

**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**

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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 Occupant's 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

**September 11, 2001**  
**Moments Before 8:46 a.m.**

# Building Population

	WTC1	WTC2	Total
Estimated Total Population of Survivors*	7,500**	7,900	15,400
<b>Statistical Precision Calculations</b>			
Sample n	427	376	803
Standard Error (p)	1.90%	1.92%	1.36%
Standard Error (Total)	750	900	1200
<b>Number of Decedents</b>			
Decedents	1,434***	599***	2,033*** - 2,189****
<b>Total Building Population</b>			
Total	8,900	8,500	17,400

\* Includes only occupants with badges

\*\* includes only occupants below floor 92.

\*\*\* Calculated from Cauchon as 1,434 + 599

\*\*\*\* Calculated as 2,749 – 403 first responders – 157 airplane passengers

# Occupant Characteristics

## Age

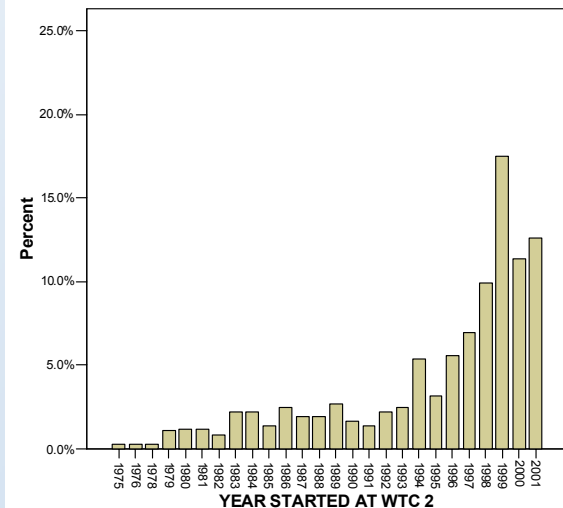
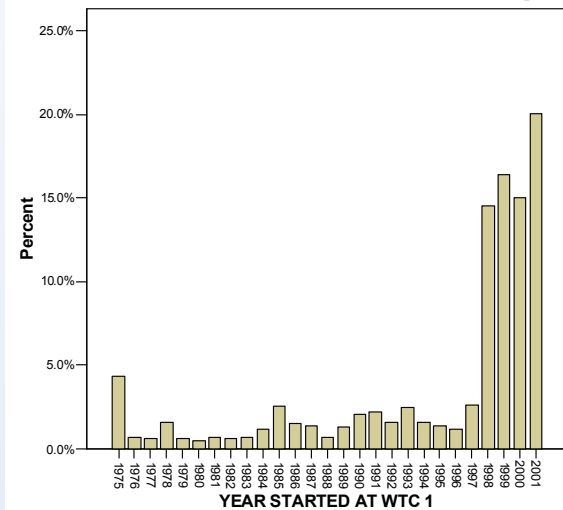
N	Valid	439
	Refuse	1
Mean		45
Median		46
Minimum		22
Maximum		73

**WTC 1**

N	Valid	361
	Refuse	2
Mean		45
Median		44
Minimum		21
Maximum		74

**WTC 2**

## Years in Building





# World Trade Center Occupant Preparedness

- During the year from Sept. 11, 2000 to Sept. 11, 2001, how many fire drills did you take part in at the World Trade Center?
  - At least one: 66%
  - None: 17%;
  - Don't know: 17%
- 93% of fire drill participants were shown closest stairwell.
- Approximately half (51%) of WTC occupants had never used a stairwell at the World Trade Center prior to September 11<sup>th</sup>.

