Federal Investigation of the Evacuation of the World Trade Center on September 11, 2001

J.D. Averill[1], D. Mileti[2], R. Peacock[1], E. Kuligowski[1], N. Groner[3], G. Proulx[4], P. Reneke[1], and H. Nelson[5]

This paper presents the findings of the NIST World Trade Center Investigation describing the occupant evacuation of WTC 1 and WTC 2 on September 11, 2001. The egress system, including stairwells and elevators, is described along with the evacuation procedures. The population in WTC 1 and WTC 2 on September 11, 2001 at 8:46 a.m. is enumerated and described, where the background of the population was relevant to the subsequent evacuation, including training, experience, mobility status, among others. The progress of the evacuation of both towers is described in a quasi-chronological manner. A decedent analysis explores where occupants were located when each tower was attacked. Multiple regression models were built to explore the sources of evacuation initiation delay (why people did not immediately start to leave the building), as well as stairwell evacuation time (how long the average occupant spent in the stairwells per floor). Issues identified as contributing to either slowing or aiding the evacuation process were explored. Egress simulations provided context for estimating how long WTC 1 and WTC 2 would have taken to evacuate with different populations, using three different models, and subject to different assumptions of damage to the building.

1. Investigation Scope

The National Institute of Standards and Technology (NIST) announced its building and fire safety investigation of the World Trade Center (WTC) disaster on August 21, 2002. This WTC Investigation, led by NIST, was conducted under the authority of the National Construction Safety Team Act (Public Law [P.L.] 107 231).
The goals of the WTC Investigation were to: (1) investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the WTC disaster. (2) serve as the basis for:

- » Improvements in the way buildings are designed, constructed, maintained, and used;
- » Improved tools and guidance for industry and safety officials;
- » Recommended revisions to current codes, standards, and practices; and
- » Improved public safety.

[1]Natonal Institute of Standards and Technology, Gaithersburg, MD, USA
[2]University of Colorado – Boulder, Boulder, CO, USA
[3]John Jay College, New York City, NY, USA
[4]National Research Council Canada, Ottawa, ON, Canada
[5]Independent Consultant

The objectives of the NIST-led Investigation[1] of the WTC disaster were to: (1) determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft; (2) determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response, (3) determine what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1 and 2, and (4) identify, as specifically as possible, areas in current building and fire codes, standards, and practices that warrant revision.

The Investigation included eight interdependent projects that, in combination, met the objectives. A detailed description of each of these eight projects is available at http://wtc.nist.gov.

2. Background

While most attention has properly focused on the nearly three thousand people who lost their lives at the World Trade Center site that day, five times that many people successfully evacuated from the WTC towers due to heroic efforts of occupants, as well as emergency responders. Understanding why many, yet not all, survived the World Trade Center attacks was one of the four objectives of this Investigation.
Success in evacuating a building in an emergency can be characterized by two quantities: the time people needed to evacuate and the time available for them to do so.
To the extent the first time exceeded the second, it follows that there will be casualties. When the second time exceeds the first, perhaps by some suitable margin, nearly all should be able to evacuate the building.

The Investigation Team examined the design of the building, the behavior of the people, and the evacuation process in detail to ascertain the parameters that factored prominently in the time needed for evacuation. In order to accomplish this objective, numerous sources of data were collected and analyzed, including: over 1,000 new interviews with survivors; a collection of over 700 published interviews with WTC survivors; 9-1-1 emergency calls; transcripts of emergency communication among building personnel and emergency responders; historical building design drawings, memoranda, and calculations; building modifications and upgrades; formal complaints filed with Occupational Safety and Health Administration (OSHA); and other relevant material.

3. Interview Methodology

There were three forms of interviews with survivors: 803 telephone interviews, over 225 face-to-face interviews, and 6 focus groups.

[1] NIST is a nonregulatory agency of the U.S. Department of Commerce. NIST investigations are focused on fact finding, not fault finding. No part of any report resulting from a NIST investigation into a structural failure or from an investigation under the National Construction Safety Team Act may be used in any suit or action for damages arising out of any matter mentioned in such report (15 USC 281a, as amended by P.L. 107 231).

