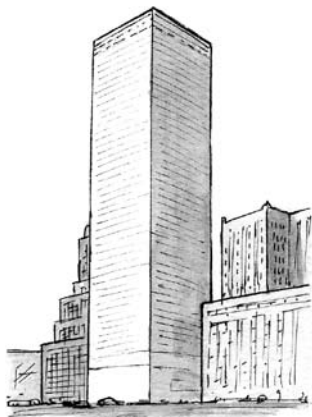# NOVA

Building on Ground Zero

PROGRAM OVERVIEW

NOVA takes a look at what can be learned from the World Trade Center disaster.

The program:

- reviews the structure of the Alfred A. Murrah building in Oklahoma City and details how the building suffered a progressive collapse when bombed in 1995.
- notes that the American Society of Civil Engineers found that the World Trade Center (WTC) towers performed well

#7 World Trade Center

  when attacked and that there was no tradeoff of safety for economy in construction.
- reviews findings from the National Institute of Standards and Technology (NIST) detailing how and why the WTC towers collapsed.
- reports on NIST conclusions that the WTC had no structural flaws that could account for its collapse—the towers fell due to the interplay between the impact damage and fire.
- summarizes some of the NIST recommendations for improving safety standards that resulted from the study of the WTC collapse.
- specifies safety features being designed into China's World Financial Center in Shanghai, which will be the world's tallest building when completed.
- details the safety features in the newly rebuilt #7 WTC building (the third skyscraper to collapse).
- explores the question of how safe is safe enough?

Taping Rights: Can be used up to one year after program is recorded off the air.

CLASSROOM ACTIVITY

Activity Summary
Students research safety feature and building code changes that were recommended in response to major disasters, including fire, hurricanes, and terrorist acts.

Materials for Each Team
- copy of the "Learning from Disasters" student handout
- copy of the "Proposed Changes" student handout

Materials for Each Student
- copy of the "Evaluation Card" student handout

Background
When a disaster involving a human-made structure occurs, an investigation is launched to determine what happened. The investigating team examines the condition of the building prior to the disaster, the structural integrity of the building, how the event progressed, how the fire and safety features and procedures functioned, the evacuation system, how the building's occupants behaved, and the activities of emergency responders. In this activity, students research disasters through the eyes of an investigative team and argue before a panel of judges for the adoption of safety features or building codes that would be applied locally, regionally, or nationally.

In the first part of the activity, students work in teams to locate information on six disasters that led to code revisions. They look specifically for how each disaster may have impacted recommendations for safety features or building codes for the area.

In the second part of the activity, students select two suggested safety feature or building code revisions and argue before a panel of peer evaluators for the adoption of the selected features or codes. Student judges will vote to implement or reject the features or codes based on the strength of the presented arguments.

Video is not required for this activity.

Classroom Activity Author
A teacher for 25 years, Shannon C'de Baca teaches and serves as a consultant for national and state agencies working to improve science teaching. Her teaching practices have been recognized with national awards from the Milken Family Foundation and the National Science Teachers Association.

Procedure

1 Ask students what types of events qualify as major disasters. Do students think a disaster occurring today might have a lower loss of life than a similar disaster occurring in the early 1900s? Why or why not?

2 Organize students into teams and distribute the "Learning from Disasters" and "Proposed Changes" student handouts. Explain that each team will collect data on six disasters that resulted in proposed changes to existing safety features or building codes.

3 To help students identify types of data to collect, create a class list of elements designed to help prevent human loss during an emergency. These elements may include type of construction materials (and their level of flammability), fire alarms, smoke alarms, sprinklers, number and location of exits, and evacuation plans.

4 Have students collect data outside of class over a one- to two-week period. (Some Web sites for research are recommended in Activity Answer starting on page 4.) After they have concluded their research, assign or have students choose two specific safety features or building code changes they would like to recommend for a building or buildings found locally, regionally, or nationally (such as office buildings, hotels, hospitals, movie theaters, stadiums, airports, and residential homes).

