

***RETHINKING EGRESS:
A VISION FOR THE FUTURE
Workshop Proceedings
April 1-3, 2008, Warrenton, Virginia***

Jason D. Averill and Richard D. Peacock
Building and Fire Research Laboratory

Ralph L. Keeney
Duke University

November 2009



U.S. Department of Commerce

Gary Locke, Secretary

National Institute of Standards and Technology

Patrick D. Gallagher, Deputy Director

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

National Institute of Standards and Technology Technical Note 1647

Natl. Inst. Stand. Technol. Tech.Note 1647, 75 pages (March 2010)

CODEN:

ABSTRACT

New technologies, design challenges, and research are rapidly redefining the state-of-the-art in building evacuation. Therefore, the time is right to rethink the entire infrastructure of egress from buildings. Approximately 40 experts from a variety of disciplinary backgrounds assembled in Warrenton, VA from April 1-3, 2008 in order to consider building evacuation, starting with a blank sheet of paper.

Structured around the principles of “Value-Focused Thinking” (a text authored by workshop moderator Ralph L. Keeney), the participants were encouraged to consider values, objectives, and alternatives. This process combined the benefits of free-thinking brainstorming with a formalism which encouraged evaluation of the potential for new ideas. By the conclusion of the third day, over 400 ideas had been developed, along with metrics for future evaluation of the ideas.

EXECUTIVE SUMMARY

Of the 30 recommendations published in the final report of the Federal Investigation into the Collapse of the World Trade Center, several focused on providing reliable egress for occupants from high-rise buildings. Specifically, “building evacuation systems 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 technology.” Combined with the potential for the use of elevators for evacuation and firefighter access to revolutionize the process of evacuation, a complete reevaluation of egress systems was warranted.

A novel workshop, composed of a broad spectrum of disciplinary experts, provided a forum for discussion and innovative insights. The principal objective of the workshop was to facilitate a reassessment and definition of egress objectives and to develop a vision for the future of the means of egress. Roughly 40 individuals, representing world-class expertise in architecture, disabilities, disasters, emergency management, engineering, firefighting, psychology, regulations/inspections, site development, and sociology, assembled in Warrenton, VA to envision a new future for occupant and firefighter safety in tall buildings. This report is a summary of the process and findings from the workshop.

The workshop was structured around the process described in “Value-Focused Thinking” by Ralph Keeney. The participants started with a set of values and objectives for occupants in high-rise buildings. By first explicitly considering high-level values and objectives, participants were then better able to develop specific innovative solutions which would enable accomplishment of the objectives.

The report contains five primary sections. First, the motivation and purpose of the workshop are presented. Second, the theory underlying the format of the workshop is reviewed in order to provide context to the meeting chronology. Third, a summary of the events of the workshop, organized chronologically, is presented. Fourth, the principal outputs of the workshop are presented: a summary of objectives of building egress, a list of all of the alternatives which accomplish one or more of the objectives, and a table which summarizes a preliminary evaluation of a sample cross-section of alternatives. Finally, the appendices include the attendees, forms used for brainstorming, and the results of group discussions.

WORKSHOP FINDINGS: OBJECTIVES

An objective is a statement of something that one desires to achieve in a given decision context. The decision context for this workshop was emergency egress from large buildings. It is important to distinguish between two types of objectives: fundamental objectives and means objectives. The fundamental objectives characterize the essential reasons for interest in the decision situation. A means objective is of interest because achieving it can contribute to achieving the fundamental objectives. The workshop produced seven fundamental objectives, as well as a number of means objectives.

The seven fundamental objectives identified by the participants were:

- Save lives and prevent injuries to occupants
- Save lives and prevent injuries to firefighters/responders
- Minimize property damage
- Minimize impact on property operations
- Minimize economic costs
- Reduce stress
- Reduce grief

Additionally, 12 categories of means objectives were identified. These included:

- Enhance detection
- Maximize situation awareness
- Make people feel safe
- Minimize response time
- Enhance communications
- Enhance safety
- Facilitate responder access
- Isolate fire
- Minimize evacuation time
- Improve knowledge about the system
- Improve education and training
- Provide easy egress procedures

WORKSHOP FINDINGS: ALTERNATIVES

Over 400 individual alternatives were identified which contributed in part or whole to the accomplishment of one or more of the identified objectives. These alternatives are shown in the workshop findings (Section 4.0) of this report. The alternatives were grouped into 18 categories:

- Sprinklers / Active Suppression Systems
- Protect in Place / Areas of Refuge
- Building Construction Changes
- Building Material Changes
- Fire Service
- Elevators
- Societal /Regulatory / Legal Changes
- External to the Building
- Communication
- Information Systems
- Pre-event Planning
- Efficient Use of Egress System
- Enhance Stairwell Evacuation / Reduce Stairwell Load
- Design Process / Risk Informed Performance-Based Design
- Enhance Reliability of Building Systems
- Event Procedural Changes

- Enhanced Event Detection
- Other Alternatives

WORKSHOP FINDINGS: EVALUATION OF CROSS-SECTION OF ALTERNATIVES

Finally, roughly ten percent of the alternatives (37) were selected for preliminary evaluation, which approximated a cross section of the total list. The selected alternatives were each evaluated by nine groups of three persons using three distinct criteria: usefulness, feasibility, and creativity. Alternatives that were identified as both highly useful and feasible, included:

- Real-time building / fire data to responding fire service personnel
- Simultaneous use of elevators and stairs
- Emergency notification system to all occupants – phone, email, TV, satellite, public address
- Notify occupants via cell phone
- Real time monitoring of movement in stairs
- Install readily visible directional indicators at key locations
- Normal and emergency movement systems should be integrated
- Enhance visibility of exit signs: larger, flashing or digital signage
- Two-way communication between fire service and occupants during event
- Photoluminescent markings
- Base designs on risk assessments
- Electronic monitoring of all components of standpipe
- Retrofit sprinklers in all high-rise buildings
- Provide hardened floors at intervals in tall buildings
- Provide mechanical means to allow fire hose to penetrate stairwell doors while keeping smoke from entering

In conclusion, the workshop produced hundreds of alternatives for improving egress from buildings during fire emergencies. No single alternative addresses all egress objectives; however, with further research and study, some combinations of alternatives have the potential to rethink the entire means of egress from buildings. A follow-up workshop in the future may result in an actionable roadmap to realize the potential identified during the 2008 Rethinking Egress Workshop.

CONTENTS

Abstract	3
Executive Summary	4
1.0 Background	10
2.0 Workshop Format	12
Outline and Process of the Workshop	12
The Objectives of Emergency Egress.	14
The Alternatives Generated for Emergency Egress	15
Appraisal of Selected Alternatives	15
Use of the Workshop Results	16
3.0 Workshop Session Summary	17
April 1, 2008: Day 1 of the Workshop	17
Averill: Welcome	17
Keeney: Workshop Process	18
Sanders: Fire Department Operations in High-Rise Buildings	18
Jacobsen: Leveraging Information in Building Evacuation	19
Galioto: Challenges Facing Architects for Super-Tall Buildings	20
Mileti: The Social Science of Building Evacuation	20
Abboud: Structural Engineers, Fire, and Egress	21
Nelson: The Legacy of the 1971 Airlie House High-Rise Life Safety Conference	22
Alternatives and Objectives	22
April 2, 2008: Day 2 of the Workshop	23
April 3, 2008: Day 3 of the Workshop	26
Evaluation	26
Concluding Remarks	27
4.0 Workshop Findings	29
Consolidated Emergency Egress Objectives	29
Consolidated Alternatives to Improve Emergency Egress	33
Individual Evaluations of Alternatives	44
Acknowledgments	47
5.0 Appendices	48

Appendix A: List of Attendees..... 49

Appendix B: Rethinking Egress Workshop Agenda 51

Appendix C: Forms for Structured Brainstorming..... 52

Appendix D: Techniques to Stimulate Recognition of Values..... 70

Appendix E: Results from Group Discussion 71

ORGANIZATION OF THE REPORT

The Rethinking Egress report contains five primary sections.

- Section 1.0 Background: the motivation and purpose of the workshop are presented.
- Section 2.0 Workshop Format: the theory underlying the format of the workshop is reviewed, in order to provide context to the meeting chronology.
- Section 3.0 Workshop Summary: a summary of the events of the workshop, organized chronologically, is presented.
- Section 4.0 Workshop Findings: the principal outputs of the workshop are presented. These outputs include a list of all of the identified objectives of building egress, a list of all of the alternatives which accomplish one or more of the objectives, and a table which summarizes a preliminary evaluation of a sample cross-section of alternatives.
- Section 5.0 Appendices: the list of attendees, forms used for brainstorming, brainstorming techniques, and the results of group discussions are presented.

1.0 BACKGROUND

Following the Federal Investigation of the Collapse of the World Trade Center and subsequent report, the National Institute of Standards and Technology (NIST) partnered with with the National Institute of Building Sciences and its Multihazard Mitigation Council (MMC) to implement recommended changes to existing standards of practice and building codes and standards. Of the 30 recommendations published in the final report, several focused on providing reliable egress for occupants from high-rise buildings. Specifically, “building evacuation systems 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 technology.”

During its deliberations, the MMC committee reviewing the report recommendations concluded that the use of elevators for evacuation and firefighter access in high-rise buildings had the potential to revolutionize the process of evacuation to such a significant degree that a complete reevaluation of egress systems was warranted. A workshop of multi-disciplinary experts in the field would provide a forum for discussion and innovative insights. In collaboration with NIST staff, a small number of technical experts were identified to assist with planning the workshop, shown on the left of this page.

Workshop planning sessions were held in-person and by conference call, throughout 2007. Early in the planning, the value of a professional moderator with expertise in structured brainstorming was identified. Ralph Keeney (Duke University) was retained in order to help organize the workshop around the framework described in his seminal text, “Value-Focused Thinking: A Path to Creative Decisionmaking.”* Subsequently, the workshop was scheduled for April 1-3, 2008, at the Airlie Conference Center in Warrenton, Virginia.

Rethinking Egress Planning

- **Najib Abboud of Weidlinger Associates**
- **Carl Galioto of Skidmore, Owings & Merrill, LLP**
- **Clas Jacobson of United Technologies**
- **Dennis Mileti of the University of Colorado-Boulder**
- **Russ Sanders of the National Fire Protection Association**

Rethinking Egress Moderator

- **Ralph Keeney of Duke University**

* Keeney, Ralph L. “Value-Focused Thinking.” Harvard University Press, Cambridge, MA. 1992.

*Trust that little voice in
your head that says
"Wouldn't it be interesting if..."*

And then do it.

- Duane Michals

2.0 WORKSHOP FORMAT

The principal objective of the workshop was to facilitate a reassessment and definition of egress objectives and to develop a vision for the future of the means of egress. As the genesis of the workshop was the findings from the Investigation of the World Trade Center collapse, a particular emphasis was placed on egress from tall buildings. The process used to structure the workshop was based on the framework described in the seminal decision sciences text, “Value-Focused Thinking: A Path to Creative Decisionmaking,” by Ralph Keeney. Keeney was retained to moderate the workshop in order to maximize the effectiveness of the process. This section presents the structure and format for the workshop in order that the reader can better interpret the workshop results and findings. The process included three basic steps: identify objectives (what do you want to accomplish?), identify alternatives (how do you want to accomplish your objective?), and evaluation of alternatives. The flow chart for this process is shown in Figure 1 on the following page.

OUTLINE AND PROCESS OF THE WORKSHOP

The overall structure of the workshop was based on three premises: (1) all thinking is done in individual’s minds, as there is no collective mind, (2) in discussions, individuals tend to narrow their thinking to focus on the discussed content, and (3) individuals working in a group can expand on the ideas of others. Hence, we wanted to stimulate thinking by the individuals to get all of the relevant ideas from each individual first, and then expand these with personal interaction.