3.1. Telephone Interviews

The telephone interviewees were randomly selected using independent proportionate stratification from a list of occupants who had badges to enter WTC 1 or WTC 2 on September 11, 2001. In other words, each occupant of a particular tower had an equal probability of being selected. Roughly 400 occupants in each tower were interviewed in order to achieve a high level of statistical precision within each tower. Reported percentages from tower-specific survey data (n = 400) exhibited sampling errors no greater than 2.5 percentage points, and 95 percent confidence intervals of percentages are no greater than ± 5 percentage points. This level of precision was more than adequate for examining characteristics of occupants and egress attributes. The telephone interview results enabled a scientific projection of the population and distribution of occupants in WTC 1 and WTC 2, as well as causal modeling to explore fundamental egress issues such as sources of evacuation delay.

3.2. Face-to-face Interviews

The objective of the face-to-face interviews was to gather first-hand accounts and observations of the activities and events inside the buildings on the morning of September 11th. This approach identified unknown information, aided in the evaluation of technical hypotheses, and explored motivations for occupant behaviors, while allowing for comparisons to the telephone interview data. A typical face-to-face interview averaged approximately two hours. The methodology for the face-to-face interviews was a synthesis of two established methodologies, designed to assist survivors in providing comprehensive and accurate accounts of their evacuation, given the latency between experience and interview.

3.3. Focus Group Interviews

Six focus groups were conducted in order to elicit accurate group representations of specific events or themes and complement the findings of the telephone and face-to-face interviews. The focus groups were: (1) occupants located near the floors of impact; (2) floor wardens; (3) mobility challenged occupants; (4) persons with building responsibilities; (5) randomly-selected evacuees in WTC 1; and (6) randomly-selected evacuees in WTC 2.

4. WTC 1 and WTC 2

The team documented the WTC egress system, including the location of the three primary stairwells, exit doors, core hallways, transfer corridors, wall construction, location and layout of the 100+ elevators in each tower, and emergency communication devices. WTC 1 and WTC 2 each consisted of 110 stories above the Concourse Level (or 109-stories above the plaza / Mezzanine Level) structure. There were also 6 basement levels below the Concourse Level. Although the towers were similar, they were not identical. The height of WTC1 at the roof level was 1,368 ft (418 m) above the Concourse Level (6 ft taller than WTC 2), and WTC 1 additionally supported a 360 ft (110 m) tall antenna on the roof for television and radio transmission. Each tower had a square plan with the side dimension of 207 ft 2 in. (63.2 m). Each tower had a core service area of approximately 135 ft x 87 ft (41 m x 27 m), although the core space changed on tenant spaces throughout the towers. Placing all service systems within the core provided column-free floor space of roughly 31,000 sq ft (2,900 m^2) per floor outside the core. The long axis of the core in WTC 1 was oriented in the east-west direction while the long axis of the core in WTC 2 was oriented in the north-south direction.

Stairwells

WTC 1 and WTC 2 each had three primary stairwells designed for emergency egress, designated as A, B, and C. There were additional stairwells located in the basement levels (B1 – B5), convenience stairs for tenants leasing multiple floors, and mechanical room stairs. Stairwells A and C were 1.1 m (44 in.) wide and extended from floor 2 (plaza or Mezzanine Level) to floor 110 (lower mechanical space). Stairwell B was 56 in. (1.4 m) wide and ran from the subgrade 6 levels below ground to floor 107 including the Concourse (main lobby); there was no exit from Stairwell B onto the 2nd floor (plaza / Mezzanine Level).

The WTC 1 and WTC 2 stairwells were occasionally routed horizontally around equipment on mechanical floors, through what were called transfer hallways. Stairwell B required a horizontal transfer at floor 76. For all other floors, stairwell B maintained vertical alignment through the building. Stairwells A and C required several horizontal transfers, some longer than others, which ranged from several feet to over 100 ft (33 m).