**September 11, 2001**  
**8:46 a.m.**

# WTC 1

“I saw the plane halfway in the building.”  
(90’s)

“The door blew open from the closet,  
causing my chair to hit the desk.”  
(50’s)

“We felt the entire building shake and saw  
some people who were sitting in chairs  
slide across the floor.” (10’s)

“I was walking through the mall towards  
tower one to get to the elevator. The  
lights flickered. I stopped in my tracks  
and looked around. I saw a brown  
cloud coming down the center corridor  
in the lobby, and I feared for my  
safety. The brown cloud had a heavy  
density and reached from floor to  
ceiling. It looked to me like it was both  
smoke and debris. It first came from  
the center corridor, but by the time it  
reached the revolving doors (a split  
second later) it seemed to come from  
every direction. At this point, the  
revolving doors exploded They  
seemed to vaporize.” (Concourse)

WTC 1 - First Awareness	
Felt something (building moving, impact, shaking, swaying)	63 %
Heard something (boom, crash, explosion, rumbling)	30 %
Saw airplane	2 %
Other	5 %

Data consistent throughout building  
Only small number witnessed fire  
and smoke at first awareness

## WTC 2

WTC 2 – First Awareness*	
Felt something (building moving, impact, shaking, swaying)	11%
Heard something (boom, crash, explosion, rumbling)	51%
Saw smoke, flame, or debris	16%
By other person (face-to-face, telephone)	14%
Saw airplane	3%
Other	6%

\*Primarily from Tower 1

“I saw the plane crash into [WTC 1]” (100’s)

“I noticed it was getting dark and I saw massive bright orange flames wrapping themselves around the building.” (90’s)

“My boss came in and told us to evacuate.” (30’s)

“I heard a loud roaring sound.” (10’s)

Observations vary by floor (height).  
Many observations of fire(ball),  
debris

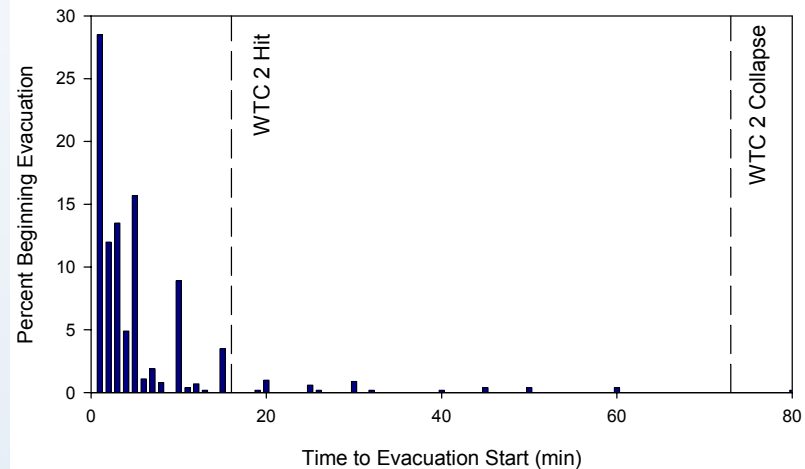
**September 11, 2001**  
**8:47 a.m. – 9:02 a.m.**

# WTC 1

“In the hallway...there were no walls left...and the bathroom seemed to be missing. There was a hole in the wall near the elevator (in the hall) and fire was coming up onto our floor through that hole. (90’s)

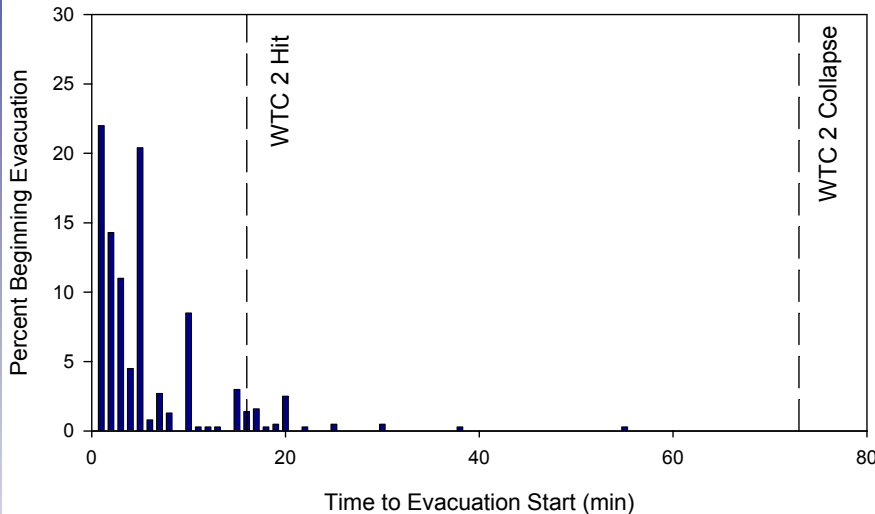
“To me everything seemed normal, all the ceilings were fine, the electricity was fine...” (70’s)

“I was close to the windows. The windows were broken and I saw things from the office were going out the window.” (20’s)



- 92% of survivors began evacuation before WTC 2 was hit; 29% within 1 minute.
- 21% exited WTC 1 before WTC 2 was hit.

