatch, fire department dispatch, and emergency management dispatch and site security may result in inadequate situational awareness.
- A building may have no capacity to provide public address announcements or instructions through the floor warden system.
- The electro-mechanical systems integral to life safety may be compromised by a single event.
- The emergency broadcast system may be useful in large-scale emergencies.

## Issue 3: Occupant Preparedness

- Layouts can be confusing to unprepared occupants (i.e. transfer floors). In addition, occupants are often unprepared to evacuate a building. Preparedness includes adequate knowledge of the evacuation procedures and systems, and adequate means for pathway illumination.
- Emergency plans are filed to achieve regulatory compliance, but may not adequately implemented in practice.
- Floor wardens may not be present or remember / perform responsibilities.



## Issue 4: Technology

- Elevator door restrictor plate can entrap building occupants in the event of an emergency.
- Egress systems do not allow all occupants an equal opportunity for evacuation (e.g., hardened elevators, exterior escape devices, or stairwell navigation devices).
- Lack of adequate egress models and systematic methodology for accounting for human behavior during evacuation.