5 When students have gathered their information, have them present their recommendations to the class. Provide each student with a copy of the "Evaluation Card" student handout. Have all students list each team being evaluated on a separate sheet of paper and use the criteria on the "Evaluation Card" handout to rate each proposed change.

6 All students who are not presenting should evaluate the presenting team. After each team has been evaluated, poll the students to see how many think the proposed changes should be adopted and how many do not. Following each evaluation, ask the class to provide feedback on the stronger and weaker points of the arguments.

7 To conclude the lesson, discuss what students learned. Ask students to consider the different types of buildings in their own communities. What kind of safety features and building codes should apply to the different kinds of buildings found in their area?

8 As an extension, have half the class prepare an argument that every building should be built for a worst-case scenario, such as the impact of a jet airliner. Have the other half of the class argue the counterpoint.

Each disaster listed led to specific safety feature or code recommendations, several of which were similar and not all of which were adopted. Students will generally argue for adoption based on the lives or property that might have been spared had the feature or code been in place and enforced. Arguments against will range from cost to the statistical probability of a similar event. A brief summary of each event and some of the resulting proposed changes are listed below.

Date: **November 28, 1942**
Event: **Cocoanut Grove Night Club Fire**
Location: **Boston, Massachusetts**
Cocoanut Grove was a fine dinner, music, and dance club. One evening, a fire swiftly engulfed the club, killing 492 people and injuring 166 others. This, the deadliest nightclub fire in U.S. history, led to a nationwide reform of fire codes and safety features.

When a fire began in a decorative palm tree, patrons panicked and tried to escape through the one revolving door entrance. The door became jammed with people and would not operate (the club's maximum capacity had been exceeded by hundreds). Exit points were limited: a plate glass window was boarded up, side doors were welded shut, and the few remaining exits that did operate opened inward, reducing the evacuation rate. Flammable decorations made it difficult for people to see the exit signs.

The cause of the fire was not determined. While the club had passed inspection shortly before the fire, many violations had been overlooked. The electrician who wired the club was not licensed.

Safety recommendations included:
- banning flammable decoration in Massachusetts public facilities (nightclubs).
- requiring that all fire exit doors open outward.
- calling for owners to not lock or block any fire exit door.
- installing always-visible exit signs.
- flanking revolving doors by at least one normal outward-opening door.
- calling for a review of the way maximum capacity is determined and enforced.

The Cocoanut Grove Inferno
www.boston.com/news/daily/21/archives_cocoanut_112292.htm
Features a retrospective article on the fire 50 years later.

Date: **May 28, 1977**
Event: **Beverly Hills Supper Club Fire**
Location: **Southgate, Kentucky**
One hundred and sixty-five people died and more than 200 were injured, making this the third deadliest nightclub fire in U.S. history. Faulty old aluminum wiring was blamed as the cause. No one noticed the fire until the blaze was beyond control. The building had flammable decorations, no audible fire alarms, no sprinkler system, and no fire doors.

Safety recommendations included:
- increasing the number of available exits and requiring lighted signs on all exits.
- outlawing unsafe aluminum wiring in locations where it is not already prohibited.
- requiring that all older nightclubs install sprinkler systems.
- tightening restrictions on nightclubs regarding the use of flammable decorations and materials that might give off toxic fumes when burned.
- requiring fire doors on stairways at each level of the building.
- requiring audible fire alarms in all public buildings.
- revamping the way state government agencies supervise code enforcement.

The Beverly Hills Fire: Tragedy Rooted in Code Violations
www.enquirer.com/beverlyhills/chronology.html
Chronicles the history of the supper club, including information about the fire.

The Beverly Hills Tragedy
www.cincypost.com/bhfire
Supplies a time line of the fire and factors that contributed to the high number of deaths.