# WTC 2



- 91% began evacuating before Tower 2 was hit; 22% within one minute of WTC 1 impact.
- 41% of the survivors exited the building before WTC 2 was hit.

**“We were instructed to go back to our offices and that the building was secure. So, I started back to my office. As I exited the fire escape and met my supervisor, I was told that he wanted me to leave the building and not follow the instruction to stay.” (90’s)**

**“Heard the building was secure by announcement...Kept moving down the stairs to exit the building. Came to a uniformed person holding the door open in the 44th floor sky lobby. We were asked to exit the stairwell area and to use the elevators to go back up, [but we] kept on going to exit the building.” (80’s)**

# WTC 1

Life in Danger?	Others	Self
Initial Awareness	48%	41%
Interim Period	63%	52%

“As I was leaving, it didn't seem as bad as I thought in the office and I decided that I would just walk all the way down and reassess the situation and go back to the office if things were OK.” (70's)

“I felt that my life was threatened. I also thought of 1993 bombing and I know what some of my friends went through.” (70's)

“I felt safe because I watched previous documentaries and I was informed that I was safe in my building. I went back to the fax machine.” (60's)

Activities Before Evacuation	
Talked to others	70 %
Gathered personal items	46 %
Helped others	30 %
Searched for others	23 %
Talked on telephone	16 %
Moved between floors	8 %
Fought fire or smoke	6 %
Shut down computers	6 %
Continued working	3 %
Other activities	25 %



## WTC 2

### Used elevator for entire evacuation

- “The decision to use the elevators was based on the fact that there was no fire in our building.” (100’s)

### Used stairs and elevators

- “I was raised in Los Angeles; I was taught that in case of emergency situations and disasters to avoid elevators” (100’s) – Decision was made to use stairs until the PA announcement, when respondent used an elevator to evacuate.

Initial Evacuation Mode	
Stairwell A	18%
Stairwell B	18%
Stairwell C	14%
Stairwell A or C	10%
Used elevator	18%
Don't Know [Stair]	23%

### Did not consider elevator use

- “I knew one shouldn’t take an elevator in an emergency situation” (30’s)

**September 11, 2001**  
**9:03 a.m.**

# WTC 1

Some noticed minor disturbances when WTC 2 was hit; many never mentioned anything related to Tower 2 being hit.

“I answered the [cellular] phone and my wife was telling me that another plane had struck Tower 2 and she said get out of the building as fast as you can; it is a terrorist attack.” (40’s)

“I felt the air clear up due to a big gush of wind that cleared the smoke (this happened when building 2 was hit by the plane).“ (60’s)

“The building shook. Not anything like the first time [but] it rocked. We stopped briefly on the 31<sup>st</sup> floor.” (60’s)

“Very soon after entering the stairwell, someone with a Blackberry communication device received word that a corporate jet had hit the building. Later the info was clarified as to what kind of plane. Later [there was] a report of the second plane hitting.” (50’s)

