Final Report

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Introduction

Oklahoma State University (OSU) created a 50-minute video as a learning resource to be integrated into existing undergraduate courses to educate students about the importance and content of documentary standards related to building egress. The video was developed in Oklahoma, but is applicable throughout the entire United States of America.

The objective of the proposed video is to help students to identify common errors that are made relating to the documentary standards for egress systems in order to help to ensure that these problems are addressed before an emergency occurs. The standards to be addressed are the International Building Code (IBC 2015) and the National Fire Protection Association standard that addresses building egress (NFPA101 Life Safety Code).

Problem

Proper egress system design is important for life safety in buildings. In the event of an emergency evacuation, people inside the building need to be evacuated in an efficient and safe manner. While the standards address these requirements for egress systems, designers, code officials, employers and/or building owners can violate these requirements due to poor understanding of the standards, lack of adherence to the requirements, reconfiguration of the space, security concerns, poor maintenance, or economic concerns. Many fatal emergencies (e.g. Beverly Hills Supper Club fire) have occurred in buildings where the requirements of the standards were not met.

Recently, the Oklahoma Fire Marshal addressed the Oklahoma American Institute of Architects, stating that a huge backlog for code reviews is occurring throughout Oklahoma. Similar situations are occurring throughout the United States. This is due not only to budget cuts, but also to the fact that code compliance in architects' plans is lacking. Architects rely on Fire Marshals to correct code errors, and the office is simply not able to keep up. Non-code compliance can result in significant economic impact. There are significant delays when the drawings are submitted multiple times. The changes that are required later in the process typically cost significantly more than changes at the conceptual design phase. In addition, the changes caught during construction can lead to the loss of floor space that could otherwise have been used for commercial or similar activities.

Although there are numerous emergency egress training videos, those videos focus on developing emergency evacuation plans. An educational video focusing on emergency egress building design strategies and hazard identification in accordance with the standards is not known to exist before this video. The video also addresses people's state of mind in an emergency to show how safe egress design is essential for safety. The video is targeted to students in the fields of fire protection, architecture, and civil engineering; however, training on this safety topic is applicable to workers and/or employers in almost any workplace.

Our experience with teaching students about the standards is that they have difficulty grasping the importance, basis, and nuance of the requirements. Even though the topics are covered in lecture and the students are tested on them, the students do not understand why they have to be used and fail to apply them independently when developing designs or reviewing drawings. By being able to see the consequences of failure to adhere to the standards or to understand how particular emergency events impact the standards, students will be able to apply the standards as intended. The use of three-dimensional models will enable them to see and better internalize the requirements.

Goals

The primary goal of the video was to improve a viewer's understanding of the code and his or her ability to identify code issues in building floor plans. The intention is that this would be achieved by not only demonstrating essential calculations of egress design using visually appealing contemporary buildings with three-dimensional models, but also by incorporating powerful first-hand accounts of emergency experiences. Relevant case studies which directly influenced code standards and changes are explained and diagrammed. The case studies and human perspective stress the importance of the methodical calculations. The video is easily accessible and has been widely distributed to academic programs throughout the country that teach areas related to the building codes. The main advantage to a video over traditional lecture material is that viewers who have difficulty with the material can review the film repeatedly. Viewers can also understand the needs of different occupants. Featuring a variety of community groups, including children, the elderly, and college students in the videotaping reinforces the varying abilities and experiences of occupants.

Viewers are expected to understand the importance of standards in safe egress design, to be able to perform basic code calculations, to design buildings that are code compliant, and to be able to identify errors in drawings. All of these skills are covered with examples and case studies within the video,

Project Outcomes

Table 1 shows the original timeline.

Table 1: Original Timeline

Tasks	Person Responsible	Completion Date	Result
Quarter 1 – July 1 to September 30			
Develop FDS+Evac simulations based on code & historical events	Bryan Hoskins	September 2014	Will be able to visually present the consequences of incorrect egress design
Model at least two well-known buildings and perform simulations	Jeanne Homer	September 2014	Can show egress features in isolation and also the connection to good egress system design
Quarter 2 – October 1 to December 31			
Submit financial and performance reports	Bryan Hoskins	October 30, 2014	The required financial and performance reports will be submitted
Record/Simulate fire drills and/or crowd exiting	Bryan Hoskins	November 2014	Footage to show how conditions for building occupants can change during a fire and options people have
Develop draft film	Jeanne Homer	December 2014	Various elements completed and coalesced into draft film.
Quarter 3 – January 1 to March 31			
Present draft film to	Bryan Hoskins or	January 2015	Surveys will provide an