Date: **August 16–29, 1992**
Event: **Hurricane Andrew**
Location: **South Florida**

This hurricane battered South Florida in late summer of 1992. Damage estimates of $25 billion made it the third-most expensive disaster in U.S. history. About 65 people died and 250,000 people were left homeless. Advance warnings prompted evacuations for southern Florida, the Florida Keys, Louisiana, and eastern Texas. Winds reached almost 300 kilometers per hour before the hurricane made landfall on the Florida coast. Officials credited the low number of deaths to advance warning and evacuations.

Safety recommendations included:
• requiring that carpenters supplement the nails holding roofs to walls with metal clips.
• sheathing new buildings entirely in plywood (not just the lightweight foam insulation previously used) before siding is put on.
• using more roofing nails and gluing down corner shingles.
• making slight revisions to the regional evacuation plan.
• using more impact-resistant glass and installing bolts around windows to enable homeowners to more easily install precut plywood over windows during storms.

New Building Code Brings Cost, Confusion
www.sptimes.com/2002/ webspecials02/andrew/day2/story1. shtml
Relates information about building codes that address foundations and roofs.

Post Andrew Summit Raises Call for Tougher Standards
hurricane.lsu.edu/_in_the_news/ june_02_naples.htm
Includes information about codes related to wind damage.

Date: **September 11, 2001**
Event: **World Trade Center Attack**
Location: **New York City**

Hijackers flew two commercial airliners into each of the two 110-story WTC towers. More than 2,700 people died from the attacks, including more than 400 emergency responders. Nearby buildings also suffered extensive damage when the two towers collapsed.

The high-speed aircraft inflicted considerable damage on the structural components of both towers. The towers probably would have remained standing had the aircraft not dislodged fireproofing elements; the lost thermal insulation allowed heat from fires to weaken structural components and lead to collapse.

Safety recommendations included:
• improving fire protection of structural members.
• providing backup sprinkler systems (sprinklers, standpipes, and hoses).
• providing backup systems for fire alarms and smoke management.
• improving shielding materials for elevators.
• considering the use of impact-resistant materials around stairwells.
• widening stairwells and increasing distance between exit stairways throughout the building.
• improving evacuation systems.
• upgrading emergency communication systems.

Building Standards and Codes: Who Is in Charge?
wtc.nist.gov/pubs/Recommendations. pdf
Provides the National Institute of Technology and Standards' suggestions for the way buildings are designed, constructed, maintained, and used as well as for evacuation and emergency response procedures following the WTC attack.

FEMA Executive Summary
www.fema.gov/pdf/library/fema403_ execsum.pdf
Summarizes events that occurred at the WTC and explores whether building codes should be changed to make future buildings more resistant to attacks.

Date: **February 20, 2003**
Event: **The Station Nightclub Fire**
Location: **West Warwick, Rhode Island**

Ninety-eight people died and more than 180 were injured in the fourth deadliest nightclub fire in U.S. history. The band on stage at the time, Great White, lit its own pyrotechnics without a required city permit, which set off flammable soundproofing installed behind the stage. There were no fire extinguishers on stage. Sprinklers were not installed (or required) at the time. The total number of people may have exceeded maximum capacity. When the fire began, panic caused a stampede to the door. Though the exits had signs that were lit, people couldn't see them because of thick smoke. The club had recently passed inspection after correcting minor violations.

Safety recommendations included:
• installing sprinkler systems in all new and existing nightclubs.
• tightening restrictions on the use of flammable decorations and soundproofing materials and pyrotechnics.
• increasing evacuation rates by changing the maximum capacity of the main exit to accommodate at least two-thirds of the maximum-allowed occupants.
• eliminating the practice of letting older nightclubs out of meeting newer code requirements.
• requiring redundancy in fire protection systems.
• increasing the number of portable fire extinguishers in nightclubs.
• increasing fire inspection and code enforcement for new and existing nightclubs.
• conducting research to better understand how people behave during emergencies.