## WTC 2

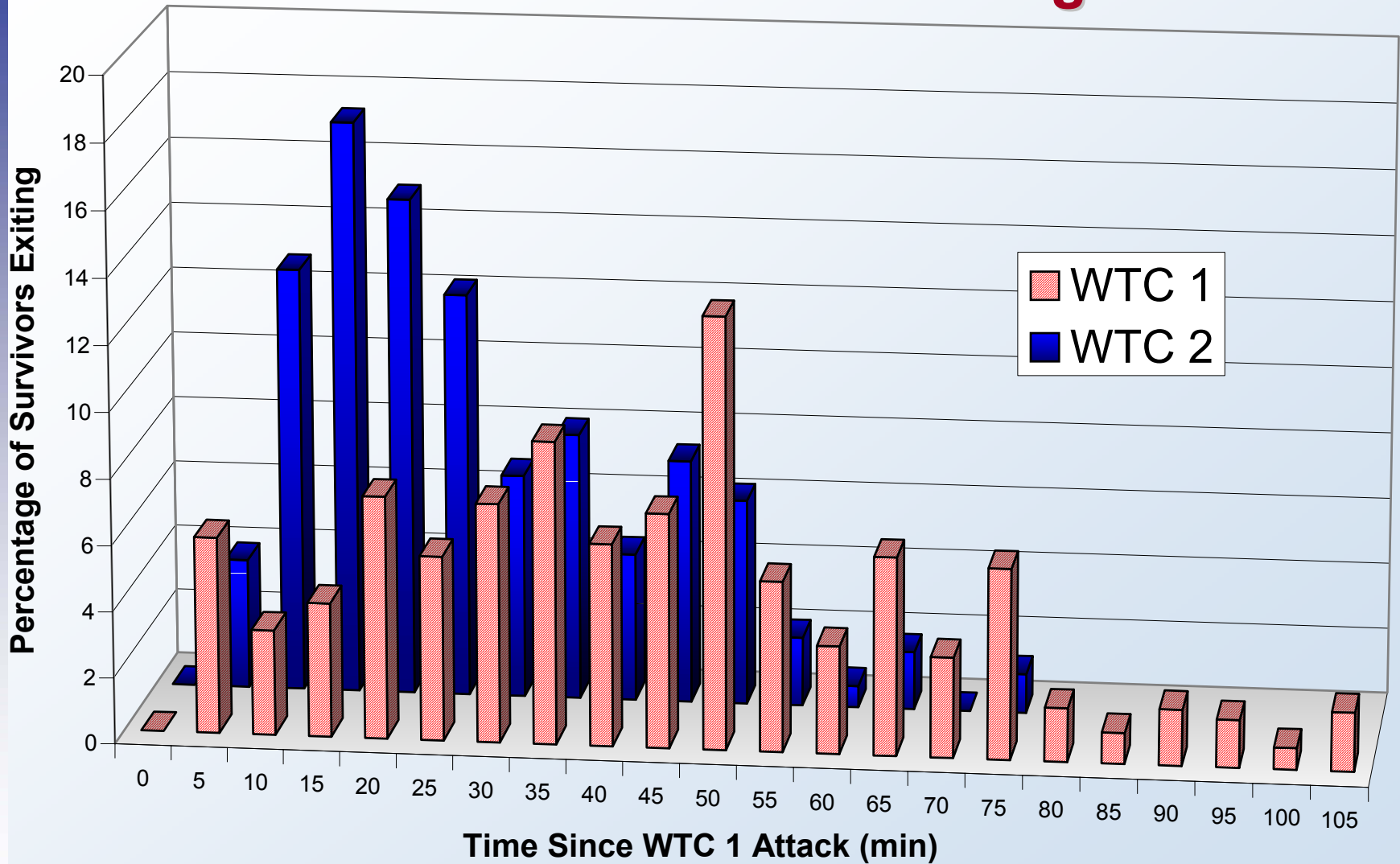
- “It was clear that something hit the building...the stairwell swayed and it was as if the building was doing the ‘twist’.” (90’s)
- “I felt an explosion and saw fire and smoke coming from the corridor. The whole building was shaking and breaking glass was cascading down the building. The smoke was a light grayish and the flames leapt out of the corridor from the pressure.” (70’s)
- “I heard a loud noise, felt the building shake, and the temperature in the air went up.” (60’s)