Thus, in the morning of the first day, we initially asked individuals to write every idea that they thought would be relevant to the workshop, so that they would be less concerned about exactly when their points of view would be discussed and more willing to create new ideas. However, the bulk of the first morning was five presentations from different perspectives on the problem of egress. In the first afternoon, individuals worked alone using a variety of techniques to generate egress alternatives and a set of objectives that they hoped would be achieved by such alternatives. This provided a foundation for the next two days.

In the morning of day 2, participants met in groups of approximately seven to create additional alternatives based on their collective thoughts. Then, the entire workshop discussed some of these alternatives and embellished them. On the second afternoon, the individual groups considered in detail two processes: effective egress and fire fighting. Three groups identified all of the steps that would be necessary for effective egress from a very large building, and one group listed all the steps necessary for fighting a fire in a very large building. These steps were then used to generate still more potential alternatives to facilitate egress.

The third morning of the workshop included a preliminary evaluation of a subset of the alternatives. One purpose was to find out the types of

Key Definitions

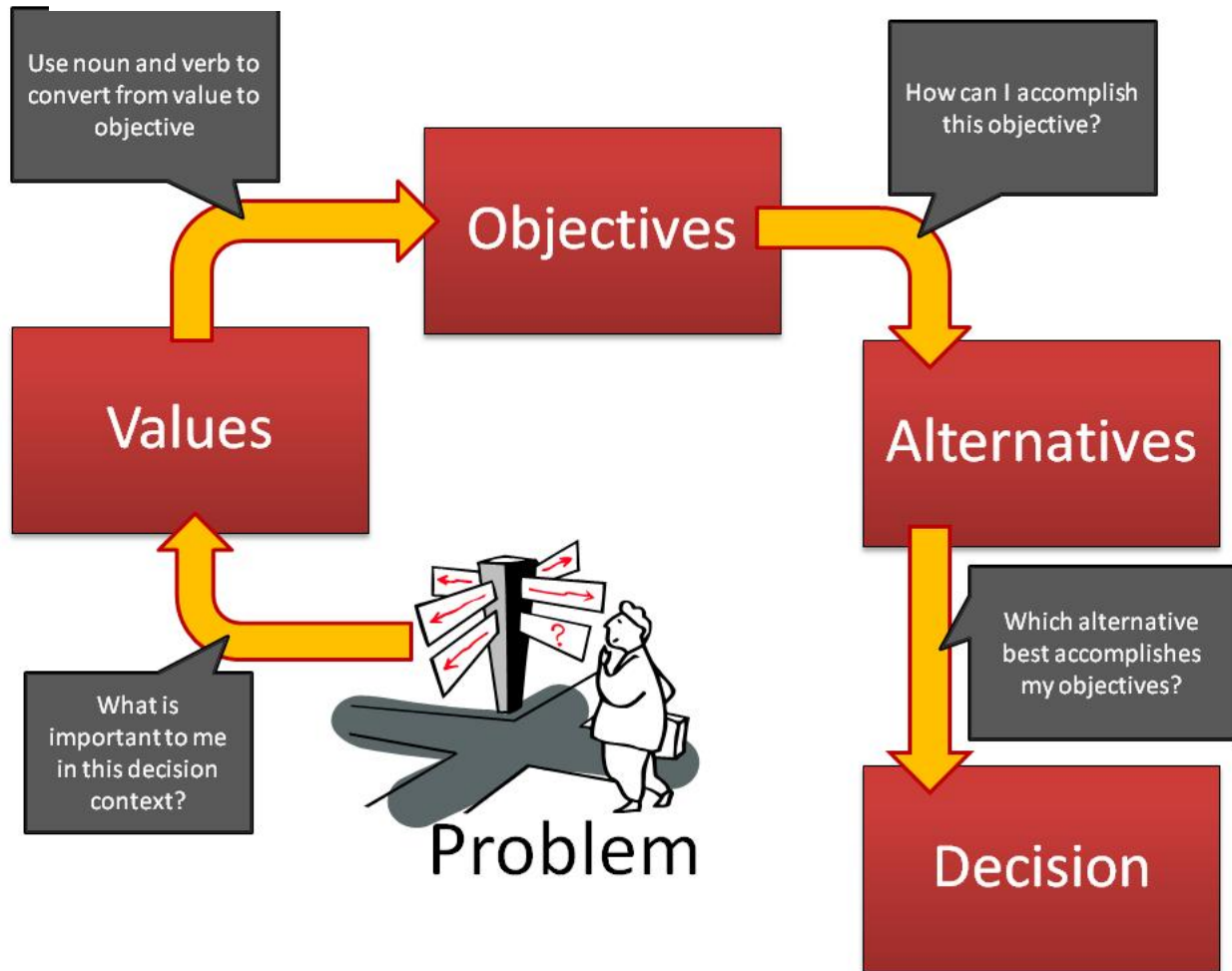
Values: anything that one cares about concerning the decision.

Objectives: a statement of something that one desires to achieve.

Alternatives: actions totally under the control of a decision maker that may influence the degree to which at least one of the objectives is achieved.

alternatives that seemed most useful and that had a high feasibility of being practical in the near future. A second purpose was to identify those categories of alternatives that were particularly creative, and hence, perhaps more appropriate for further in-depth creative activities to develop additional alternatives.

FIGURE 1: FLOW CHART FOR VALUE-FOCUSED THINKING



THE OBJECTIVES OF EMERGENCY EGRESS

An objective is a statement of something that one desires to achieve in a given decision context. In our situation, the decision context is emergency egress from large buildings. It is important to distinguish between two types of objectives: fundamental objectives and means objectives. The fundamental objectives characterize the essential reasons for interest in the decision situation. A means objective is of interest because achieving it can contribute to achieving the fundamental objectives.

To identify the objectives for a given decision situation is not easy. One begins with the set of values appropriate to the decision, in which values are defined as anything that one cares about concerning the decision. Therefore, the concepts and techniques of value-focused thinking were used in this workshop to stimulate the identification and creation of alternatives to facilitate egress from large buildings. The principal steps are summarized in Figure 1. First, all the values of each of the individuals were identified. These values were then used to specify a clear and coherent set of objectives for emergency egress. Each of the objectives identified by an individual was then used by that individual to create alternatives that could better achieve those objectives. Subsequently, individuals worked in groups to identify additional alternatives through their collective creative processes. The entire procedure might be referred to as value-focused brainstorming.

In identifying the list of values that provide a basis for objectives, each individual was asked to list all values they felt were appropriate for the decision. However, experience suggests that almost everyone ends up with an incomplete list, so there are a number of techniques to stimulate thinking about additional values. The techniques that we used in the workshop are given in Appendix D.

Once a set of values was listed by an individual, the individuals were asked to restate each value as an objective. An objective can be stated using a verb and an object, such as maximize safety, minimize lives saved, or avoid property damage. With this common format for stating objectives, they are much easier to understand and much easier to structure.

After each of the individuals converted each of their values to objectives, all of the objectives were organized on the first evening of the workshop and a means-ends objectives network was created. This network included the fundamental objectives and the means objectives for decisions concerning emergency egress. The basic information used to create the means-ends objectives network is presented in the workshop findings (Section 4.0) of this report. This list deleted multiple statements of the same objectives and organized the objectives into categories.

Each objective concerned only one object of importance. Value tradeoffs among the achievement of different objectives are obviously critical in evaluating or choosing alternatives, but such value tradeoffs are not desirable at the stage of listing and organizing objectives. As an example, one means objective is to minimize egress time and one fundamental objective is to minimize injuries to individuals. There certainly would be cases where rushing the egress to reduce the egress time to a minimum could result in additional injuries to those evacuating the building. This would not necessarily be preferred to a slower egress that did not cause those injuries. This preference would naturally be addressed in dealing with the value tradeoffs among objectives and with the consequences that the means objectives have on the fundamental objectives. Those tradeoffs must be recognized, but we do not need to state a means objective such as to “reduce egress times while maintaining safety”, as this would combine two objectives and the implied causal effects and value

tradeoffs into that one objective. To do so mixes up the notions of what are the objectives and what are the relationships, both causal effects and value tradeoffs, among them.

THE ALTERNATIVES GENERATED FOR EMERGENCY EGRESS

An alternative is defined as any action that is totally under the control of a decision maker that may influence the degree to which at least one of the objectives of emergency egress is achieved. The decision maker can decide to implement it or decide not to implement it. Every alternative should at least contribute positively to achieving one of the means objectives or one of the fundamental objectives. If this did not happen, then of course there would be no reason to consider it.

During the workshop, there was a discussion about whether the term alternative should be something different including option, tactic, strategy, choice and so forth. In this document, we mean that the alternatives are the aggregation of any of those similar ideas, where similar means something under the control of decision makers that can be done that would influence egress.

Note that most alternatives are not complete solutions. Rather, one might rather think of these as elements of alternatives. Specifically, one could do something that would facilitate movement of disabled people in stairways in a particular building. This does not mean that would be the only thing that would be done to facilitate emergency egress. Other alternatives that might reduce the size of a fire once it had started in a building or that would better communicate information to people about how to egress in the event of an emergency could also be implemented. Thus, it is appropriate to consider many of the alternatives generated in this workshop as elements of what might be considered a complete package of potential solutions.

The complete list of alternatives developed at the workshop is given in the workshop findings (Section 4.0) of this report. In addition, this section presents the categories of alternatives that the workshop team subsequently developed on the second evening to facilitate communication and organization of the alternatives. This organization was also helpful for a rough appraisal of some alternatives as discussed in the next section.

APPRAISAL OF SELECTED ALTERNATIVES

On the last day of the workshop, each of the participants were asked to evaluate about 40 alternatives selected by the workshop staff. While the results are shown in the workshop findings (Section 4.0, Table 1) of this report, it is important to note that the results are very preliminary for several reasons. First, the alternatives were not necessarily well-defined, as they were described by only a few words. Second, information was not available about details of the alternatives, such as how it might be implemented. Third, different participants naturally had their expertise in different aspects of egress and may not have had a complete understanding of other aspects. And the knowledge of some participants about certain aspects of an alternative was not available to other participants. Recognizing these caveats, it remained useful to go through the preliminary evaluation.

The preliminary evaluation was a very quick appraisal of the summary comments of the various individuals. The alternatives were evaluated by nine groups of three individuals. They were evaluated on three criteria: quality, feasibility, and creativity.

- Quality was defined as how effective the alternative could be, assuming that it could be implemented.
- Feasibility was defined as the chance that the alternative could be effectively implemented within 10 years.
- Creativity concerned the originality of the idea.

From observing the teams in the process of discussing and evaluating the alternatives, it appeared that it would be worthwhile to develop a more substantial and clearer evaluation form and process. This may provide insights about the low-hanging-fruit, meaning the alternatives that almost everybody would agree on in terms of overall effectiveness and on how quickly they can be implemented to improve egress. This evaluation would also try to identify some types of the alternatives where very creative ideas might have a big impact in the future.

USE OF THE WORKSHOP RESULTS

The set of objectives provide a sound basis for creating alternatives and for subsequently evaluating alternatives for emergency egress. It also provides a basis for modification and improvement. Given the way the set of objectives was obtained as a collection from numerous knowledgeable individuals, we would expect that the scope of these objectives would incorporate most of the concerns one would have with emergency egress. However, there are likely some concerns missing and many of the concerns that are explicitly included might be focused more clearly with additional thinking.

The set of alternatives for emergency egress documents a large number of potential actions that one can consider. This should provide a foundation for any additions that might be made in the future. It seems reasonable that there would be thousands of potential alternatives that could facilitate emergency egress from buildings. The set of alternatives documented here, and their categories, begin to define the full scope for most of the types of alternatives that might be feasible within a 10-20 year period. We believe that additional types of alternatives can likely be identified and within both new and existing categories, additional focus in creating alternatives would be useful.

3.0 WORKSHOP SESSION SUMMARY

The principal objective of this highly-interactive, free-thinking workshop was to facilitate a reassessment and definition of egress objectives and to develop of a vision for the future of the means of egress, especially in tall buildings. The agenda for the workshop is shown in Appendix B.

