Pedestrian and Evacuation Dynamics 2005

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Editors

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With 256 Figures, 111 in Color, and 42 Tables

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Opening Speech at the University

Dear State Secretary Mag. Eduard Mainoni,
Dear Prof. Dr. Hans Kaiser,
Ladies and Gentlemen, dear colleagues:

On behalf of the Organising Committee of the PED 2005 it is my pleasure to welcome you to Vienna.
I feel honored to have had the opportunity to contribute to the organizing efforts and to meet with all the renowned specialists assembled here.

I would like to acknowledge the support of our main sponsor, the Federal Ministry of Transport, Innovation and Technology, as well as our other sponsors, TraffGo HT and Arsenal Research.

I am especially pleased that Eduard Mainoni, the State Secretary of the Federal Ministry of Transport, Innovation and Technology could join us here today. He is leading the Project for the Austrian state-supported Program for Safety Research.

I hope all of you will have a very successful conference and a pleasant stay in our beautiful city. Thank you! «

Nathalie Waldau

Opening Speech HSTS Mag. Eduard Mainoni

Dear Prof. Dr. Hans Kaiser,
Distinguished Members of the Organisation Committee,
Invited speakers and distinguished guests
Ladies and Gentlemen!

It is a pleasure for me to welcome you at the Third International Conference on Pedestrian and Evacuation Dynamics at the Technical University of Vienna.

Most of all, I would like to warmly welcome all the researchers and practitioners from more than 17 countries who visit Vienna to participate in this conference. I hope all of you had a pleasurable journey and might already have had the opportunity to grasp some of the charm of this city.

This year's conference on Pedestrian and Evacuation Dynamics is the third one in a series of conferences. The first was held in Duisburg, Germany in 2001 and the second one in Greenwich, UK 2003. It is a pleasure for me to welcome you know in Vienna to PED 2005.
It is also a pleasure for me to welcome the two persons who have hosted the previous conferences: Prof. Michael Schreckenberg from the University of Duisburg-Essen and Prof. Ed Galea from the University of Greenwich.

You might know the famous quotation from Isaac Newton: "If I have seen further it is by standing on the shoulders of giants."
Even though the term giants might sound a bit exaggerating in this context, it shows nevertheless the very important function of continuity and tradition. Being able to accumulate and refine the knowledge on crowd dynamics and all aspects of evacuation and pedestrian movement is one of the major benefits of a series of conferences. And is certainly not an exaggeration, if one claims that this conference series on Pedestrian and Evacuation Dynamics plays a pivotal role in the advancement of these fields.

Of course, this advancement is fostered by the passion and commitment of researchers and practitioners alike. Without you, the participants of this conference, this would not be possible. You are probably interested in different aspects of pedestrians, crowds, egress, and evacuation processes.

Nevertheless, you came here to present your results, discuss them with your colleagues, and exchange views and knowledge. This is a clear sign for the vitality and the attractiveness of the field you are working in. Furthermore, each and every person can profit from this conference, since all of us are usually members of crowds.

This is obvious in large cities like Vienna. Public transportation systems are built for mass transport. Large gatherings of people are a characteristic feature of modern cities and therefore for modern societies.

Because of the importance of this subject, I am proud to say, that this years conference is held under the patronage of His Vice Chancellor Hubert Gorbach and is financially supported by the Federal Ministry of Transport, Innovation and Technology (15.000 € in total: ½ received in March/April 2005, rest after the conference).

As we are talking about security and research, let me say a few brief words about the Austrian Security Research Program, which is coordinated by the Federal Ministry of Transport, Innovation and Technology:

The Austrian Security Research Program KIRAS was recommended by RFTE (Austrian Council for Research and Technology Development) in July this year with a first budget of € 5 Millions for 2005. (2005-2013: 110 Mio. € in total)

In order to that Austria is the first EU-Member State, with a national Security Research Program, and it is part of the 7th EU-Framework-Program.

A call for expressions of interest will start by the end of the year. The FFG (Austrian Research Promotion agency) will act as project coordinator and as point of contact for applicants.

The main aims of the national program are:
- » *Generation of the knowledge, which is needed for the reaching of the security-political goals of Austria*
- » *Increase of objectively measurable security for the population and the security-feeling of the individual*
- » *Achievement of security-relevant procedure and technology jumps*
- » *Growth of the Austrian security economy*
- » *Structure of Excellency within the field of the security research*

At the EU-level the Preparatory Action PASR (2. Call finished, Preparation of 3 Call in 2006) is continued.

At the moment the security research agenda and overall governance with the help of ESRAB (European Security Research Advisory Board), in consultation with Member States, with other security "user" DG´s and with EDA (European Defence Agency) is prepared. It should start 2007 and be supported with 1 Billion € per year.
Additional specific implementation rules (e.g. contract aspects, funding level, handling of classified information, participation) are established.