### Observations of Survivors Still on Floors at 9:03

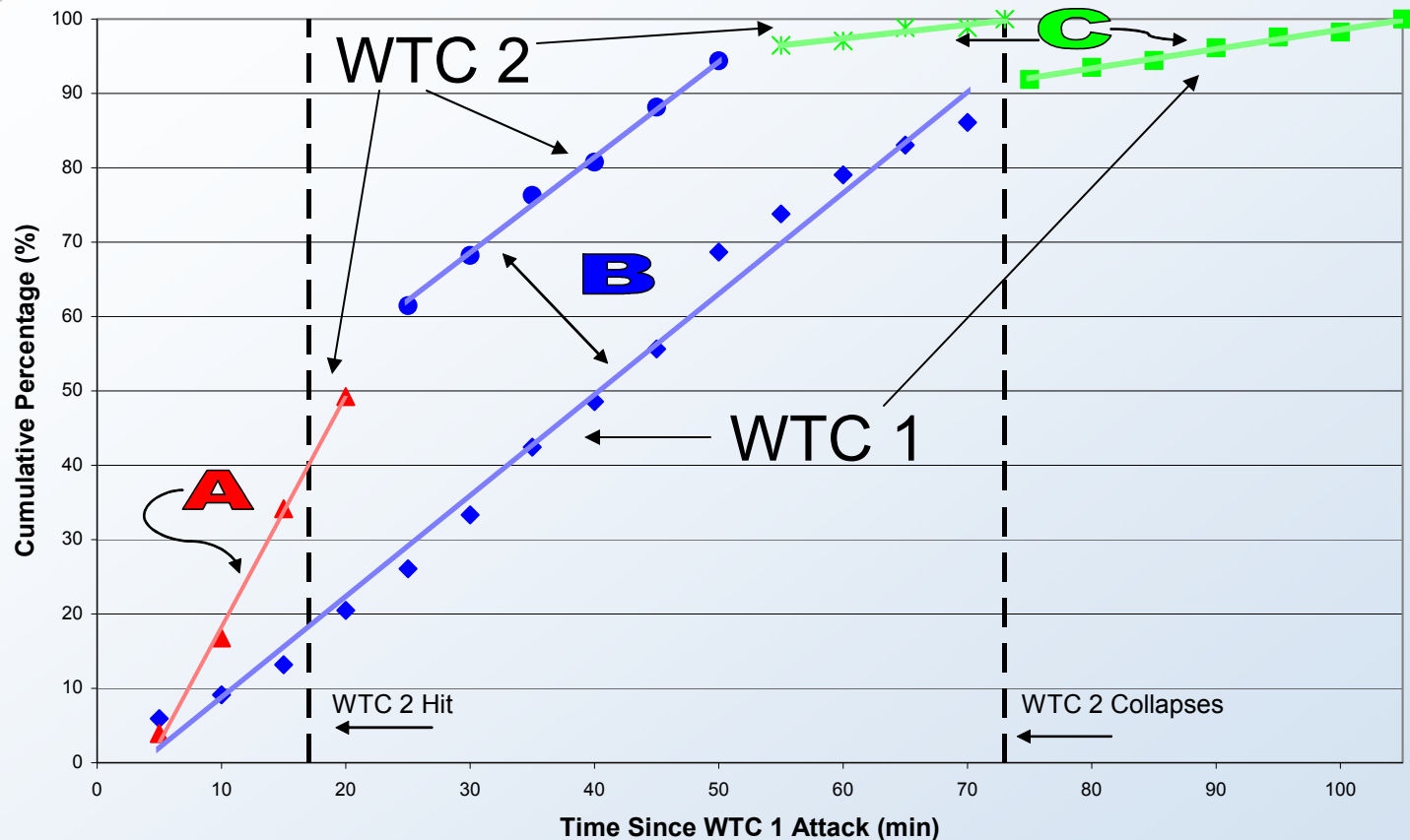
Power outage/flick	37%
Fallen Ceiling tiles	29%
Jet Fuel	20%
Smoke	18%
Collapsed walls	18%
Fire or flames	12%
Fire alarm sounding	12%
Fatally injured people	10%
Extreme heat	10%
Sprinklers	2%

**September 11, 2001**  
**After 9:03 a.m.**

# Time Until Out of Building



# September 11, 2001 WTC Evacuation Rate



	A	B	C
WTC 1	/	1.4	0.3
WTC 2	3.1	1.3	0.2

- A – Elevator use doubles exit rate compared to stairs only
- B – Exit rate similar using stairs only
- C – Rate slows ~ 20 minutes prior to collapse for WTC 1 and WTC 2