APRIL 1, 2008: DAY 1 OF THE WORKSHOP

AVERILL: WELCOME

Jason Averill of NIST opened the workshop by welcoming everyone present, along with the wider audience participating via webcast. First, Averill highlighted some of the constraints of current egress systems and practices in high rise buildings. A concept as simple as building stairs is poorly understood: for example, how much benefit is conveyed to the occupants by an incremental change in stair width? Given the substantial up-front, life-cycle, and opportunity costs of stairwells, Averill argued that a stronger technical basis for performance should be established.

Next, he urged participants to consider the elevators. Since everyone enters a building by elevators, and we know that people tend to exit the way that they entered, shouldn't we use elevators to exit most tall buildings? As buildings are designed to be taller than ever, the impetus to improve our understanding and performance of egress system is magnified.

Averill contended that the current state of egress requirements reflects three realities: lack of basic research, lack of concentrated effort directed at the problem, and regulatory inertia. This workshop was seen as a first step towards defining an egress system which is reliable, robust, cost effective, and well-understood.

Averill described the participants as representative of the continuum of disciplines which contribute to the safety of people in buildings during egress. He also emphasized that the mission of the workshop was to explore emergency egress in buildings considering the interaction of the physical and social environments. The ground rules for the workshop were stated:

- Everything discussed is part of the public domain.
- The discussion is to be positive, because an atmosphere of creativity, free thought, and sharing yields better results.
- Participation by everyone is of the utmost importance.
- Participants should be open to the process of structured brainstorming.

After reviewing the logistics for on-site participants and introducing the experts who assisted with the planning of the workshop, Averill turned over the floor to the moderator, Ralph Keeney.

KEENEY: WORKSHOP PROCESS

Keeney briefly described his background, and reviewed the purpose of the workshop. The principal resource available for the success of the workshop was the vast experience of the assembled experts. Therefore, the purpose of the moderator was to enable the transfer of the vast experiences in the minds of the participants onto paper. After briefly reviewing the agenda, Keeney turned the floor over to the presenters. The remainder of the morning was devoted to presentations. The purpose of the presentations was to establish a foundation of common knowledge that would enable all of the participants to better apply their disciplinary expertise in the context of the other disciplines. Presentations were delivered by Russ Sanders, Clas Jacobsen, Carl Galieto, Dennis Mileti, Najib Abboud, and Bud Nelson.

SANDERS: FIRE DEPARTMENT OPERATIONS IN HIGH-RISE BUILDINGS

Russ Sanders reviewed fire department operations with respect to building occupant and firefighter safety. As a context for operations, Sanders discussed risk assessment and mitigation. Risks for the fire service responding to a building fire tend to increase with the height of the building for several reasons:

- Most aerial apparatus can reach only 8 stories. This removes the option of rescue by fire department ladder above 8 stories.
- Master streams are rarely effective and therefore, the fire service is forced to rely on offensive interior operations, which tend to be the most dangerous operations.
- Lead times to get people and equipment (tools and air bottles, e.g.) high in a building can be significant.
- The taller the building, the larger the number of people who can be caught above the fire.

Sanders then reviewed the process of fire scene size-up, including determination of building type, size, time of day, location of fire, presence of built-in protection systems (sprinklers in-particular).

The incident commander (IC) has three basic priorities upon arrival on the scene of a building fire:

- life safety,
- extinguishment, and
- property protection.

These are not independent, but interdependent concerns. In order to address these concerns, the fire service must address complex and evolving challenges, including ventilation within buildings, fire suppression, situation awareness, and the interface between fire service and occupants in the stairwells. For example, one of the most complex aspects of high-rise firefighting is ventilation. While the fire service puts out a fire with water, it controls the fire by controlling the ventilation. Properly controlled ventilation can dramatically reduce the risks to the occupants and firefighters, while improper ventilation can result in civilian or firefighter deaths.

The only way for the fire service to verify that a building has been evacuated is to conduct both a primary and secondary search. This requires that the fire service maintain control and integrity (free of smoke and heat) of the stairwells. Pre-planning and knowledge of the characteristics of the building when the fire department arrives on-scene is a significant advantage. This requires active

participation of the building management, who are most knowledgeable about the specifics of the fire safety systems.

JACOBSEN: LEVERAGING INFORMATION IN BUILDING EVACUATION

Clas Jacobsen reviewed the role of information technology (IT) in building evacuation. He told us that we need to manage the flow of mass, energy, and bits. Mass is the flow of people through the building, energy is the fire, while bits is the data and information; in modern buildings, the bits are growing dramatically over time. The challenges going forward are to use computation and communication to enhance egress performance.

We have dynamically evolving information flows. In order to harness this information, the building community needs to consider three basic questions: who pays, who plays and who decides? An important testbed for understanding the evolution of these information systems is modeling. Modeling makes precise what the underlying problems in the system are, while also providing uniformity.

Jacobsen then discussed some of the many problems with integrating all of this information into a single systems approach:

- Systems issues are multiscale and multiphysics.
- Uncertainty propagation in the system can overwhelm the utility of the output. However, one approach is to consider the use of reduced-order models
- Codes and regulations need to keep up with “cyberphysical” systems: IT controlling physical systems.
- The information should be available in multiple locations: off-site (en-route for firefighters) and on-site (through a fire panel).
- Information flows are diffuse and lack organization. Opportunities for analysis and presentation to occupants and firefighters should be considered, such as decision support tools.
- The human-machine interface requires development.
- Current generation predictive models currently are computationally expensive. New techniques in reductive methods should be considered in order to produce answers on the time scale required for actionable results.
- The interfaces between components are where many problems emerge. The systems are dynamic; in particular, the time scales do not always align.

GALIOTO: CHALLENGES FACING ARCHITECTS FOR SUPER-TALL BUILDINGS

Carl Galieto provided a review of the state-of-the art of super-tall building design using examples from the tallest buildings currently under construction. Growing economies are building towers taller than ever before. Along with the height of the building come increasing demands for security at several levels: perimeter, enclosure, core, and emergency access core. These requirements often conflict with the goals of building egress and emergency services ingress. One solution which included use of pressurization systems and protected elevators currently utilized in high-rise design was reviewed.

The majority of tall buildings are mixed-use buildings. The use-groups often found at highest portions of super-tall buildings (observation decks, restaurants, hotels, assembly spaces, e.g.), often include occupants who are unfamiliar with the egress systems in the building, which creates a particular challenge for high-rise egress design

Finally, Galieto compared the increased risk of designing high-rise buildings to the increased risk of ships out at sea. Those ships require life boats which are able to protect passengers from an adverse event on the ship. Super-high-rise buildings require innovative egress solutions which are comparable to the risks inherent to the building under consideration.

MILETI: THE SOCIAL SCIENCE OF BUILDING EVACUATION

Dennis Mileti summarized the state-of-the-art knowledge base from psychology, social psychology, sociology, and human factors as it related to building evacuation or other appropriate protective actions. The research base for the talk extends over 60 years and was compiled by Mileti and Kuligowski.

The factors which influence human behaviour are well-known. By consolidating and implementing this body of knowledge, egress performance can be improved. Key findings include:

- Panic can happen, but is rare and words cannot prevent or cause panic. However, building design can influence panic: e.g., doors that swing outwards and sufficiency of egress paths.
- Building evacuation is not a continuous process. It happens in “lumps and bumps.”
- Alarms should interrupt ongoing life. However, the alarm simply sends people in search of additional information. People don’t remember indicators, unless the indicator is drilled into people, relentlessly. To alert people, the alarm should be as intrusive as possible.
- People are hard-wired to think they are safe, that disasters happen to other people, and therefore, that it is probably a false-alarm.
- Conflicting information abounds. Formal alerts compete with informal alerts, which are cues from the surrounding environment that something is wrong.
- Seconds of delay can cost lives in a fire emergency, but people are wired to perceive that they are safe. Until they confirm the risk through milling (talking with other people) or external cues, occupants will delay.
- When instructions are delivered to occupants, several aspects of communication are well established in the literature:
 - Channels: the more the better. If you want people to take an action, warn them through as many channels as possible and ensure consistency amongst channels.

- Frequency: the same message should be repeated as many times as possible; Madison Avenue has known for years that people will not remember something until you repeat it ten times.
- Content: the single most important message that can be delivered to an occupant is what you want them to do. Don't talk about the fire or the earthquake, but give them specific, actionable advice.
- Style: keep it simple, precise, authoritative, accurate, and avoid jargon. Be internally consistent.
- Source: tell them who is speaking. The most authoritative source is different depending on the situation, but surveys indicate that firefighters are the most authoritative source in the United States (but for only 35% of the population).
- Cues are critical. Fire trucks, smoke, flames, and floor wardens who are leading an evacuation are all strong cues. Meanings may be different, however, depending on the filters that occupants bring to the event. Filters include education, age, gender, race, language, associations with co-workers, parental status, social isolation, experience, etc.
- Information needs do not cease when the alarm is sounded. Once the occupants are started, they still require additional guidance.

ABBOUD: STRUCTURAL ENGINEERS, FIRE, AND EGRESS

Najib Abboud discussed how the patterns of increased urbanization are driving the trend towards taller buildings. The trend is being set on a worldwide stage, and is currently focused on multi-use skyscrapers (vertical cities). The driving force behind the multi-use prototype is risk management: if one real estate sector is down, the other use groups can maintain a revenue stream for the owner. This presents challenges for a single building core to serve all of the different occupancies, both structurally and from an egress perspective. With that background, Abboud then summarized three challenges for the structural engineering community: public policy, integration of fire and structural engineering, and materials innovations in response to new threats.

The first challenge is establishment of public policy. Standardization sets a level playing field from an economic perspective. Without standards, few projects will break the trend. What is safe? What is life safety? How long do you need the building to stand? These are the public policy questions that codes and standards need to specify. The technical challenges are achievable once the public policy is established.

The second challenge is to integrate fire engineering with structural engineering. The two disciplines are as unintegrated as can be. The only way that structural engineers can think of fire is as a load. Conversely, the information needs to be provided to the structural engineer in those terms: intensity, duration, location, and statistical probability. Hurricanes and earthquakes are reduced to return frequency, and fire needs to be considered similarly.

The third challenge is to adopt lightweight, flexible materials which can resist a variety of loads, including blast, fire, and vandalism. Traditional materials are either too heavy to build tall buildings with or too light to resist the variety of loads imposed. New materials such as one-inch, ultra-high strength concrete are being developed to ensure integrity of the core, including stairwell enclosures which can preserve exit paths for evacuating occupants.

NELSON: THE LEGACY OF THE 1971 AIRLIE HOUSE HIGH-RISE LIFE SAFETY CONFERENCE

To conclude the invited presentations portion of the workshop, Bud Nelson shared his experience with the 1971 Airlie House Conference of High Rise Life Safety, which served as an inspiration for the current workshop. The objective of the 1971 conference was to bring independent disciplines together and develop the concept of a systems approach to fire in high-rise buildings. The first element of the systems approach was the threat from fire. The second element was force modification (sprinklers, compartmentation, etc). The third element was to protect the exposed. All of these systems concepts can be translated directly to an analysis of the egress system. However, much additional research will be required in order to prevent ‘garbage in, gospel out.’

The 1971 workshop had tremendous impact on the design of today’s high rise buildings, including the advent of deterministic modelling. Concepts of fire safety evaluation system, performance based design, and systemic building design can trace many of their roots right back to the Airlie House Conference Center. Indeed, a workshop can have tremendous impact. But only if the participants carry forward the ideas.