class & collect surveys before/after viewing	Jeanne Homer		effective evaluation of the draft training film
Analyze survey results to identify problem areas	Bryan Hoskins	March 2015	Qualitative and Quantitative review of surveys will reveal needed changes for the film
Revise film based on feedback from student survey	Jeanne Homer	Continues into 4th Quarter	Survey results incorporated into film so that the instruction will provide the intended learning.
Quarter 4 – April 1 to June 30			
Submit financial and performance reports	Bryan Hoskins	April 30, 2014	The required financial and performance reports will be submitted
Finish revisions to film	Jeanne Homer	June 2015	Copies of film sent to NIST and film available for free download on OSU website
Final close-out report completed & submitted	Bryan Hoskins	June 2015	All reporting requirements successfully completed
Fall 2015			
One-Day workshop in Gaithersburg, MD	Bryan Hoskins and Jeanne Homer	Fall 2015	Participate in one-day workshop

(2014) July to September:
The July to September activities have not been completed yet. Because the grant was not awarded until after the start of the school year, it was not possible to hire the teaching assistants to conduct the originally intended work for this period in the fall. It resulted in the timeline being rearranged. A shorter draft film was developed which focused on the key aspects of the film. The shorter version was necessary in order to present it to students before the end of the semester. One of the contemporary buildings was designed as of March 31st. The other building will be completed by the end of May. The FDS+Evac simulations will be completed in the summer.

(2014/2015) September-March:
The draft film was developed by the end of March. This included the video footage of crowds. The draft film was shown to students coinciding with the visit of NIST staff (after the March time frame, but already completed). The results from the students viewing it is being processed currently.

(2015) April-September:
The majority of the video has been completed during this period, including videotaping, architectural digital modeling, the majority of permissions, voiceover, some animating, adjustments per the survey feedback, and compilation by ITLE. All the teaching assistant money will have been spent by the end of the fall semester. The video includes case studies’ influence

on the code and examples that teach students about code basics.

(2015/2016) September-March:
The video was completed. In early November, Dr. Hoskins presented NIST with a nearly complete video, and Professor Homer will present the video to a group of American Institute of Architecture professionals. A professional code official will do a final review of the video, and it will be burned to DVDs and placed on a server with a link for everyone to access.
The video was released with and without captioning on youtube (non-captioned: https://www.youtube.com/watch?v=9bKLrl_CBHo and open captioned: https://www.youtube.com/watch?v=K9PTRHgxtzY), easily accessible to any student, instructor, and professional throughout the country. A high-resolution file on a DVD was sent to every accredited school of architecture and fire protection and safety program in the country.

The 50-minute video covers basic emergency egress design, and begins with general definitions of occupancy classifications, highlighting important issues to consider for each. It continues with simple calculations of occupant load, as those numbers determine many aspects of egress design. Throughout the video, fundamental definitions are diagrammed and demonstrated verbally, graphically, and in videotaping. Both historical and contemporary case studies are also integrated throughout the video to reinforce egress standards by explaining egress failures, analyzing why they occurred, and sharing accounts of victims' first-hand experiences. NIST and the National Fire Protection Association provided clips of controlled testing, including a recreation of a nightclub fire in real-time as it happened without sprinklers, and then with sprinklers, demonstrating the dramatically different results. A demonstration of more detailed calculations, such as the number of required exits and width of corridors, doors, and stairs, is enhanced with animated graphics, as are maximum travel distances. These are repeated later in the video at a quicker pace with an elementary school example.

In the design of egress systems, there are several key concepts to understand and features that need to be applied in order to ensure that the people in the building can safely evacuate. These features can improve daily use of the building, but the failures of the system are not noticed until an emergency occurs. These features are:

- Occupancy classifications- definitions and examples are provided. Determining the intended use of a building affects many subsequent aspects of egress design.

- Occupant load- the maximum number of expected occupants at any given time in a building or room is determined. This number is used to calculate the number of exits and their widths.
- Exit Access, Exit, and Exit Discharge- definitions and examples are provided. Exit Access is the area of the egress system that leads from an occupied area to an Exit. An Exit is the safe portion of the egress system that leads to Exit Discharge. Exit Discharge leads to a public way.
- Adequate exit width- scenarios demonstrate how decreases in egress width below the levels required in the standards can greatly increase the required safe egress time (RSET).
- Changes in width- a decrease in width, even if still above the code minimum, will force people to get cut off and increase RSET. The standards do not allow for it, but it is one that students have trouble understanding.
- Merging flows- where two components meet, the egress width has to be sufficient to meet the needs of the combined flow.
- Door swing- a door swinging inward can cause people to become trapped as the crowd surges behind them.
- Main entrance requirements- scenarios have more people heading towards the main entrance and showing the need for that exit to have sufficient capacity. The standards require that the main entrance in assembly occupancies have a greater capacity for this reason.
- Remoteness of exits/exit discharge- the standards require that exits are located remotely, but this can be neglected by people not familiar with the standards.
- Dead-end corridors- presence of a dead-end corridor can cause people to become confused as they look for an exit or bypass an exit during an emergency.
- Common path of travel- having only a single egress path from a given location can be fatal when that path becomes blocked.
- Maximum travel distance- the standards place restrictions on how far exits can be from the most remote areas of a room or building.
- Increasing level of safety along an egress route- it is required that once people are in a safe exit, they must remain in a location of safety until exit discharge.