Elevators

The World Trade Center complex contained more than 240 elevators, with 99 elevators serving the above-ground levels in each of the two main towers and an additional 7 elevators serving primarily the sub-grade basement levels. In the towers, the elevators were arranged to serve the buildings in three sections divided by skylobbies, which served to distribute passengers among express and local elevators.

5. Occupant Characteristics

NIST estimates that there were 8,900 ± 750 people in WTC 1 at 8:46:30 a.m. on September 11, 2001. Similarly, NIST estimates that there were 8,540 ± 920 people inside WTC 2 at 8:46:30 a.m. New York City officially announced 2,749 fatalities at the World Trade Center, including emergency responders, airplane passengers and crew (not including the 10 hijackers), and bystanders. NIST estimated that of the 17,400 ± 1,180 occupants inside WTC 1 and WTC 2 at 8:46:30 a.m., 2,163 – 2,180 perished. (No information could be found for 17 persons. The remaining individuals were emergency responders, airline passengers, or bystanders.) More than twice as many occupants were killed in WTC 1 as WTC 2, largely due to the fact that occupants in WTC 2 used the 16 minutes between the attacks on WTC 1 and WTC 2 to begin evacuating, including the use of elevators by some occupants in WTC 2.

The demographic characteristics of the evacuees were explored where the characteristics were relevant to the evacuation on September 11, 2001. Few differences in the characteristics of WTC 1 or WTC 2 were observed. Men outnumbered women roughly two to one. The average age was mid-forties. The mean length of employment at the WTC site was almost six years, while the median was 2 and 3 years for WTC 1 and 2, respectively. Sixteen percent of 2001 WTC evacuees were also present during the 1993 bombing, although many other occupants were also knowledgeable about the 1993 evacuation. Two-thirds of the occupants had participated in at least one fire drill during the 12 months immediately prior to September 11, 2001. Eighteen percent did not recall whether they had participated in a fire drill during that time period and eighteen percent reported that they did not participate in a fire drill during that time period.

6. September 11, 2001 - Evacuation

6.1.

In WTC 1, all three stairwells and the elevators were destroyed in the impact region, extending as low as floor 92. No occupant evacuated from above the 91st floor, although some survived until the building collapsed after 102 minutes. Helicopter rescue from the roof was considered by an NYPD aviation unit but deemed not possible due to the heat and smoke from the building fire. Occupants of both towers delayed initiating their evacuation after WTC 1 was hit. In WTC 1, the median time to initiate evacuation was 3 minutes for occupants from the ground floor to floor 76, and 5 minutes for occupants near the impact region (floors 77 – 91). Occupants observed various types of impact indicators throughout the building, including wall, partition, and ceiling damage and fire and smoke conditions. The most severe damage was observed near the impact region, fatally trapping some occupants. Announcements in WTC 1 were not heard by the occupants, despite repeated attempts from the lobby fire command station to order an evacuation. Damage to critical communications hardware likely prevented announcement transmission. Evacuation rates reached a peak, steady-state in approximately 5 minutes, and remained roughly constant until the collapse of WTC 2, when the rate in WTC 1 slowed to about one-fifth of the peak, steady-state. WTC 1 collapsed at 10:28:22 a.m., resulting in approximately 1,500 occupant deaths, 111 of which were estimated to be below the 92nd floor. A rest station for mobility challenged occupants was established in WTC 1 somewhere between floors 12 and 20. Less than ten minutes prior to the collapse of WTC 1, the occupants and helpers on the floor were ordered to evacuate, although it remains unclear whether all rest station residents survived.