DEVELOPING ALTERNATIVES AND OBJECTIVES

During the afternoon session, participants worked independently to identify egress alternatives and objectives for the workshop. Using forms[†] distributed by Keeney, participants were asked to put their thoughts on paper and then to discuss these thoughts as a mechanism for generating more ideas. Once completed, the forms were collected with the promise that they would be copied and returned and that the thoughts and ideas written on the forms would later be summarized by NIST staff and the summary distributed so that it could serve as the foundation for later discussions. Participants devoted the remainder of the afternoon session to:

- Listing alternatives that may enhance egress (Form 2),
- Listing objectives that may enhance egress (Form 3),
- Listing values (what the participants care about regarding egress. Form 4),
- Expanding the list of values (Form 5),
- Convert each of the values to objectives (Form 6), and
- Creating alternatives or elements of alternatives using each objective (Form 7).

Keeney pointed out that listing objectives is important to better understand the breadth of the egress issue and to provide a basis to stimulate the creation of alternatives. Alternatives are important because their implementation, after refinement, is how one improves egress.

During the evening of the first day, the NIST staff and Keeney synthesized the results and developed a comprehensive list of objectives. The list can be found in the workshop findings (Section 4.0) of this report.

[†] The forms used in this and the forms used in subsequent workshop exercises are included with the workshop agenda in Appendix A.

APRIL 2, 2008: DAY 2 OF THE WORKSHOP

Keeney greeted everyone and explained the agenda for the day and how the results from the previous day were synthesized. He utilized a means-ends objective network as a framework for organizing the objectives collected from Day 1 of the workshop.:

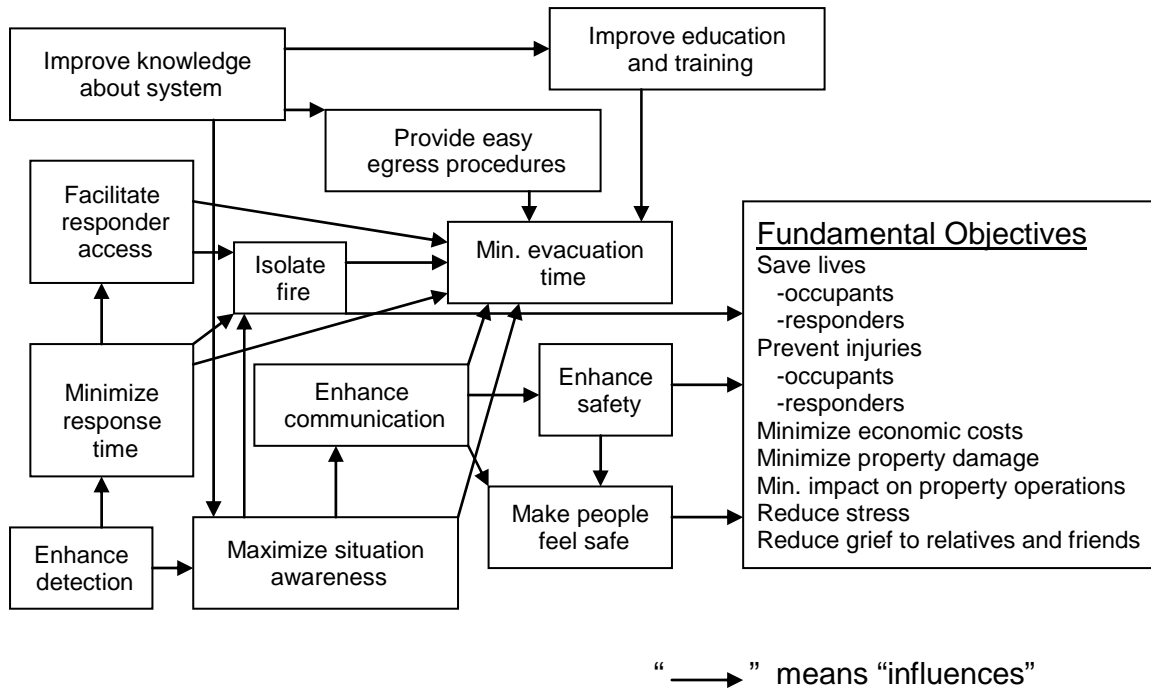


FIGURE 2: MEANS-ENDS OBJECTIVES NETWORK FOR EMERGENCY EGRESS

Keeney noted that the fundamental objectives listed by the workshop participants were very similar and could be summarized by the following objectives:

- Save lives of occupants and of firefighters/responders
- Prevent injuries to occupants and of firefighters/responders
- Minimize property damage
- Minimize impact on property operations
- Minimize economic costs
- Reduce stress
- Reduce grief

Keeney pointed out that they arrived at these fundamental objectives by grouping participant responses into general categories and relating means to ends, which are what become the fundamental objectives..

Keeney said that the alternatives listed on the forms could affect the achievement of all fundamental objectives. He also mentioned that among the responses, there were some objectives that had crept in among the alternatives as well as some alternatives among the objectives. The obvious changes were made to put both objectives and alternatives in their appropriate lists. The remainder of the morning session was devoted to working group discussions to expand the alternatives.

During the afternoon, the working groups focused on effective egress and fire fighting. The result was a detailed description of the steps involved in effective egress from a very tall building, and additional alternatives for facilitating egress were identified. The deliberations of each of the working groups are summarized in Appendix E.

Considerable discussion was devoted to the sky bridge concept and the idea of buildings sharing resources and equipment. Opinions varied on the ideas. It was noted that the use of sky bridges is being explored in Australia, but that it is a massive undertaking that requires a totally new way of thinking and modifications to building codes. Others indicated that the concept is a difficult one to use and should be considered only on a case by case basis. Still others suggested that egress is only one benefit of sky bridges; they can be used to create an urban network with vertical links within buildings and people become familiar with their evacuation routes because those are the routes they use on a daily basis. One group member mentioned the 1969 book, *Urban Design Manhattan*, which explored the idea of interconnecting buildings on many levels but did not specifically address emergency egress. A proposal for redevelopment of the World Trade Center complex called for the use of sky bridges, but it was unsuccessful; it would have been a very good example of how to develop a large site into one complex of functional, integrated buildings. Technical design issues involving such things as different response frequencies were mentioned as were the legal issues (not simply a contractual issue but also an entitlement issue in real estate law). It was noted that elevators account for about 15 percent of a tall building's energy usage and that sky bridges linking lower floors could reduce elevator use and, consequently, energy use and cost.

During discussion of the egress process and the firefighting process, both processes involved the following steps:

- Determining that an event has occurred,
- Verifying that the event is real or false,
- Notifying people that an event is taking place and action is needed, and
- People receiving this information and determining the correct action to take.

Differences in function – high rise buildings of mixed occupancy and use, assembly buildings, and general use buildings – were discussed in terms of the impact building use has on egress system requirements.

During the afternoon session, the group reconvened to hear and debate the results of the working group discussions. Averill suggested the each group provide a summary of their discussion and identify the steps taken in the process as well as alternatives discussed and other ideas addressed for a significant amount of time. Summaries of the working group discussions appear in Appendix E.

Once the participants convened again as a single group, Averill asked whether specific areas require long-term research. The general consensus was that information and communication techniques are most in need of improvement. It was felt that this is where research, organization, and funding should be concentrated. Another point of view was that presenting technical aspects to a non-technical audience warrants more work. There are also many questions about cost, research could strive toward more cost-effective solutions and dual purpose solutions to satisfy clients and justify the cost. It was also noted that the technological ability to get information exists and this data needs to be displayed, in real time, in such a way that staff on the scene and then the first responders can evaluate the data. Another point brought up was that emergency egress is directly influenced by how the everyday people movement functions.

Averill pointed out that NIST has started a systematic program of data collection of fire drills in buildings. This covers multiple occupancies, heights, and counter flow issues. A matrix exists that we're trying to fill out over time in order to find out how these systems behave. Another aspect of the study is the human behavior issues. We have all the equipment to gather this data but have encountered problems gaining access to buildings. He continued that there are differences between fire drill data and real emergency data and of course right now only fire drill data is available.

APRIL 3, 2008: DAY 3 OF THE WORKSHOP

Averill reminded everyone that up until this point the discussion concentrated heavily on objectives and alternatives and the context of building egress. This information needs to be used in the discussion of moving forward, he stated.

The last day was devoted to discussing the groups' ideas of where the efforts and research are best targeted. The lists of alternative suggestions were synthesized and many new innovative ideas came up. The list was divided into categorical ideas. Averill also suggested other topics for general discussion such as gaps, research areas, implementation, and research and development – in general, areas that may have been missed.

Peacock explained how several NIST staff took all 400+ alternatives (listed in the following section of this report) and organized them into categories; means, methods, tactics, and strategies. The bins were:

- Sprinklers / Active Suppression Systems
- Protect in Place / Areas of Refuge
- Building Construction Changes
- Building Material Changes
- Fire Service
- Elevators
- Societal / Regulatory / Legal Changes
- External to the Building
- Communication
- Information Systems
- Pre-event Planning
- Efficient Use of Egress System
- Enhance Stairwell Evacuation / Reduce Stairwell Load
- Design Process / Risk Informed Performance-Based Design
- Enhance Reliability of Building Systems
- Event Procedural Changes
- Enhanced Event Detection
- Other Alternatives

EVALUATION

The last exercise of the workshop was to separate into groups of 3-4 persons and go through all the ideas and rate them using a numeric scale from 1-9 on the viability of the various ideas. The participants were urged to draw on their expertise to rate the ideas and determine how different and “out of the box” the ideas are compared to current practices. The forms (presented in Appendix C) were passed out and everyone formed small groups. Upon completion of the assessments, the input was then averaged in order to determine how the group rated the alternatives. During this time there was continued discussion on the benefits of further research in all aspects of egress.

Averill mentioned that there will be a follow-up workshop that will be as inclusive as possible. There were many mentions that this really is an international issue and there will be a lot of

conferences in future dealing with related issues to which this group could carry forth the findings of the workshop.

Following the discussion, Peacock summarized the evaluations (the results are included in Table 1 of the workshop findings (Section 4.0) of this report). Keeney pointed out that the numerical responses were averaged based on the majority. On the feasibility scale, a range was used. That does not summarize everything but many of the alternatives do have a range. Peacock continued that the results varied from the bottom of the scale to the top of the scale resulting in very divergent results. Those that were rated high might be considered “low hanging fruit” that merits further consideration. Due to the brief time in which the evaluation was conducted, it was suggested that perhaps additional comments can be included after the meeting ends. It was also mentioned that while some did not agree with a proposed idea, but could support something close to it.

The floor was turned over to Keeney, who expressed his delight in the breadth, depth of knowledge, and experience of the participants. He thanked everyone for their hard work and genuine interest in creating the alternatives. This conference resulted in a fairly comprehensive set of objectives for egress and a very broad range of alternatives, he stated. This happens when everyone does individual thinking and then collective thinking.

CONCLUDING REMARKS

Averill offered concluding remarks which summarized the workshop. He indicated that the workshop had taken a very close and in-depth look at building egress and evacuation. The presentations were informative and enlightening. The workshop yielded a comprehensive set of high-level objectives, including the fundamental objectives, and many alternatives.

A few key concepts were persistent themes throughout the workshop and are summarized below:

- Information is crucial. Gathering it. Processing it. Communicating it. In an era of change, no aspect of building evacuation is changing faster than information. With power, however, comes responsibility. Simply because we CAN collect a piece of information, does not mean that we should force feed that to our emergency responders, our building managers, or our occupants. It must be carefully assessed and presented in a manner which incorporates what we know about human factors, social psychology, and situation awareness. Above all, however, information must not be ignored.
- Building evacuation procedures must be robust and adaptable. The procedures must adapt to (a) changes in the event and (b) different threats and scenarios.
- Design must make egress systems (first) obvious and intuitive and (second) integrated into the everyday use of the building, without compromising our growing desire for physical security. Elevators may be an alternative which allows occupants in tall buildings to go out the way they came in, as well as provide egressibility to persons with mobility impairments, in the same way the ADA provided accessibility.
- Solutions which can apply to the existing building stock as well as our new construction will have greater impact in terms of the number of people and lives affected.
- Technology should be harnessed to deliver notification and induce direct action. Cell casting, desktop computer interruption, PDA's, cable television, improved signage, and other modes should deliver reliable, timely, updated information targeted to specific people.