- Locked exit doors- for security reasons, employers can lock doors in violation of the standards to prevent people from stealing or leaving without paying; scenarios show how heading towards a locked door can potentially lead to loss of life.
- Fire Rating- materials and assemblies are rated in terms of their relative level of fire resistive performance.
- Sprinklers- the presence of sprinkler systems can greatly increase the chances of survival in a fire emergency, although they are not necessarily designed to extinguish a fire.

Case Studies

Examples of egress system failures are discussed in the format of brief case studies. By visually presenting the consequences of less effective or incorrect design, students, employers and workers who view the film will be able to better personalize why these egress system features are critical to remember when designing buildings. In addition, it is noted how these particular tragedies impacted standards in the code. Listed in order of appearance, the case studies featured include:

- Triangle Shirtwaist Factory Fire, New York, 1911- doors were locked, and doors swung inward.
- Imperial Food Processing Plant, North Carolina, 1991- doors were locked.
- Garment Factory Fire, Karachi, Pakistan, 2012- doors were locked.
- Beverly Hills Supper Club Fire, Kentucky, 1977- it was over capacity and had no sprinkler system, exits were not adequate in number nor width, and dead-end corridors led people to other banquet rooms.
- Cocoanut Grove Fire, Boston, 1942- main revolving doors jammed, doors were locked and/or blocked, exit signs were not visible, and doors swung inward.
- The Kiss Nightclub Fire, Brazil, 2013- overcrowded with inadequate exits.
- The Station Nightclub Fire, Rhode Island, 2003- there was no sprinkler system, inadequate width at the main entry doors, and blocked exits.
- Cincinnati US Bank Arena, 1979- there was not enough entry capacity.
- Love Parade Disaster, Germany, 2010- inadequate entry width for the capacity.
- MGM Grand Fire, Las Vegas, 1980- no sprinkler system, and seismic joints allowed smoke to travel up the tower.

- Our Lady of Angels School Fire, Chicago, 1958- fire door was not closed. Caused many schools to upgrade their facilities and to perform fire drills.

Impact

During early development, a 22-minute draft video was shown to a class of architecture and architectural engineering students in the Comprehensive Design Studio and to a class of fire protection and safety technology students in the Structural Design for Fire and Life Safety course. The intent of the draft video was to determine what the target audience found to be most helpful and what they did not like about the video. This enabled changes to be made for the final version was done that would best suit the needs of contemporary students learning about building codes.

A questionnaire was distributed to the students asking them about their impressions of the video and what elements they would like to see more of as the video was expanded. Similar results were found for each class.

The architecture students completed a questionnaire regarding its content. The results are below, and the input assisted in how to proceed with the video. They overall appreciated the video and its direction. To complete the video, students noted that they would like to see another modeled building and case studies, but some thought that the Pathfinder models would be redundant. Ultimately, the more detailed stair diagram was eliminated due to video time constraints.

Emergency Egress Video Draft Questionnaire		
		Average Response (1 low – 5 high)
1	Was the information clearly presented?	4.55
2	Did the diagrams help to explain the verbal content?	4.63
3	Would you review the video on your own?	3.97
4	Would this video be helpful to you in understanding egress better?	4.55
5	Knowing the content will expand, please rate what you think would be helpful information to include:	----

	Another building example with contemporary design and complicated egress issues	4.45
	Examples of previous fires and what went wrong	4.30
	Models using Pathfinder (or similar) showing people moving in an egress situation	3.69
	More detailed stair diagram explaining the important aspects of egress stair design	4.03

The fire protection students had similar responses. All of the possible expanded content had some students rate at five and others at one; there was nothing that was universally indicated as essential.