At Least 96 Killed in Nightclub Inferno
www.cnn.com/2003/US/Northeast/02/21/deadly.nightclub.fire
Describes the nightclub fire and outlines reasons for the high number of deaths.

NIST Rhode Island Nightclub Fire Investigation Team Calls for Improvements
www.nist.gov/public_affairs/releases/mar_3_05_ribriefing.htm
Reports on safety recommendations issued after the nightclub fire.

Date: **August 29, 2005**
Event: **Hurricane Katrina**
Location: **Gulf Coast**

Hurricane Katrina made landfall as a Category 4 storm. The 362-kilometer-per-hour winds produced a six-meter storm surge that topped or destroyed the levee and flood wall system protecting the city. Death tolls vary but current figures are about 1,800. Damage from the storm could be $75 billion or more.

Safety recommendations included:

- implementing and enforcing the International Building and Residential Codes wind and flood provisions that require homes and businesses built along the Gulf Coast to withstand winds of 210 to 240 kilometers per hour.
- installing metal strapping from a building's foundation to its rooftop to hold each roof in place.
- building most new multifamily dwellings, such as condominiums, over a parking garage.
- reinforcing corners of structures with double-nailed shingles and installing impact-resistant windows with a plastic interlayer to prevent shattering.
- adopting codes similar to Dade County, Florida (neither Mississippi nor Louisiana had uniform state building codes).
- considering redrawing the floodplain maps to increase the elevation for homes from 4 meters above the likely flood level to 5.5 to 7.5 meters.

Rebuilding a Culture of Safety on the Gulf Coast
www.iccsafe.org/news/bsj/0406_rebuilding.pdf
Reports on the types of damage caused by Katrina and includes information on the importance of strict building code requirements.

Residential Wind Damage in Hurricane Katrina
www.hurricane.lsu.edu/files/katrinafinal.pdf
Discusses how effective four building improvements—opening protection, straps/clips, upgraded roof deck, and secondary waterproofing—would have been had they been in place when Katrina hit. In this report, the four improvements are called "mitigating options."

LINKS AND BOOKS

Links
NOVA—Building on Ground Zero
www.pbs.org/nova/wtc
Learn why the towers were innovative and what led to their collapse, read one survivor's story, outfit a firefighter, explore the atomic structure of metal, and more.

Engineering Practice
www.onlineethics.org/eng/index.html
Contains cases, discussions, and ethical guidelines bearing on the professional responsibilities of engineers.

Cities and Buildings Database
content.lib.washington.edu/buildingsweb/index.html
Offers a searchable collection of images of buildings worldwide.

SkyscraperPage
www.skyscraperpage.com/diagrams
Provides diagrams of skyscrapers and a searchable diagram and statistics database of skyscrapers worldwide.

Books
The Art of Construction
by Mario Salvadori.
Chicago Review Press, 1990.
Explains how structures are built and describes how to build models using common materials.

**Spiderwebs to Skyscrapers:
The Science of Structures**
by David Darling.
Dillon Press, 1991.
Includes hands-on activities that explore foundations, materials, arches, and structures.

The Visual Dictionary of Buildings
by Fiona Courtenay-Thompson and Roger Tritton.
Dorling Kindersley, 1993.
Provides structural details of buildings from many locations in the world.