- We need to ensure accurate, timely, and reliable communications for firefighters. Firefighters need a way to communicate to the occupants and a way to obtain information from the occupants.
- As a community, cost-benefit analysis of many of the alternatives needs to be considered. However, cost-benefit analysis requires a measure of performance and an assessment of cost. In many cases we fall short of both.
- Finally, evacuation will not always be the preferred solution. Protect in place, phased evacuation, and areas of refuge may minimize business interruption, as well as minimize harm to occupants. The nature of the threat will dictate the appropriate response.

Averill then thanked the participants and NIBS staff and declared the Rethinking Egress workshop adjourned.



FIGURE 3: 2008 RETHINKING EGRESS WORKSHOP PARTICIPANTS

4.0 WORKSHOP FINDINGS

The findings of the workshop presented here are compilations of emergency egress objectives and alternatives identified. The objectives listed below in **boldface** include all fundamental and means categories of objectives. The statements in regular text under the boldface objectives are responses provided by individual participants. They indicate specific concerns that should be considered as part of the corresponding objective.

CONSOLIDATED EMERGENCY EGRESS OBJECTIVES

Save lives

- Maximize survivors
- Staying alive
- Mitigate consequences of events (death, injury, stress)

Save occupant lives

- Save lives of occupants

Save responder lives

- Save lives of first responders
- Minimize risk to life of external agencies required for evacuation
- Preserve emergency responder life safety

Prevent injury

Prevent occupant injury

- Minimize the harm to all people during evacuation
- Minimize the injury level (short term) of survivors in exposed population
- Minimize the injury level (long term) of survivors in exposed population

Prevent responder injury

- Minimize or reduce risk of injury (short term) of external agencies
- Minimize or reduce risk of injury (long term) of external agencies

Minimize economic costs

- Reduce societal cost of loss of lives
- Reduce societal cost of protecting lives
- Reduce business cost of protecting lives
- Ensure cost effective construction and operational costs
- Reasonable costs – first and continuing
- Minimize or reduce the cost in terms of disruptions caused by evacuation
- Minimize or reduce the cost of enabling the actual evacuation
- Use no more resources than society is willing to expend
- Provide solutions that are cost effective
- Decrease cost of building and variety of buildings
- Reduce egress costs and carbon footprint
- Maximize return
- Decrease cost of the building
- Prevent law suits

Minimize property damage

- Improve first responders' abilities to safeguard property
- Save properties

Preserve property

Minimize impact on property operations

- Prevent loss of business
- Minimize impact on building operations
- Minimize negative impact on the functionality of the building
- Allow normal functioning of building
- Avoid unnecessary disruptive evacuations

Reduce stress

- Minimize post traumatic stress
- Reduce stress on occupants
- Reduce stress on emergency staff
- Minimize or reduce physical and mental stress on evacuees
- Reduce panic
- Move people without undue stress
- Minimize possibility of panic and other destructive behaviors
- Prevent confusion

Reduce grief to relatives and friends

Enhance communication

- Increase confidence in message and communication system
- Develop trust in the message and communication system
- Allow responders to communicate effectively within building
- Notify all occupants in structure of emergency and need to evacuate
- Improve communication to building occupants
- Provide the most detailed information possible to occupants

Minimize response time

- Assure appropriate response

Minimize evacuation time

- Reduce time
- Minimize total egress time
- Decrease evacuation time
- Provide high-capacity/short time egress
- Enable immediate start of evacuation
- Simplify egress process
- Speed up building evacuation
- Provide efficient egress system
- Create efficient handicap egress
- Provide equality for egress of disabled and able bodied occupants
- Develop methods to increase speed of evacuation
- Quickly move/guide population away from harm (smoke, fire, biological, chemical)
- Ability to coordinate an orderly exit
- Provide uncompromised pathways
- Provide the earliest possible notification

Enhance safety

- Increase safety, irrespective of location
- Make evacuation process safe
- Keep occupants safe
- Provide safe egress for all occupants
- Provide safety for all occupants regardless of age or mobility
- Maximize life safety
- Increase safety of community
- Provide safety for all occupants
- Provide safety for occupants
- Provide safety from fire for all occupants
- Ensure that no one is left behind
- Ensure timely rescue of injured or 'at risk' occupants
- Ability to move vast amounts of people safely
- Move people to a safe place for a range of threats
- Reduce fire department interference with occupants evacuating building
- Move people to a safe place with a range of people
- Remove people from imminent danger
- Enhance responder safety
- Retain flexibility to rescue other building occupants if conditions change
- Ensure system works for different types of emergencies/threats
- Allow escape without aid of fire fighters
- Operate during failure of city utilities (water or electricity)
- Ensure it can be maintained

Make people feel safe

- People feel safer
- Enhances "sense of safety"
- Provide a safer environment
- Give occupants a sense of security
- Provide occupant confidence
- Increase confidence in message and communication system

Maximize situation awareness

- Provide real-time information to incident command and to occupants
- Assess available information to enable management of occupants and staff
- Incorporate knowledge of the specific event
- Provide real-time information to incident command and to occupants

Facilitate responder access

- Enable responder access to problem area(s)
- Provide access to fire fighting operations
- Facilitate firefighting
- Separate firefighting from evacuation
- Clear building area for firefighting
- Provide for safe and effective firefighting operations
- Free up responders
- Maintain uncompromised pathways
- Allow the fire department to do their job – control the fire, prevent collapse, etc

Improve education and training

- Manage behavior of population to ensure safety, comfort, and security
- Increase population's perception of risk
- Enhance timely occupant action in an emergency

Improve knowledge about system

- Increase knowledge of the occupants
- Understand requirements/capabilities of population not to make situation worse, put them in more danger,
- Develop a framework to evaluate solutions on a risk basis for various scenarios
- Provide verifiable and quantifiable benefit
- Provide solutions that stakeholders accept

Isolate fire

- Improve fire service use of technological systems
- Improve fire fighting to reduce egress needs

Enhance detection

- Allow for quicker detection of the fire

Provide easy egress procedures

- Provide a resilient and simple system
- Reduce complexity and increase reliability
- Obviate the need for special skills and special equipment on part of occupants
- Ensure egress systems are as simple as possible
- Simplify procedures
- Ask occupants to do only things they understand
- Ask occupants to do only things with which they are familiar
- Reduce space set aside for emergency use alone
- Increase dual or multi functionality
- Flow with normal or expected human behaviour

CONSOLIDATED ALTERNATIVES TO IMPROVE EMERGENCY EGRESS

The following list of alternatives are specific means for accomplishing one or more of the objectives identified in the previous section. The groupings were prepared one evening during the workshop and do not represent a preferred or optimal grouping of alternatives, but simply one way to organize the ideas into common themes.

ALTERNATIVES INVOLVING SPRINKLERS / ACTIVE SUPPRESSION SYSTEMS

- Use sprinklers and compartmentation
- Redundant water supplies
- Mandate sprinklers in all building, except residential
- Retrofit sprinklers in all high-rise buildings
- Increase sprinkler spray design basis to suppress a full-floor fire
- Increase sprinkler density with building height
- Improve reliability of existing building water supplies and sprinklers
- Less trade-offs for sprinkler systems
- Increase sprinkler reliability
- Improve sprinkler system design
- Mandate sprinklers for all buildings – including residential

ALTERNATIVES INVOLVING PROTECT IN PLACE / AREAS OF REFUGE

- Increase number of places of safety
- Areas of rescue assistance in stairs
- Transitional refuge areas for resting and transition to elevators in super tall buildings
- Safety zones
- Protected queuing spaces
- Zoned floors to create “safe” areas for people awaiting evacuation
- Areas of safety
- Providing areas with safe sections
- For very large, or very tall, or very complex buildings → fully protected, adequately lit, properly ventilated refuge spaces of adequate size and a means of two-way communication with the emergency response team
- Protect in place (no egress)
- Provide alternative areas for egress assistance

ALTERNATIVES INVOLVING BUILDING CONSTRUCTION CHANGES

- Lightweight innovative materials for egress paths
- Control fuel load to avoid evacuation
- Enhanced fire resistive construction for high-rise buildings
- Reduce fuel loads in buildings
- Limit use of combustible materials
- Self-protected buildings – sprinklers, fire/smoke resistant construction
- Prevent fires from occurring in the first place through material selection and control
- Build buildings to egress standards

ALTERNATIVES INVOLVING BUILDING MATERIAL CHANGES

Protected corridors, stairways, skybridges
Harden existing buildings
Develop new structure external to existing buildings
Place exit signs high and low
Battery backup for egress lighting
Hardened evacuation routes
Design buildings not to collapse
Shorten evacuation routes
Mechanize evacuation routes (moving walkways, elevators)
Improve quality of egress routes – finishes, natural light, view
Adequate lighting
Adequate width/capacity of egress
Adequate signage
Smoke control system with training for fire department use
Protected exit route
Install readily visible directional indicators at key locations
Normal and emergency movement systems should be integrated
Egress systems designs that reflect human behavior
Pressurized stairwell
Effective smoke control
Move standpipes
Separate emergency cores
Create horizontal and vertical compartmentation
Use horizontal dimension for egress rather than rely on vertical
Improve visibility of signage
Require battery back-up and emergency generators
Increase use of daylight through windows and skylights
Build-in ergonomics to system designs
Require separation of egress paths
Make exits attractive, functional and normally used
Color stairs make them more user friendly
Alternate discharge at base of building
Horizontal exits
Building subdivision
Confining smoke, heat, and fire to a small portion of the building
Fire/smoke isolation of elevators the lobbies
Flashing exit signs
Require/provide manual and automated vent opening in buildings
Provide hardened floors at intervals in tall buildings
Durable (temp, smoke, impact) enclosure envelope
Enhance illumination
Ensure smoke control has an emergency power supply or that all dampers are fail safe
Improve signage
Provide large “fire doors” to compartmentalize large floor plans
Prevent smoke from entering stairs
Structure the building for dispersion (allow for evacuation without competition)
Enhance visibility of exit signs: larger, flashing or digital signage
Enhance paths to exits with pavement markings

Locate exits in generally used areas such as toilets
Place painted or tiled lines to the exits
Flashing or re-designed signs

ALTERNATIVES INVOLVING THE FIRE SERVICE

Access for fire fighters independent of occupant egress
Simple to use protective breathing apparatus
More effective emergency responders
Do not bring fire fighters into tall buildings
Equipment lift for fire fighters
Fire fighter elevators
Robotic fire fighting equipment
Wireless technology to monitor fire command station en route to incident
Provide building repeaters systems for portable radio coverage with tested and maintained system
Dedicated fire fighter ingress
Get firefighters out of stairs
Rapid fire service intervention
Responder's stairwell
Prepositioned assets
Separate firefighter access from occupant egress
Increase training and education for firefighters
Provide on-site fire brigades for high-occupancy buildings and complexes
In-house fire brigade will obviate need for outside firefighters
Increase funding for research and development on firefighter equipment / technology
Dedicated firefighting stairwell
Better ventilation to support firefighting
Adequate staffing and equipment to handle emergency
Building conditions available at command center
Wireless communication that can be relayed from building to command post
Train firefighters on new technological systems
Designated assembly areas for emergency responders
Mandate onsite training of firefighters
Provide reference materials in fire houses
Real-time building / fire data to responding fire service personnel
Standardized, flexible system to communicate with occupants and emergency responders using conventional communication devices and technology
Capability to maintain incident command from remote location
Fighting fires from adjacent buildings
Training of responders for occupant response
Train fire service to operate building fire response systems
Have a local fire company for large buildings
Provide fire fighting vestibule at each story – outside of the stairs
Provide air to recharge oxygen bottles for fire fighters in high-rises
Install a dumb waiter in stairway or elevator shaft for FF equipment (not personnel) and install a smaller (30") stairway for fire fighter access
Position fire brigades within high-rise buildings (with occupancies greater than 10,000) that are trained for managing egress as well as fighting fires. These could be private or city

employees. Additional skills, with value to the building owner or occupants, would be exploited for times when no emergency was present