6.2. WTC 2

The evacuation of WTC 2 was markedly different from the evacuation of WTC 1. There was a 16 minute period after WTC 1 was attacked, but before WTC 2 was attacked. During this time period, occupants were forced to decide whether to remain inside WTC 2, and if they decided to leave, they had to choose between using one of the three stairwells or using an elevator. Further complicating this decision process were multiple, conflicting announcements around 9:00 a.m., first instructing occupants to return to their offices, and then within one minute of impact, instructing them to begin an evacuation if conditions on their floor warranted that decision. Over 90 percent of WTC 2 survivors started to evacuate the building prior to its being attacked. Sixteen percent of the survivors used elevators to evacuate. Approximately 75 percent of the occupants who were above the 78th floor (the lowest floor of impact) descended to at least below the impact region prior to the attack on WTC 2. Over 40 percent of the survivors had left WTC 2 prior to 9:02:59 a.m. After WTC 2 was attacked, at least 18 individuals used Stairwell A, located in the northwest corner and furthest from the impact damage, to descend below the 78th floor to evacuate the building. Additional public address announcements were made after the airplane strike on WTC 2, although occupants who survived generally did not hear those announcements. After the initial peak in evacuation rate due to concurrent elevator and stairwell usage, the rate reached a steady-state similar to the rate observed in WTC 1 until approximately 20 minutes prior to collapse of WTC 2. The evacuation rate during the final 20 minutes dropped significantly, likely due to a decreased number of occupants remaining in the egress system below the 78th floor. NIST analysis indicated only eight occupants initially below the 78th floor were killed when WTC 2 collapsed at 9:58:59 a.m. Overall, NIST estimated that 626 occupants of WTC 2 perished.

7. Causal Modeling

Using the statistical power of the telephone interview results, two models were constructed to explore the primary components of total evacuation time: evacuation initiation delay and stairwell traversal time. Each model explained between 49 percent and 56 percent of the variance in the ultimate dependent variable, which are high levels for human behavior studies.

7.1. Evacuation Initiation Delay

The first component of total evacuation time is the time delay prior to starting evacuation. This was defined as the time from the attack on WTC 1 until the occupant left the floor using a stairwell or elevator to leave the building. The factors that best predicted

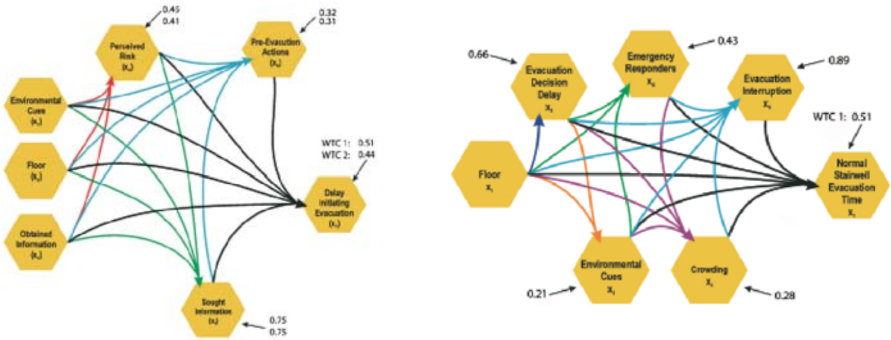

Figure 1: Causal models for (left) evacuation initiation delay (WTC 1 and WTC 2) and (right) normalized stairwell evacuation time (WTC 1).

evacuation initiation delay in WTC 1 were (1) which floor the respondent was on when WTC 1 was attacked, (2) whether occupants encountered environmental cues (smoke, fire, debris, etc.), and (3) seeking additional information (or milling) about the nature of the event. In WTC 2, the same process occurred as in WTC 1, except that perceived risk (sense of immediate danger) was a predictor of seeking additional information (along with floor and environmental cues).

7.2. Normalized Stairwell Evacuation Time

The second component of total evacuation time was the time spent in the stairwells. This analysis determined the factors and social processes that influenced the normalized stairwell evacuation time per flight of stairs for the people who evacuated out of WTC 1 on September 11, 2001. WTC 2 was excluded from this analysis because evacuees used stairs, elevators, and/or a combination of both for their evacuation and could not be separated for the analysis. Evacuation time was defined as the average number of seconds per flight of stairs that it took people from the time they entered a stairwell until they completed their evacuation out of the building. The model used to predict important factors in stairwell evacuation time again used variables that preliminary analyses and general evacuation theory suggested as salient.