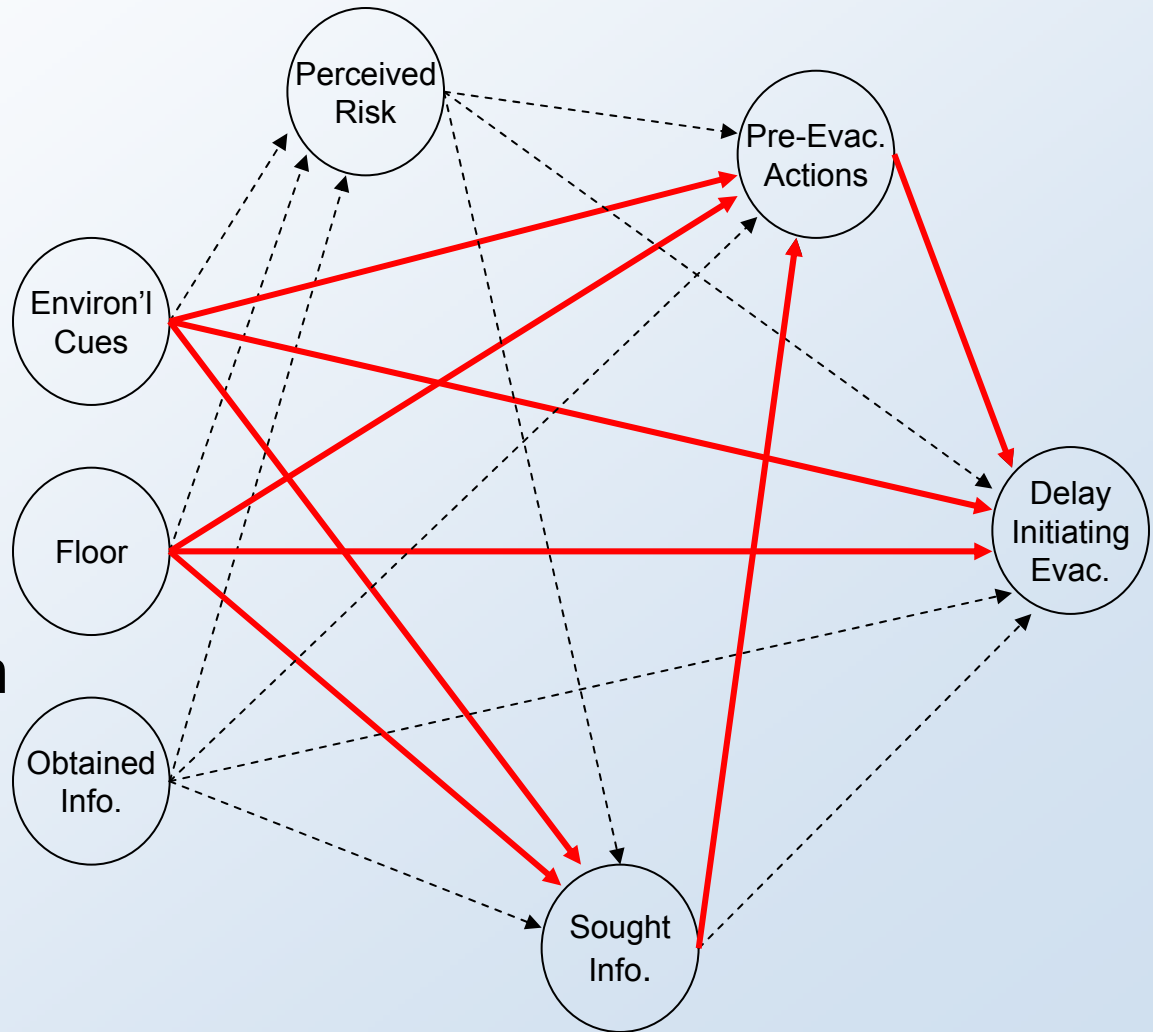
# Reported Aids & Constraints to Evacuation