- Vestibules for standpipe to fight fires
- Improve fire department training
- Provide mechanical means to allow fire hose to penetrate stairwell doors while keep smoke from entering
- Cell phone notification to emergency responders

ALTERNATIVES INVOLVING ELEVATORS

- Simultaneous use of elevators and stairs
- Use elevator or other mechanical means
- Protected elevators for disabled
- Protected elevators for evacuation of transitional refuge areas
- Hardened elevators
- Protected elevator lobbies
- More aggressively educate officials, owners, and providers about the benefits of protected elevators
- Use elevators
- Provide incentives to increase elevator use
- State-of-the-art-elevators
- Training and drills in the elevators (maybe video training)
- Use of elevators for egress
- Require elevators vestibules in all buildings with elevators
- Provide equipment hoist/shaft for fire fighting equipment
- “Hardened” elevators with reliable, alternative power
- Improve elevator doors to reduce smoke stratification in buildings – may increase evacuation time
- Make use of elevators accepted by the public
- Lock out and tag out elevator power

ALTERNATIVES INVOLVING SOCIETAL /REGULATORY / LEGAL CHANGES

- Don't build high buildings
- Develop risk “scale” for building occupants
- Bill for response based on risk
- Incorporate response costs in investment, design and development cost
- Revalue sprinklers (in real costs)
- National standards for crowd management and evacuation training
- Tear down tall buildings
- National high-rise building codes that require modern egress
- Increase integration of rules such as emergency and security to reduce conflicts
- Quantitative performance criteria
- National standard for emergency action protocols
- Make occupants more fit
- Staggered density in buildings
- Provide immunity from lawsuits for research-driven approaches
- Standardize evacuation procedures across country by emergency type
- Prevent lawsuits
- Standardize inspection program and testing

- Limit tradeoffs
- False alarm requirements with penalty for false alarms
- Legislate immunity for performance-based design
- Require regular testing and inspection
- Required modeled systems to be tested after installed
- Look at evacuation from an urban scale
- Develop threat strategies and evacuation strategies
- Share emergency systems with multiple buildings
- Standardize egress strategies according to type of emergency
- Annual tests of emergency systems: generators under full load, fire pumps, egress
- Restrict the heights of tall buildings
- More research money for egress studies to obtain more realistic and up to date data
- Analyze time necessary to evacuate building safely prior to spending money
- Improve public education on eating healthy to reduce obesity problem in this country
- Limit assembly occupancies at the top of buildings
- Require periodic tests of smoke control systems
- Don't reduce the fire-resistance of building elements when sprinklers are installed
- Ensure decision makers consider cost/benefit analysis for each alternative
- Change standards and regulations

ALTERNATIVES EXTERNAL TO THE BUILDING

- Chutes / slides / controlled descent devices
- Horizontal egress or skybridge
- Transporters
- External evacuation devices
- Use platforms and chutes for external evacuation
- Provide skybridges to connect buildings together
- Skybridges every 5 floors – many buildings linked together
- External devices
- Horizontal / skybridges
- Use bridges between buildings to create horizontal exits
- Explore use of external evacuation systems
- Bridges to other buildings
- Connections – permanent or temporary – to adjacent buildings
- Create egress 'lifeboats' or escape pods
- Provide helicopter sites at all tall buildings
- Install deployable bridges in new buildings that can couple, with minor modifications, to adjacent existing buildings
- External devices, platform devices
- Personal egress modules for external egress

ALTERNATIVES INVOLVING COMMUNICATION

- Highly motivating alarm/alert/management systems
- Communications to and from all parties
- Standard visual emergency communication system
- Emergency notification system to all occupants – phone, email, TV, satellite, public address

Egress communication system
Utilize all methods of communications in an integrated network
Earlier notification of the need to move
Simple, effective communication
Robust communications
Active egress management systems
Communicate instructions to occupants to steer the evacuation
Design interoperable emergency communication systems amongst responders
Design real-time communication to maximize effectiveness
Use technology such as cell phones, PDA's, computers, phones for timely communication
Two-way communication between fire service and occupants during event
Two-way communication in stairwell
Include security for fire alarm devices
Broadcast instructions over cell phones
Video broadcast to cellular with voice over instructions
Use loud and intrusive communication modes (video and audio)
Real time pictorial emergency communication system
Multiple communication messaging systems
Two-way communication between fire fighters / responders and occupants
Protect fire notification system
State-of-the-art communication systems
Situation awareness
Symbolic / iconic notification system for incident type and action required of occupants
Improve pictorial representation of emergency communication (international symbols)
Integration of communication systems into existing buildings
Communication – two-way between occupants and first responders
Broadcast alarms/warnings on cell phone networks at building
Broadcast alarms to computer networks in building
Initiate alarm/message earlier to people – so that elevators could be used for longer
Notify occupants via cell phone
Universal emergency ringtone
Use sound via cell phone to guide to exits
Language preference for cell phone/PA announcements
Regular announcements that include emergency egress information
Announcements in multiple languages

ALTERNATIVES INVOLVING INFORMATION SYSTEMS

Building guidance systems
Distribute relevant information in real-time
Real-time signage used on daily basis that results in high level of occupant acceptance
Enhanced information to building occupants and management
Intelligent alerting and response decision-making software
Print emergency egress instructions on the back of notepads, placemats, other locations that are readily available to transient occupants
Provide multi-lingual instructions
Have pre-recorded messages ready for use
Utilize dynamic signage to provide information
Dynamic reactive signage

Precise information
Innovative means to provide information to people (cell phones, blackberries)
Real-time reporting of conditions
Visualization technology
Facilitate milling
Better situational information
Use public service announcements to increase perception of risk
Increase usage of icons, pictographs and signage to direct occupants
Real time monitoring of movement in stairs
Occupancy badge and readers so you know where people are
Provide remote monitoring and control of large building fire systems
Provide people with the right messages (content, style, etc)
Real-time information to occupants about what is going on in the building (where the smoke is, where others are, where firefighters are)
Personal monitoring for people with disabilities
Increase the elements required to be monitored
Information should be transmitted to the responding group (fire department, etc). It should refer to the incident (nature, existence), procedural status, population activities, structure (exit use, stair, route loss, etc.)
Multi-modes – visual, aural; should make use of traditional notification, visual systems, PC screens, TVs, PDAs, cell phones, etc.
Graphical screens could be used to maximize the information that can be provided
Critical that information is consistent, dynamic, comprehensive and adaptive
Live voice, provided by someone of authority

ALTERNATIVES INVOLVING PRE-EVENT PLANNING

Common plan of action for everyone: everyone evacuates by stairs
More effective emergency staff
Clear evacuation plans
Consider normal use of building
Train staff
Practice egress frequently
Interact with evacuees
Focus on one plan
Educate and train occupants
Emergency planning with programmed response
Make it clear there are other hazards than fire
Pre-tested evacuation routes
Occupant fire safety training
Engage occupants during training to improve procedures
Create a mechanism of learning about the building environment and systems that is fun
Active management of egress process
Make stairs part of the normal building use
Web-based training
Require egress drills
Education
Educate and train building emergency managers
Mandate evacuation drills for multiple scenarios

- Communicate preplan to fire fighters and occupants
- Have preplan available during response
- Reevaluate preplan on periodic basis
- Create training courses for fire service and stakeholders
- Involve occupants in solutions for egress from buildings
- Training of building occupants related to building communication systems
- Mandatory fire drills
- Require fire drills for building occupants more often
- Require more realistic fire drills – actual movement and alarms
- Require fire drills for spaces with casual users (malls, retail, bars/restaurants)
- Concise, meaningful pre-plans not only on file but pre-reviewed by potential incident responders
- Provide incentives for occupants to participate in evacuation drills, eg., a trophy to the work unit that had the most employees climb and/or descend the most number of stairs. This could be tied to a physical fitness program
- Train/educate/practice all procedures
- Train/educate occupants not to delay and tell them why
- Present occupants with actual simulation/videos of what could happen in a real event
- Have occupants go through firefighter training – experience a real event
- Participate development of plans and procedures/education/training → involve them in the process
- Conduct pilot project to demonstrate
- Exposing occupants (in a safe way) to actual fire conditions (e.g., theatrical smoke)
- Floor wardens must be people with some authority
- Subgroup managers should be incorporated into plans for assembly buildings – to lead the people out of the building
- Heavy training of subgroup managers
- Subgroup managers need to stay in constant communication with the emergency manager
- Causing egress via a noxious odor or intolerable sound
- Develop alternative egress plans

ALTERNATIVES INVOLVING EFFICIENT USE OF EGRESS SYSTEM

- Enhanced stairway descent devices
- Evacuation aids for disabilities
- Photoluminescent markings
- Building wayfinding/guidance system
- Overhead rails for disabled movement systems in stairs
- Set door swing to stairs to not interrupt flow
- Disable email systems for more rapid initiation of egress
- Gravity-driven, lightweight vehicles for mobility-impaired individuals
- Create multi-use emergency routes
- Equalize loads on all evacuation routes
- Motorized egress devices for people with disabilities

ALTERNATIVES TO ENHANCE STAIRWELL EVACUATION / REDUCE STAIRWELL LOAD

- Multiple and wide staircases
- Install tracks in stairwell handrails for trolley seats to be used by all occupants
- Use electroluminescent strips in hotels
- Recalculate stair widths
- Set doors to stairs to allow for traffic flow
- Positive pressure for stairwells
- Increase stair capacity
- Increase number of stairs
- Force stair usage in everyday activities
- Use vestibule for hose line deployment without contamination of stairwell
- Paint stairs in white paint
- Widen the stairs
- Remove fire equipment from stair towers
- Design stairs with fire fighting procedures in mind
- Positive air pressure in stairs
- Wider stairs
- Dedicated egress stairs for responders
- Develop periodic 'rest areas' within stair towers
- Require some level of hardening at exit (stair) enclosure
- Third stairwell for fire fighters

ALTERNATIVES IMPACTING THE DESIGN PROCESS / RISK INFORMED PERFORMANCE-BASED DESIGN

- Base designs on risk assessments
- Model-based evaluation of designs
- Standardize design basis events and performance objectives to set public policy
- Develop cost/benefit tools to deal with rare, high consequence events
- Use modeling to estimate evacuation time for buildings for different circumstances
- Consider worst-case scenarios and build in countermeasures
- Use modeling to estimate evacuation time for buildings for different circumstances
- Use egress modeling to choose between alternative evacuation strategies in response to designated scenarios
- Perform engineering analysis to evaluate emergency procedures
- Improve accuracy of evacuation software
- Egress models should consider more threats than just fire
- Perform cost/benefit analysis of solutions
- Publish articles on scenarios which need to be considered
- Design for hazmat and weapons of mass destruction, including chemical detectors
- Use performance-based criteria for all threats, more than just fires
- Develop process for creating threat scenarios and performance basis for providing alternatives acceptable to stakeholders
- Base design on risk and performance-based design
- Develop an understanding of all of the events that would prompt full building evacuation
- Establish risk factors

ALTERNATIVES THAT ENHANCE RELIABILITY OF BUILDING SYSTEMS

- Leave power on for egress
- Low exit signs
- Regular inspections
- Coordinated systems control
- Better lighting
- Sensing systems should be fail-safe
- Provide redundant systems
- Enhance reliability of sprinklers by electronic monitoring of flow
- Design detection systems to reject false alarms
- Constantly use systems to ensure it will work during an emergency
- Increase number of escape routes
- Backup power for evacuation components
- Electronic monitoring of all components of standpipe
- Two remote sources for sprinkler water
- Monitor all life safety systems
- Maintenance of integrity of egress paths
- Redundant passive as well as automatic protection
- Meaningful quality control before opening of the facility
- Meaningful follow-up quality assurance throughout the life of the building at reasonable frequency
- Document, calculate, observe construction and fully accept ultimate responsibility
- Provide redundant water and electrical supply independent of city utilities
- Increase monitoring of building safety systems