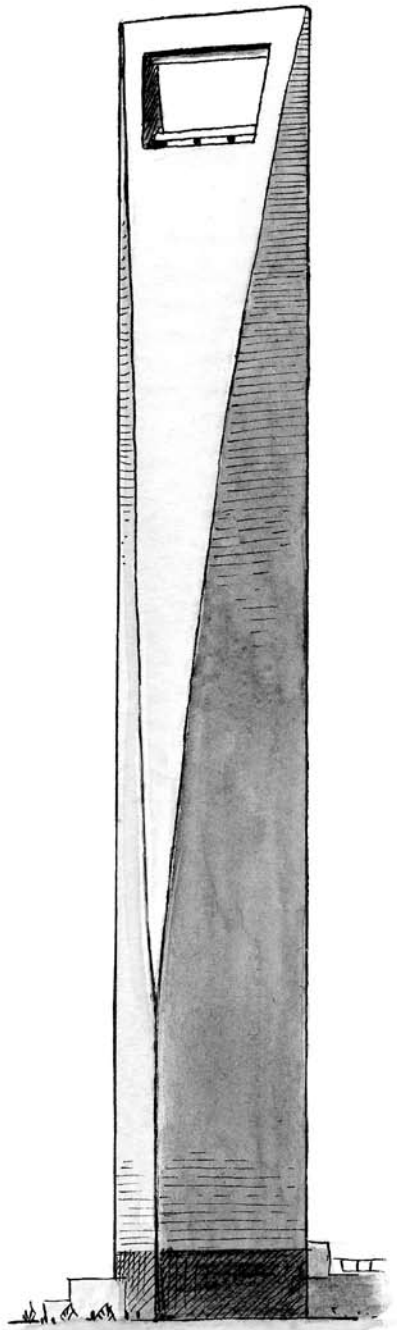**Why Buildings Fall Down: How Structures Fail**
by Matthys Levy and Mario Salvadori.
W.W. Norton & Company, 2002.
Uses case studies to illustrate why structures like buildings, bridges, and dams have sometimes failed.

Learning from Disasters

After a disaster, an investigative team is formed to determine what happened. In this activity, you will be researching disasters through the eyes of an investigator and arguing for the adoption of local, regional, or national safety features or building codes.

Procedure

1   Research the following historic disasters that resulted in recommended or adopted changes in safety features or building codes.
    • Cocoanut Grove Nightclub Fire
    • Beverly Hills Supper Club Fire
    • Hurricane Andrew
    • World Trade Center Attack
    • The Station Nightclub Fire
    • Hurricane Katrina

2   Write a short description of each disaster, highlighting key statistics of where and when it occurred, why it occurred, and how many people were injured or died. If possible, your research should also note:
    • the factors that contributed to any injuries or deaths.
    • a time line of disaster events.
    • what, if any, advance warning there was and how people reacted to the warnings.
    • any changes in safety features or building codes suggested following the disaster.
    • why these suggested changes might prevent this level of loss in a similar disaster.

3   For each disaster, brainstorm any other safety features or building codes you would recommend. Include your reasoning for any proposed changes.

4   When you have finished gathering information, select two safety feature or building code changes that you will recommend for adoption for a particular building or types of buildings. Fill out the "Proposed Changes" handout with your choices and why they should be adopted.

5   Your team will present its recommendations to the class, which will evaluate the proposed changes based on a set of criteria. You will be asked to do the same for your classmates. Then the class will vote to accept or reject your proposals.

Shanghai World Financial Center

NOVA

Proposed Changes

Choose two safety features or building code changes
to recommend for adoption in a building or buildings
of your choice. Your argument should include
evidence from your research. It is important in every
argument that you think about both sides. Think
of evidence that would support the safety feature
or building code you propose as well as evidence that
would oppose your proposal. Write your answers on
a separate sheet of paper.

What are your two proposed changes?

From which disaster(s) you researched did these
proposed changes result?

What kind of buildings do you think need the
proposed changes (i.e., apartment dwellings, high-rise
office buildings, hotel complexes)?

Should the changes be adopted locally, regionally,
or nationally?

What are the arguments for the adoption of your
proposed changes?

What are the arguments against the adoption of your
proposed changes?