The main process that led to increased normalized stairwell evacuation time in the evacuation of WTC 1 on September 11th was straightforward and clear. Floor (increased distance to safety) substantially increased the odds that people would encounter environmental cues. Floor also increased delay in starting evacuation (this relationship was elaborated upon in the first model), which, in turn, also increased the chances that people would encounter environmental cues. But it was encountering environmental cues that had a large and direct effect on increasing the amount of time that people spent, on average, to traverse their evacuation stairwell. In addition to this multi-step process with environmental cues as the key predicting variable, interrupting the process of evacuation for any reason also increased the amount of time, on average, that people used to descend their evacuation stairwell.

8. Egress Modeling

Multiple evacuation models were used to simulate different WTC tower evacuations, subject to a number of assumptions. The goal of the modeling was to frame an understanding of actual evacuation findings on September 11, 2001. Simulations demonstrated that a phased evacuation (also known as defend-in-place, whereupon occupants on the fire floor and the immediately surrounding floors descend to three floors below the fire floor) would have taken between 4 minutes to complete without delays in evacuation initiation and 11 mintues to complete with evacuation initation delays between 0 and 10 minutes. Total evacuation of a tower assuming a full occupant load without visitors (19,800) would have required as few as 92 – 112 minutes. With visitors (total population 25,500 people) total evacuation would have required as little as 114 – 142 minutes. The ranges reflect two different model outputs, each assuming two different delay times (no delay and a ten minutes distribution of delay times). An evacuation simulation for 8,800 people (approximately the number present in each tower on September 11, 2001) in the absence of any damage to the building, would have required at least 52 – 71 minutes, depending on the model or the delay times. Finally, the model output was 'calibrated' to approximate the gross evacuation rates observed in WTC 1 and WTC 2 on September 11, 2001. Once the model input necessary to approximate the observables was determined, additional occupants were added in order to estimate how many occupants might have been unable to evacuate on September 11, 2001 (given the damage to the building and observed delay times) if the buildings had had larger occupant loads. NIST estimated that approximately 14,000 occupants would have been unable to evacuate from WTC 1 and WTC 2 on September 11, 2001 had the starting building population been 19,800 in each building.

9. Recommendations Related to Egress

Building evacuation should be improved to include system designs that facilitate safe and rapid egress, methods for ensuring clear and timely emergency communications to occupants, better occupant preparedness for evacuation during emergencies, and incorporation of appropriate egress technologies[2].

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[2] This effort should include standards and guidelines for the development and evaluation of emergency evacuation plans, including best practices for both partial and full evacuation, and the development of contingency plans that account for expected conditions that may require adaptation, including the compromise of all or part of an egress path before or during evacuation, or conditions such as widespread power failure, earthquake, or security threat that restrict egress from the building. Evacuation planning should include the process from initial notification of the need to evacuate to the point the occupants arrive at a place where their safety is ensured. These standards and guidelines should be suitable for assessing the adequacy of evacuation plans submitted for approval and should require occupant training through the conduct of regular drills.

Recommendation: NIST recommends that public agencies, non-profit organizations concerned with building and fire safety, and building owners and managers should develop and carry out public education campaigns, jointly and on a nationwide scale, to improve building occupants' preparedness for evacuation in case of building emergencies. This effort should include better training and self-preparation of occupants, an effectively implemented system of floor wardens and building safety personnel, and needed improvements to standards. Occupant preparedness should include:
a. Improved training and drills for building occupants to ensure that they know evacuation procedures, are familiar with the egress route, and are sufficiently aware of what is necessary if evacuation is required with minimal notice (e.g., footwear consistent with the distance to be traveled, a flashlight/glow stick for pathway illumination, and dust masks).
b. Improved training and drills that routinely inform building occupants that roof rescue is not (or is) presently feasible as a standard evacuation option, that they should evacuate down the stairs in any full-building evacuation unless explicitly instructed otherwise by on-site incident commanders, and that elevators can be used if they are still in service and haven't been recalled or stopped.
c. Improved codes, laws, and regulations that do not restrict or impede building occupants during evacuation drills from familiarizing themselves with the detailed layout of alternate egress routes for a full building evacuation[3].