ALTERNATIVES THAT INVOLVE EVENT PROCEDURAL CHANGES

- Believable defend in place strategy
- Ensure egress is only in response to real incident
- Ensure equal use of egress routes
- Design emergency procedures effectively
- Establish evacuation procedures for disabled occupants
- Guidelines for occupant evacuation
- Stairs to refuge floors, elevators from there
- Emergency procedures manuals
- Decision support systems
- Design unique procedures for each specific type of emergency
- Allow use of “normal” elevators as long as possible
- Standardize evacuation strategies
- The use of staff in a more significant role in guiding occupants out of the building
- Better use of fire wardens – maybe they are the first ones out (follow the leader)
- Occupant procedures that actually take into account what people WILL do
- Practice egress with real event scenarios – blocked stairs, theatrical smoke, fire department in stairs
- If we know that milling will occur, establish groups (evacuation groups of the occupants) to facilitate the process (since we know that they will likely get into groups anyway)

ALTERNATIVES THAT ENHANCE EVENT DETECTION

- Timely notification from detector to monitoring company
- Include adequate details on type and location of the event / detector
- Use thermal imaging systems for detection
- Automatic detection should be implemented for the spaces outside a main assembly area
- Detect chemical, biological, and radiological threats
- Detect severe weather

OTHER ALTERNATIVES

- Locator badges with counters at stairs
- Improve understanding of where people are in the building
- Motivation of people to evacuate
- Systems to motivate action
- Use egress systems on a regular basis
- More egress routes
- More building exits
- Enhanced notification systems at the local level
- Require at least one remote path of vertical egress when a central core is utilized
- Use devices to assist in compartmentalization
- Provide individual protective gear for occupants

INDIVIDUAL EVALUATIONS OF ALTERNATIVES

The alternatives were evaluated by nine groups of three persons using three distinct criteria:

- **Usefulness:** How good, in terms of achieving the fundamental objectives of egress, is the alternative IF it could be effectively implemented? Use a 1 to 9 evaluation scale where 1 is poor and 9 is great.
- **Feasibility:** What is the chance that the alternative could be effectively implemented within 10 years? Use a percentage evaluation scale, where 0 means there is no chance, 50 means there is a half chance, and 100 means that the alternative could surely be implemented.
- **Creativity:** How creative or innovative is the alternative? Use a 1 to 9 evaluation scale where 1 is a standard well-known idea and 9 is an idea that you had not heard of before.

The evaluation represents very quick simplistic aggregation done during a break at the workshop. When there was general agreement of the nine evaluation teams, roughly meaning that the dispersion of estimates were less than a third of the range of the corresponding measure for at least eight of the teams, we used the mean response. When there was more dispersion among responses, we included the range for feasibility and two estimates for each of the 1-9 scales that represent mean responses for the low and the high sets of evaluations with no characterization of how many were in each of those groups.

TABLE 1: INDIVIDUAL EVALUATIONS OF A CROSS-SECTION OF ALTERNATIVES

Useful (1-9)*	Feasible (0-100)*	Creative (1-9)*	Alternatives
* Where consistent, an average is reported; otherwise a range is reported			
9	20,100	2	Retrofit sprinklers in all high-rise buildings
7	35,99	3	Transitional refuge areas for resting and or transition to elevators in super tall buildings
1,7	5,80	3,9	Provide individual protective gear for occupants
7	50,100	3	Hardened evacuation routes
1,7	5,95	5	Mechanize evacuation routes (moving walkways, elevators)
8	75,100	2,9	Install readily visible directional indicators at key locations
8	25,100	7	Normal and emergency movement systems should be integrated
5,8	50,80	4	Build-in ergonomics to system designs
7	30,100	6	Alternate discharge at base of building
9	40,100	3,7	Provide hardened floors at intervals in tall buildings
8	40,100	3,7	Enhance visibility of exit signs: larger, flashing or digital signage
2,8	0,90	2,8	Locate exits in generally used areas such as toilets
1	0,10	1,9	Do not bring fire fighters into tall buildings
9	60,100	4,8	Real-time building / fire data to responding fire service personnel
1,7	5,90	2,7	Install a dumb waiter in stairway or elevator shaft for firefighting equipment (not personnel) and install a smaller (30") stairway for fire fighter access
5,8	20,85	7	Position fire brigades within high-rise buildings (with occupancies greater than 10,000) that are trained for managing egress as well as fighting fires.
9	30,100	7	Provide mechanical means to allow fire hose to penetrate stairwell doors while keeping smoke from entering

9	60,90	5	Simultaneous use of elevators and stairs
1,8	0,30	2,8	Restrict the heights of tall buildings
2,7	0,60	3,8	Share emergency systems with multiple buildings
3,7	0,80	2,8	Limit assembly occupancies at the top of buildings
2,8	5,85	7	Skybridges every 5 floors – many buildings linked together
3,8	20,85	7	Install external evacuation devices, e.g., platform devices
9	75,100	7	Emergency notification system to all occupants – phone, email, TV, satellite, public address
8	70,100	6	Two-way communication between fire service and occupants during event
7	40,100	4,7	Symbolic / iconic notification system for incident type and action required of occupants
9	50,100	8	Notify occupants via cell phone
3,8	80,100	9	Use sound via cell phone to guide to exits
9	60,100	5,8	Real time monitoring of movement in stairs
8	80,100	3	Photoluminescent markings
2,7	0,80	6,9	Install tracks in stairwell handrails for trolley seats to be used by all occupants
8	5,100	4,8	Base designs on risk assessments
7	5,90	5	Standardize design basis events and performance objectives to set public policy
7	5,100	3,7	Use performance-based criteria for all threats, more than just fires
8	70,100	3	Electronic monitoring of all components of standpipe
7	10,100	2,7	Ensure equal use of egress routes
3,8	0,85	3,8	Practice egress with real event scenarios – blocked stairs, theatrical smoke, fire department in stairs

ACKNOWLEDGMENTS

Staff from the National Institute of Building Sciences managed many administrative details which contributed to the success of the workshop. In particular, the report was developed with the benefit of meticulous notes from Claret Heider and Carita Tanner.

Other individuals made significant contributions of time and effort, which are gratefully acknowledged:

- Shyam Sunder, NIST
- Mat Heyman, NIST
- William Grosshandler, NIST
- Richard Bukowski, NIST
- Erica Kuligowski, NIST
- Barbara Faverty, NIST
- Najib Abboud, Weidlinger Associates
- Carl Galioto, Skidmore, Owings, and Merrill
- Clas Jacobsen, United Technologies Research Center
- Dennis Mileti, University of Colorado – Boulder
- Russ Sanders, National Fire Protection Association
- Harold “Bud” Nelson, NIST (Guest Scientist)
- The staff at the Airlie House Conference Center
- Brad Pumphrey, EastBay Media

5.0 APPENDICES

APPENDIX A: LIST OF ATTENDEES

Najib Abboud Weidlinger Associates, Inc.	Jason Averill NIST
Carl Baldassarra Schirmer Engineering	Richard Bowers Montgomery County Fire and Rescue
Richard Bukowski NIST	Diane Copeland Dillon Consulting Engineers, Inc.
Ron Coté National Fire Protection Association	Geoff Craighead Securitas Security Services USA, Inc.
Michael Dillon Dillon Consulting Engineers, Inc	Thomas Fitzpatrick Guiliani Partners,LLC
David Frable U.S. General Services Administration	Edwin Galea University of Greenwich
Carl Galioto Skidmore, Owings, and Merrill LLP	William Grosshandler NIST
Steve Gwynne Hughes Associates, Inc.	Glenn Hedman University of Illinois at Chicago
Claret Heider National Institute of Building Sciences	Matthew Heyman NIST
Clas Jacobsen United Technologies	Keith Johnson Fairfax County Fire and Rescue
Peter Johnson Arup	Edwina Juillet Consultant
Ralph Keeney Duke University	Erica Kuligowski NIST
Michael Lindell Texas A&M University	Nancy McNabb National Fire Protection Association
Dennis Mileti University of Colorado, Boulder	Harold "Bud" Nelson Formerly of NIST (Retired)
Jake Pauls Jake Pauls Consulting Services in Building Use and Safety	Richard Peacock NIST

Guylene Proulx
National Research Council – Canada

Jonathan Shimshoni
Escape Rescue Systems, Ltd.

Carita Tanner
National Institute of Building Sciences

Steven Winkel
The Preview Group, Inc.

Jerry Woolridge
Reedy Creek Improvement District

Russell Sanders
National Fire Protection Association

Janne Sorsa
Kone Elevators, Ltd.

Keith Wen
New York City Department of Buildings

Antony Wood
Council on Tall Buildings and Urban Habitat

APPENDIX B: RETHINKING EGRESS WORKSHOP AGENDA

RETHINKING EGRESS WORKSHOP

**Airlie House Conference Center, 809 Airlie Road,
Warrenton, Virginia 20187**

April 1 – 3, 2008

This workshop has been convened by the National Institute of Standards and Technology (NIST). It was organized by the Multihazard Mitigation Council (MMC) of the National Institute of Building Science (NIBS) with Funding from NIST.

Tuesday, April 1	
8 to 9 am	Breakfast
9 to 10 am	Welcome and Overview
10 to 11 am	Identification of Current Alternatives
11:30 am to 1 pm	Lunch Break (lunch served from noon to 1 pm)
1:30 to 5 pm	Guided Brainstorming
5 to 6 pm	Free Time
6 to 7 pm	Pre-dinner Social Hour (cash bar)
7 to 8 pm	Dinner
Wednesday, April 2	
8 to 9 am	Breakfast
9 to 11:30 am	Alternatives from Objectives
11:30 am to 1:30 pm	Lunch Break (lunch served from noon to 1 pm)
1:30 to 5 pm	The Process of Evacuation: More Alternatives
5 to 7 pm	Free Time
7 pm	Dinner
Thursday, April 3	
8 to 9 am	Breakfast
9 to 11:30 am	Identification of Gaps and Workshop Summary
12 noon to 1 pm	Lunch served
Transportation to Dulles Airport will depart from Airlie House at approximately 1:30 pm.	

APPENDIX C: FORMS FOR STRUCTURED BRAINSTORMING

Name: _____

1

List All Ideas that You Want to Have Considered at the Workshop

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Name: _____

List All of the Alternatives that You Think May Enhance Egress

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Name: _____

List All of the Objectives that You Think May Enhance Egress

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Name: _____

Create a List of All Values that You Care about Concerning Egress

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Name: _____

Expand Your List of Values that You Care about Concerning Egress

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

6

Name: _____

Convert Each of Your Values (On Forms 3 and 4) to Objectives (Verb and Noun)

<u>Basis</u>	<u>Objective</u>
A. _____	_____
B. _____	_____
C. _____	_____
D. _____	_____
E. _____	_____
F. _____	_____
G. _____	_____
H. _____	_____
I. _____	_____
J. _____	_____
K. _____	_____
L. _____	_____
M. _____	_____
N. _____	_____
O. _____	_____
P. _____	_____

Name: _____

Create Alternatives, or Elements of Alternatives, Using Each Objective

Basis Alternative

A. _____	_____
B. _____	_____
C. _____	_____
D. _____	_____
E. _____	_____
F. _____	_____
G. _____	_____
H. _____	_____
I. _____	_____
J. _____	_____
K. _____	_____
L. _____	_____
M. _____	_____
N. _____	_____
O. _____	_____
P. _____	_____

Name: _____

Create Alternatives, or Elements of Alternatives, Using Each Collective Objective

<u>Basis</u>	<u>Alternative</u>
A. _____	_____
B. _____	_____
C. _____	_____
D. _____	_____
E. _____	_____
F. _____	_____
G. _____	_____
H. _____	_____
I. _____	_____
J. _____	_____
K. _____	_____
L. _____	_____
M. _____	_____
N. _____	_____
O. _____	_____
P. _____	_____

9

Group Names: _____

Create Alternatives, or Elements of Alternatives, Using Each Collective Objective

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Name: _____

List All Components of an Effective Egress Process

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Name: _____

List All Components of an Effective Firefighting Process

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Group Names: _____ **12**

List Any Additional Components of an Effective Egress Process

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Group Names: _____ **13**

List Any Additional Components of an Effective Firefighting Process

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Name: _____

Create Alternatives, or Elements of Alternatives, Using Each Egress Process Component

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____

Name: _____

Create Alternatives, or Elements of Alternatives, Using Each Firefighting Process Component

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Group Names: _____ **16**

Create and Embellish Alternatives, or Elements of Alternatives, Using Each Egress Process Component

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

Group Names: _____ **17**

Create and Embellish Alternatives, or Elements of Alternatives, Using Each Firefighting Process Component

- A. _____
- B. _____
- C. _____
- D. _____
- E. _____
- F. _____
- G. _____
- H. _____
- I. _____
- J. _____
- K. _____
- L. _____
- M. _____
- N. _____
- O. _____
- P. _____

APPENDIX D: TECHNIQUES TO STIMULATE RECOGNITION OF VALUES

Use a wish list:

- If you had no constraints or limitations, what would you value?
- What elements constitute the “bottom line”?