The main Security Research Event during the EU-Council Presidency will be the European Conference on Security Research in Vienna from the 20th to the 21st February 2006.

But let me come back now to today's conference on Pedestrian and Evacuation Dynamics:

I am strongly convinced that evacuation and crowd dynamics will play a vital role in shaping the future of our societies. And I hope that the results of your research and investigations will be directly transferred into improvements of public safety and convenience and will be used for the benefit of all of us. In the light of these considerations I am especially glad that this conference takes place in Vienna. Be assured that our Ministry will closely monitor the progress of your field.

Therefore, I wish all of you fruitful discussions and many new ideas and stimulation. Let me finally thank you again for coming here and good look for your conference. **«**

Preface

Due to an increasing number of reported catastrophes all over the world the safety especially of pedestrians today is a dramatically growing field of interest, both for practitioners as well as scientists from various disciplines. The questions arising mainly address the dynamics of evacuating people and possible optimisations of the process by changing the architecture and /or the procedure. This concerns not only the case of ships, stadiums or buildings, all with restricted geometries, but also the evacuation of complete geographical regions due to natural disasters. Furthermore, also 'simple' crowd motion in 'relaxed' situations poses new questions with respect to higher comfort and efficiency since the number of involved persons at large events is as high as never before.

In principle four different methods to tackle these problems exist: One is the analysis of well documented (mainly by video) crowded situations worldwide, another one is the performance of specially designed and elaborated experiments with a certain (normally not as large as necessary) number of participants confronted with a 'real' environment and a predefined task. The third is the investigation of animal behaviour in comparable but (down-)scaled environments where the shaping of the experiments can be easier controlled. The fourth one is to perform simulations based on as realistic as possible mathematical models which incorporate the correct physical movements of the individuals as well as their psychological and social behaviours.

The first three methods have evident disadvantages: Well-documented catastrophes are always singular and rare, experiments with test subjects are not able to reproduce the quantitative (number of persons) and qualitative (emotional and behavioural) tasks of real situations and, finally, animal behaviour can only be extrapolated to human behaviour with respect to a few aspects. In contrast, simulations can, in principle, overcome most of these problems. However, they depend crucially on the quality of the underlying models. This concerns the physical motion of humans, but much more the psychological and social particularities of the individuals under consideration. These can, at least in parts, be derived from the first three methods, nevertheless the properties have to be improved step by step towards a satisfactory performance of the simulations with respect to reality.

The focus of this conference held in Vienna, the third one in a series after Duisburg (2001) and Greenwich (2003), therefore was once more on modelling and simulation of evacuation dynamics, represented by 29 contributions. In addition, pedestrian data collection (8), pedestrian dynamics (5) and collective animal behaviour (4) completed the scope of the conference (amounting to a total of 46 scientific paper in this volume). The number and the quality of these contributions give evidence for the enormous progress made in this field since the last conference only two years ago.

We would like to thank our main sponsor, the Federal Ministry of Transport, Innovation and Technology, as well as our sponsors, TraffGo HT and Arsenal Research.

Last but not least we would like to thank everyone who has helped make this conference a reality and success: the members of the technical committee, Katja Schechtner, Hubert Klüpfel, and Tobias Kretz, as well as the organizational staff: Christian Drexler, Tim Meyer-König, Martina Theissl, Yvonne Ginthör, Gabriel Wurzer, Thomas Reichart, Uemit Seren, and finally Florian Szeywerth for the website, poster and the design of the proceedings. «

Vienna, August 2006

Nathalie Waldau
Peter Gattermann
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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.

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[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.

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[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

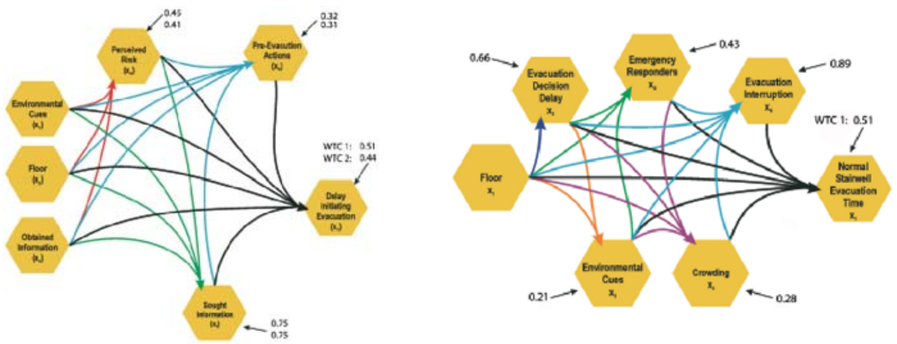

Figure 1: Causal models for (left) evacuation initiation delay (WTC 1 and WTC 2) and (right) normalized stairwell evacuation time (WTC 1).

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.