Recommendation: NIST recommends that tall buildings should be designed to accommodate timely full building evacuation of occupants due to building-specific or large-scale emergencies such as widespread power outages, major earthquakes, tornadoes, hurricanes without sufficient advanced warning, fires, accidental explosions, and terrorist attack. Building size, population, function, and iconic status should be taken into account in designing the egress system. Stairwell and exit capacity[4] should be adequate to accommodate counterflow due to emergency access by responders.
a. Improved egress analysis models, design methodology, and supporting data should be developed to achieve a target evacuation performance (e.g., time for full building evacuation[5]) for the design building population by considering the building and egress system designs and human factors such as occupant size, mobility status, stairwell tenability conditions, visibility, and congestion.
b. Mobility challenged occupants should be provided a means for self-evacuation in the event of a building emergency. Current strategies (and law) generally require the

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[3] New York City Local Law 5 prohibits requiring occupants to practice stairwell evacuation during drills.

[4] Egress capacity should be based on an all-hazards approach that considers the number and width of stairs (and doors) as well as the possible use of scissor stairs credited as a single stair.

[5] Use of egress models is required to estimate the egress capacity for a range of different evacuation strategies, including full building evacuation. NIST found that the average surviving occupant in the WTC towers descended stairwells at about half the slowest speed previously measured for non-emergency evacuations.

mobility challenged to shelter-in-place and await assistance. New procedures, which provide redundancy in the event that the floor warden system or co-worker assistance fails, should consider full building evacuation, and may include use of fire-protected and structurally hardened elevators[6], motorized evacuation technology, and/or dedicated communication technologies for the mobility challenged.

c. If protected/hardened elevators are provided for emergency responders but become unusable during an emergency, due to a malfunction or a conventional threat whose magnitude exceeds the magnitude considered in design, sufficient stairwell capacity should be provided to ensure timely emergency responder access to buildings that are undergoing full evacuation. Such capacity could be provided either via dedicated stairways for fire service use or by building sufficient stairway capacity (i.e., number and width of stairways and/or use of scissor stairs credited as a single stair) to accommodate the evacuation of building occupants while allowing access to emergency responders with minimal hindrance from occupant counterflow.

d. The egress allowance in assembly use spaces should be limited in state and local laws and regulations to no more than a doubling of the stairway capacity for the provision of a horizontal exit on a floor, as is the case now in the national model codes[7]. The use of a horizontal exit creates an area of refuge with a 2 hour fire rated separation, at least one stair on each side, and sufficient space for the expected occupant load.

Recommendation: NIST recommends that egress systems should be designed: (1) to maximize remoteness of egress components (i.e., stairs, elevators, exits) without negatively impacting the average travel distance; (2) to maintain their functional integrity and survivability under foreseeable building-specific or large-scale emergencies; and (3) with consistent layouts, standard signage, and guidance so that systems become intuitive and obvious to building occupants during evacuations.

a. Within a safety-based design hierarchy that should be developed, highest priority should be assigned to maintain the functional integrity, survivability, and remoteness of egress components and active fire protection systems (sprinklers, standpipes, associated water supply, fire alarms, and smoke management systems). The design hierarchy should consider the many systems (e.g., stairs, elevators, active fire protection, mechanical, electrical, plumbing, and structural) and system components, as well as functional integrity, tenant access, emergency responder access, building configuration, security, and structural design.

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[6] Elevators should be explicitly designed to provide protection against large, but conventional, building fires. Fire-protected elevators also should be structurally hardened to withstand the range of foreseeable building-specific or large-scale emergencies. While progress has been made in developing the requirements and technologies for fire-protected elevators, similar criteria and designs for structurally hardened elevators remain to be developed.