Evacuation Aids			Evacuation Constraints		
WTC 1		WTC 2	WTC 1		WTC 2
66%	Support from others	60%	73%	Crowded stairwells	69%
44%	Firefighters/Police	30%	51%	Firefighters/Police	27%
32%	Exit signs	35%	24%	Lack of clear instructions	29%
18%	Photoluminescent paint	11%	16%	Locked doors	7%
10%	Floor Warden	13%	11%	Poor lighting	4%
			5%	Bad/missing signage	5%



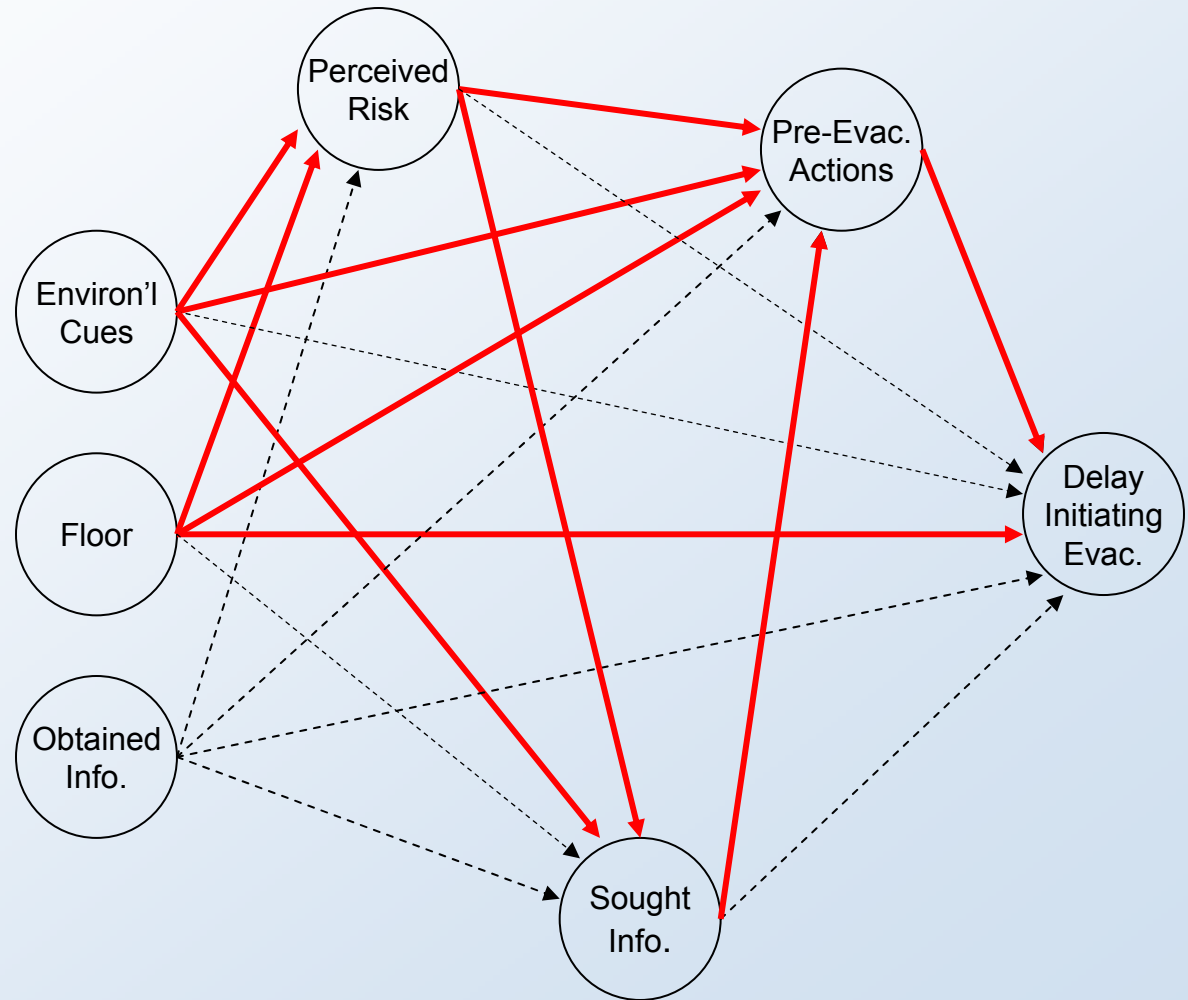
# Causal Modeling: WTC 1

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: 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.