Consider pros and cons of alternatives:

- Think of a great alternative. Why is it great?
- Think of a bad alternative. Why is it bad?
- Think of any alternative. What is good about it? Bad about it?
- Now use hypothetical alternatives with the above questions.

Imagine possible consequences:

- Think of the current situation. What is wrong with it? Right with it?
- Are there any unacceptable consequences?
- Are there any types of consequences that worry you?
- Are there possible consequences that you don’t know how to control?

Use different perspectives:

- What would occupants of the building say matters?
- What would local politicians say mattered?
- What if the reason for egress was a biological release?

Use constraints and guidelines:

- Consider any constraints on the process of egress. Why is this of concern?
- Consider ant guidelines. What is their purpose?

Ask ‘why’ for each value:

- For each value on your list, consider why it matters. Their may be multiple answers each suggests another possible value. Repeat the process until you are not generating additional values.

APPENDIX E: RESULTS FROM GROUP DISCUSSION

DAY 2: ALTERNATIVES FOR EFFECTIVE EGRESS AND FIREFIGHTING

- Group 1 - Members of this group were not sure if they were correctly differentiating between objectives and alternatives. The group generally agreed that minimizing evacuation time was the highest priority and refined this objective to read: “Timely evacuation with minimal harm to occupants.” A number of safety criteria were mentioned – for example, minimizing fatalities and injuries and maintaining building security. High on the priority list was maximizing the comfort level of occupants, be it physical or psychological. Lower on the priority list were cost and robustness of the solution. The group also addressed the various scenarios that can occur and noted that any solution must address the full range of scenarios. Components and routing systems would need to be used in as wide a range of situations as possible and this will have benefits in terms of developing occupant familiarity with the components/systems as well as in terms of maintenance and cost if the components/systems can be used in nonemergency situations. With respect to stairwells, it was noted that occupants tend to avoid them unless they use them regularly. Appropriate communication/information systems are very important and how they will be used can be treated during training exercises but their use can also be addressed during the design process. If the design is intuitive and obvious, it will encourage people to use certain routes and become intimately familiar with them. In those situations where occupants are likely to be strangers to the building, staff must be very well trained to manage the event.
- Group 2 - The group decided that alternatives actually are the tactics that can be used to achieve objectives. Expanded and increased communication was deemed to be very important both prior and during an event but also after the event. Two-way communication between the fire responders and the building occupants was identified as being of special importance. Increased use of elevators for emergency egress was discussed as were potential trade-offs that might be made in design. Group members held varying opinions on elevator use during emergencies and it was concluded that research is still needed. Evacuation devices were also discussed and additional research suggested. The need for increased planning for all types of threats was addressed as was the need for measurable performance criteria and improved sprinkler reliability. It was suggested that enhanced situation awareness be added to the list of objectives.
- Group 3 - Group 3 discussed many of the same issues as Group 2 but emphasized that evacuation is the crux of the egress problem. For example, under what scenarios do buildings have to be completely evacuated and do they really need to be evacuated? The group concluded that one general way to address this issue is to develop a process for creating threat scenarios and establishing performance metrics for providing alternatives acceptable to stakeholders. The scenarios could involve a security breach, a massive fire, or a CBR attack. By analyzing these scenarios, we can provide building designers with the tools they need to meet the performance objectives for the building. The next step would be to develop a standardized but flexible system for communicating instructions to occupants and emergency responders using conventional communication devices and technology. Also discussed were the use of sky-bridges between buildings, the use of external evacuation systems, maintaining incident command from a remote location, having stairwells discharge directly outside, and the need for improved sprinkler and monitoring systems.

- Group 4 - This group concentrated on alternatives for making people feel safer, and the group focused on increased use of technology. The systems currently used require enhancement – that is, buildings need to “see,” “hear,” and “talk’ to us. The group concluded that the best way to evacuate a building is through the use of elevators (even though simple egress methods such as stairwells would still need to be present); therefore, all aspects of making this possible should be explored. Zone-floors or safe areas and enhanced fire resistance for high-rise buildings also were discussed. Several group members indicated that the building codes permit too many trade-offs when sprinkler systems are provided.

DAY 2: PROCESSES FOR EFFECTIVE EGRESS AND FIREFIGHTING

- Group 1 - This group arranged their presentation by using distinct time periods in the overall event timeline and the participant experience timeline: first, the detection phase (either human or technological); second, the responder intervention phase; third, the decision phase; and fourth, the movement phase. The group further developed a series of scenarios which could initiate an evacuation and then categorized the events as man-made events, natural events, fire events, and security events. These events could be internal or external. The detection and process system could be separated into automatic or assessed. With automatic systems, an alarm goes off in response to whatever the event might be. With assessed systems, information is required so that someone can assess the nature or the existence of the incident and determine what the response should be. Generally, the group determined that as much information as possible should be gathered either by dedicated detection systems, CCTV, or human response to a command center in the building, and this information needs to be conveyed directly to the fire department or other first responders. This should provide the redundancy needed and should ensure that the people responding to the incident are well informed, which should reduce subsequent investigation time. This information could relate to the incident itself, the procedure, the population – where they’re going, the level of impairment – and the structure itself. The group envisioned use of a CCTV system to monitor the movement of the people in nonemergency situations. The group discussed the value of the notification system in both instigating and informing the response. The group decided that both visual and audible communication was preferred and would solve issues involving language or impairment. Guidance concerning the egress routes to use in the form of graphic displays over the doors indicating whether they are available and/or indicating the availability of routes and the direction of movement. This would require some standardization such as coloring and pictographs used. All systems would have to be adaptive and not hard-wired. The use of secondary devices such as PCs, TVs, cellphones, and PDAs also was discussed; these devices could be interrupted to ensure that people would be disengaged from their normal activities and received the message. The nature of the information passed to building occupants needs to be assertive and the time of the announcement needs to be clearly stated to emphasize that the event is real, not a drill. This announcement should be supported/reinforced by staff members. Considerable discussion was devoted to reducing the time it takes to get people to specific locations and floors. A consensus was not reached but it was determined that staff support will be needed. Accelerating the arrival of persons of authority on the critical floors was considered a top priority. It also was emphasized that structures should be people-centric – that is, designed around the occupants – and not just building a structure and then filling it with people. Information was at the forefront of all discussions as the most critical of issue in event response.

- Group 2 - This group focused on the fire fighting processes specific to high-rise buildings. The first process discussed was pre-planning for an event. Communicating these plans to the

occupants and staff is vital since these are the individuals that will be on site prior to arrival of the responders. The event itself needs to be anticipated. The code process needs to be enforced to ensure that all systems are working, thus avoiding glitches during response. Detection, both human and technological, was discussed. Many alarm systems give good information (e.g., where the alarm is, what type of alarm it is, how many zones are involved, and what type of detector was activated) but the cause of the alarm nevertheless needs to be verified. This can be done with multi-detection systems. False alarms happen frequently and there have to be ways to deal with those (e.g., impose penalties for multiple false alarms). For this group, communication was also of critical importance. Timely communication providing adequate details is important from the moment that the monitoring company detects a problem. Gathering information from the staff and occupants also is crucial. Standards for the evacuation of a building vary from place to place but a building plan is critical. Communication to the occupants in a manner that they cannot ignore is of tremendous importance. Some political questions also surfaced such as whether a smaller community with a small fire department and staff should be allowed to build tall buildings. The use of elevators for response and evacuation purposes was also discussed. The need for enhanced command center information was identified (e.g., to provide real time information from the incident site about such things as temperature on floor and smoke conditions). It was noted that hose deployment in stairwells is a continuing problem both in terms of blocking the stairwell and permitting contamination of the entire stairwell. Needed is some way to get a fire hose with positive pressure through a door while allowing the door to close so as to prevent stairwell contamination. With respect to ensuring that all building occupants have left, the group concluded that going door to door is still the only way to do it. It also was noted that post-incident information gathering, analysis, and archiving – or rather the lack thereof – by the fire department has been criticized but little has been done to improve the situation.

- Group 3 - This group addressed “general” buildings where, at any given time, a large segment of the population would range in age from very young to very old and would be of widely diverse backgrounds and ethnicity. Retail malls were considered a good example of such occupancies. In terms of emergency event, the mall is more likely than most other occupancies to experience a wide variety of events (e.g., fire, criminal activity, terrorist activity, and severe weather). Communication was identified as key by this group and participants agreed that using cellphones would be a good way of notifying occupants of the event – perhaps by creating a special emergency ringtone used only for emergencies so it would be immediately recognizable. The designers of the malls and the retailers want you to see their stores; therefore, the exit signs are obscure. The visibility of exit signs needs to be enhanced as do the pathways to the exits. CBR detection should be incorporated into mall systems and severe weather should be announced over the PA system or using the cellphones. Elevators need to be on emergency power so that mobility impaired persons can easily exit. Risk also needs to be considered. There are different risks for different hazards requiring different solutions. In developing solutions, the risks that come with the various occupancies, heights, and other factors related to a specific structure should be considered. It was noted that the mall security staff probably would be the first ones to assess the situation and would be the ones to use for crowd control.

It was asked whether current cellphone technology permits a signal to be sent to all phones and it was explained that cell casting permits a signal to be sent to all phones within a prescribed area at the same time regardless of the number. Adaptations of this technology permit it to be directed to a single building and some universities use it campus-wide. The FCC also is working on Cellular Mobile Alert Service (CMAS) standards which are now being evaluated by the industry for adoption

and implementation.

- Group 4 - This group focused on assembly buildings and the behavioral aspects of emergency evacuation. Assembly space was defined as a single large geographically complex area where occupants are generally aware of the egress routes because they are the same as those used for entry. Some discussion was devoted to comparing the impact of an event in an assembly space versus a high-rise building. People tend to receive their information in assembly space at the same time rather than at separate times which often happens in high-rises. Assembly spaces also tend to have large numbers of people in a single space and the need for well trained crowd managers is paramount. The group discussed this from an emergency planning aspect and a stadium was used as an example. The consensus was that the most reasonable approach would be to divide the crowd into manageable subgroups. The highly trained crowd managers would be in constant contact with the emergency managers, usually via radio. The emergency managers then could determine what type emergency had occurred and direct the crowd managers to ensure that the subgroups were directed and shepherded to the right places. These managers could be the same persons that greet the people as they come in to the venue. Planning and training of the crowd managers obviously would be very important, but not much time should be needed after an event occurs to start moving the crowd out to safety. Community emergency plans also were discussed in terms of their interface with building emergency plans. Ideally, if management fails, the architecture will serve to move people way from the event. The group also acknowledged that there are different strategies for seated versus non-seated venues. It was noted that very little attention has been paid to this type of occupancy in North America and that conferences on the topic would benefit from the participation of individuals like those attending the workshop