Emergency Egress Video Draft Questionnaire		
		Average Response (1 low – 5 high)
1	Was the information clearly presented?	4.63
2	Did the diagrams help to explain the verbal content?	4.45
3	Would you review the video on your own?	3.71
4	Would this video be helpful to you in understanding egress better?	4.68
5	Knowing the content will expand, please rate what you think would be helpful information to include:	----
	Another building example with contemporary design and complicated egress issues	3.73
	Examples of previous fires and what went wrong	3.89
	Models using Pathfinder (or similar) showing people moving in an egress situation	4.05
	More detailed stair diagram explaining the important aspects of egress stair design	3.60

In May 2015, the draft video was also shown to a group of three professionals in the fire protection engineering field that were taking a continuing education course at OSU. They were very impressed with the video and their main comment (before being told the purpose of the draft) was that the video needed to be longer. They found all of the content to be helpful and beneficial.

In November 2015, portions of the video were shown at the Oklahoma American Institute of Architects Convention. The title of the presentation was "Human Behavior and Case Studies' Influence on Standards in Egress Design", and Jeanne Homer presented this with Yuen Ho, the Assistant Director of Development Services for the city of Tulsa, Oklahoma. The presentation reintroduced basic concepts about egress from the perspective of human experience and case studies. Over 60 architects were present, and each was given a quiz of 12 questions. 63.5% scored a perfect score after viewing the video, 23% missed just one, 11.5% missed two, and only 2% missed more than that. The content for questions 2, 6, 7, 8, 9, 10, and 11 in particular were covered in the video clip. In the end, the architects responded well to what can normally be considered dry material. Below is the quiz with correct answers and percentage of architects who answered it correctly.

"Human Behavior and Case Studies' Influence on Standards in Egress Design"

Quiz

T/F

T **96%** 1. Race can be a factor in the number of fire-related fatalities in the US
T **100%** 2. Most people exit the way they came into the building
F **100%** 3.Everyone reacts and begins to evacuate immediately upon learning of a fire
F **90.4%** 4. People's panicking causes more deaths than delays in receiving information about a fire
F **86.5%** 5. It is a good idea to investigate a fire upon hearing an alarm.
F **100%** 6. Sprinkler installation is a guarantee that no person will be injured in the event of a fire or emergency.
F **98%** 7. People always panic in a fire evacuation.
T **92.3%** 8. Modern materials are more toxic and burn more quickly than traditional materials.
T **98%** 9. If you design a nightclub, assume people will burn things during a performance.

Multiple Choice
10. Which of these is NOT a factor in evacuation?
a. Age b. Mobility c. Awareness d. Quality of warning system
88.5% e. All of these are factors

11. Which are some conditions that can be present in a fire evacuation?
a. Smoke b. Low lighting c. Presence of toxic gases d. Loud alarm
96% e. All of these are conditions

12. What are reasons occupants' reactions may be delayed?
a. They are not sure if the threat is imminent, so they investigate
b. They are sleeping
c. They are children and not led out
d. No one else around them is evacuating
98% e. All of these

In the Comprehensive Design Studio, the impact of the video on student understanding of egress design issues is clear. A quiz requiring about 40 students to identify 10 code violations in floor plans for a two-story theatre has been given each year since 2013. In 2013, the class average was 81, and in 2014 it was 56.9. Their poor performance prompted the project of creating the video. In 2015, the year we showed a draft of the video, the class average rose to 89.1. In 2016, students could view the entire completed video, and the average rose again to 91.2.

Comprehensive Design Code Quiz Results		
	Class Average	
2013	81	
2014	56.9	
2015	89.1	Draft video introduced
2016	91.2	Final video released

A review of the draft video and a final review of the nearly completed video were performed by the Tulsa Development Services code officials, Yuen Ho and Evona Garner. They commented on several items, particularly involving new code material introduced in the adoption of the 2015 International Building Code from the 2012 version. This transition occurred during the creation of the video, so tables and reference numbers needed updating, and a few pieces of information changed, such as, how to calculate the occupant load of a mercantile space. They corrected other issues with graphic representation or animation. They were a valuable asset to the development of the film.

Lessons learned

The final video turned out very similar to what we had originally envisioned. The draft video and incorporating target audience feedback was essential in the completion of the final video. Showing it to a wider audience helped in determining what features worked and which ones did not. Also, production delays were a problem and more time allocated for that process was needed.

Potential for adoption

A youtube link and high-resolution files on a DVD was sent to all accredited schools of architecture (130) and fire protection engineering. The link will also be sent to the International Code Council, the National Fire Protection Association, Oklahoma American Institute of Architects members, NAAB (National Architecture Accreditation Board), and Building Technology Educator's Society (well over 100 members). We will continue to get feedback from these groups, and we can collect information from the youtube website. We anticipate many more views in the next school year, as the video was released in the middle of the spring semester. A reminder email with the links will be redistributed in the fall. A paper about the video will also be submitted to a journal. Two possible journals are: *Standards Engineering*, the journal of Society for Standards Professionals and *Fire Safety Journal*, the journal of International Association for Fire Safety Science.