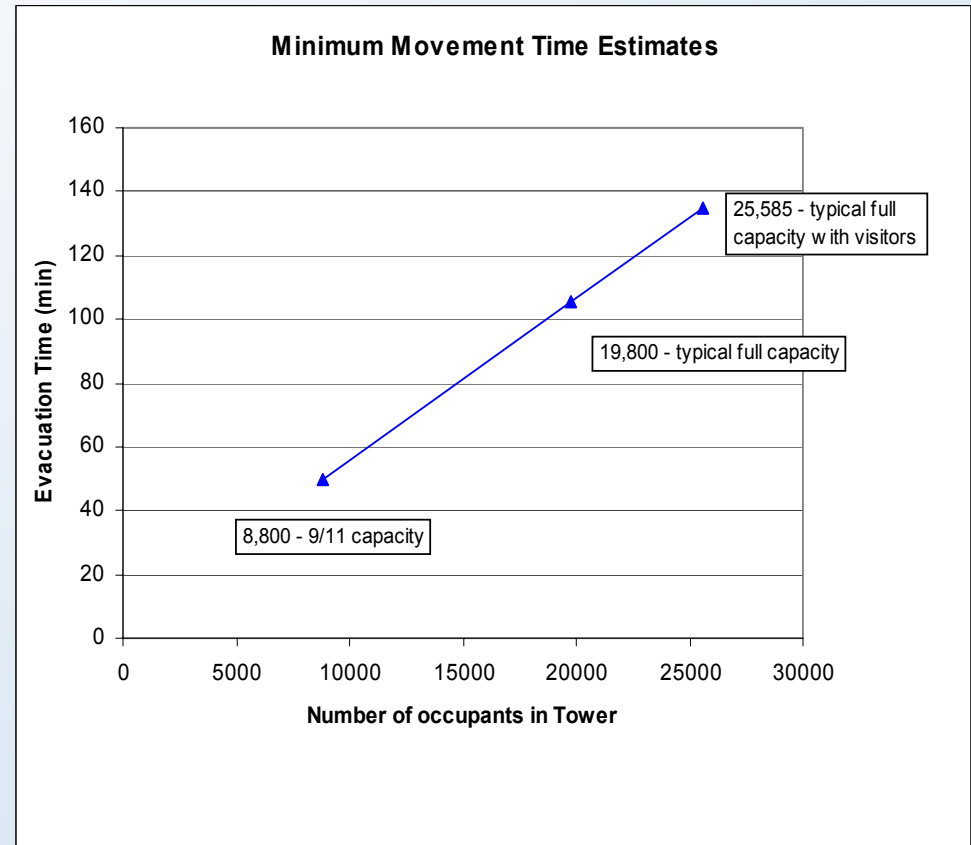


# Egress Modeling: Minimum Time

Preliminary results from  
building EXODUS

Full Tower evacuation with the  
following assumptions:

- All able-bodied occupants
- Response delay = 0 sec.
- No damage simulated
- No elevator use
- Continual stair movement (no resting in stairway)



## Findings and Conclusions

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

## Findings and Conclusions, Cont'd

- 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.

## Findings and Conclusions, Cont'd

- Self-evacuation, use of elevators for 16 minutes in WTC 2 saved roughly 3,000 lives.
- 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.

## Findings and Conclusions, Cont'd

- Preliminary results from application of existing computer egress models for a full capacity evacuation of a single WTC tower with 25,000 occupants and visitors indicate a movement time of 2 h and 15 min. Given that the actual evacuation time on September 11, 2001 was about 100 min without elevator use, a full capacity evacuation of the WTC towers with 25,000 people would have required about 4 h (2.5 times 100 min). To achieve a significantly faster total evacuation at full capacity would have required increases in egress capacity (number and width of exits and stairways).