[7] The New York City Building Code permits a doubling of allowed stair capacity when one area of refuge is provided on a floor and a tripling of stair capacity for two or more areas of refuge on a floor. In the world of post-September 11, 2001, it is difficult to predict (1) if, and for how long, occupants will be willing to wait in a refuge area before entering an egress stairway, and (2) what the impact would be of such a large group of people moving down the stairs on the orderly evacuation of lower floors.

b. The design, functional integrity, and survivability of the egress and other life safety systems (e.g., stairwell and elevator shafts and active fire protection systems) should be enhanced by considering accidental structural loads such as those induced by overpressures (e.g., gas explosions), impacts, or major hurricanes and earthquakes, in addition to fire separation requirements. In selected buildings, structural loads due to other risks such as those due to terrorism may need to be considered. While NIST does not believe that buildings should be designed for aircraft impact, as the last line of defense for life safety, the stairwells and elevator shafts individually, or the core if these egress components are contained within the core, should have adequate structural integrity to withstand accidental structural loads and anticipated risks.
c. Stairwell remoteness requirements should be met by a physical separation of the stairwells that provide a barrier to both fire and accidental structural loads. Maximizing stairwell remoteness, without negatively impacting the average travel distance, would allow a stairwell to maintain its structural integrity independent of any other stairwell that is subject to accidental loads, even if the stairwells are located within the same structural barrier such as the core. The current "walking path" measurement allows stairwells to be physically next to each other, separated only by a fire barrier. Reducing the clustering of stairways that also contain standpipe water systems provide the fire service with increased options for formulating firefighting strategies. This should not preclude the use of scissor stairs as a means of increasing stair capacity—provided the scissor stair[8] is only credited as a single stair.
d. Egress systems should have consistent layouts with standard signage and guidance so that the systems become intuitive and obvious to all building occupants, including visitors, during evacuations. Particular consideration should be given to unexpected deviations in the stairwells (e.g., floors with transfer hallways).

Recommendation: NIST recommends that building owners, managers, and emergency responders develop a joint plan and take steps to ensure that accurate emergency information is communicated in a timely manner to enhance the situational awareness of building occupants and emergency responders affected by an event. This should be accomplished through better coordination of information among different emergency responder groups, efficient sharing of that information among building occupants and emergency responders, more robust design of emergency public address systems, improved emergency responder communication systems, and use of the Emergency Broadcast System (now known as the Integrated Public Alert and Warning System) and Community Emergency Alert Networks.
a. Situational awareness of building occupants and emergency responders in the form of information and event knowledge should be improved through better coordination of such information among emergency responder groups (9-1-1 dispatch, fire department or police department dispatch, emergency management dispatch, site security, and appropriate federal agencies), efficient sharing and communication of information between building occupants and emergency responders, and improved emergency responder communication systems (i.e., including effective communication within steel and

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[8] Two separate stairways within the same enclosure and separated by a fire rated partition.

reinforced concrete buildings, capacity commensurate with the scale of operations, and interoperability among different communication systems).
b. The emergency communications systems in buildings should be designed with sufficient robustness and redundancy to continue providing public address announcements or instructions in foreseeable building-specific or large-scale emergencies, including widespread power outage, major earthquakes, tornadoes, hurricanes, fires, and accidental explosions. Consideration should be given to placement of building announcement speakers in stairways in addition to other standard locations.
c. The Integrated Public Alert and Warning System (IPAWS) should be activated and used, especially during large-scale emergencies, as a means to rapidly and widely communicate information to building occupants and emergency responders to enhance their situational awareness and assist with evacuation.
d. Local jurisdictions (cities and counties or boroughs) should seriously consider establishing a Community Emergency Alert Network (CEAN), within the framework of IPAWS, and make it available to the citizens and emergency responders of their jurisdiction to enhance situational awareness in emergencies.[9] The network should deliver important emergency alerts, information and real-time updates to all electronic communications systems or devices registered with the CEAN. These devices may include e-mail accounts, cell phones, text pagers, satellite phones,and wireless PDAs.

Recommendation: NIST recommends that the full range of current and next generation evacuation technologies should be evaluated for future use, including protected/hardened elevators, exterior escape devices, and stairwell navigation devices, which may allow all occupants an equal opportunity for evacuation and facilitate emergency response access. «

[9] Types of emergency communications could include life safety information, severe weather warnings, disaster notifications (including information on terrorist attacks), directions for self-protection, locations of nearest available shelters, precautionary evacuation information, identification of available evacuation routes, and accidents or obstructions associated with roadways and utilities.