NOVA
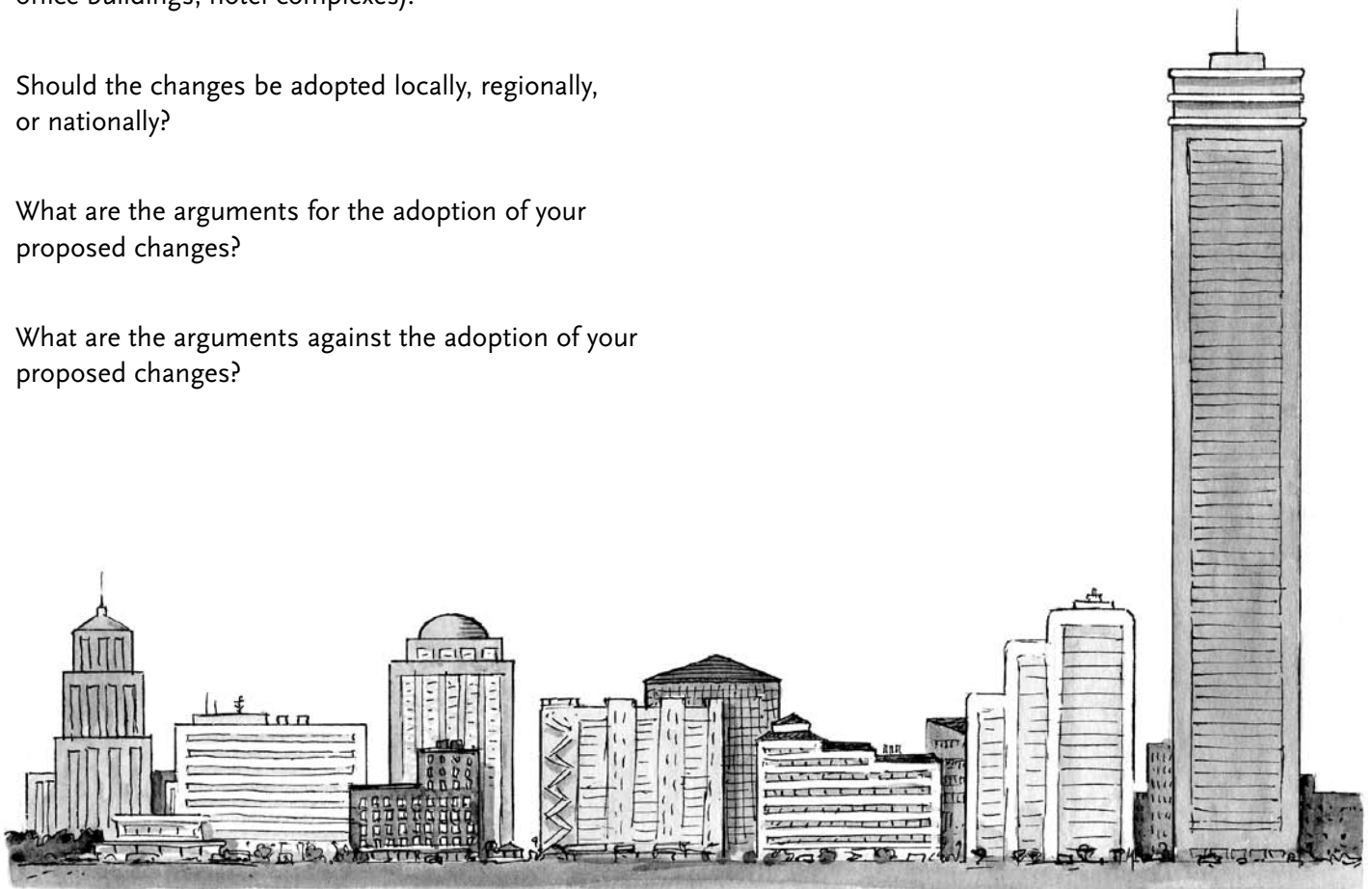
Evaluation Card

On a separate sheet of paper, list each team being evaluated and the changes being proposed. Then use the following criteria to rate each proposed change. After each team has presented, tally its score for each proposed change, and vote for whether you think each change should be adopted. A higher score represents a stronger case for adopting a proposed change.

Likelihood of Disaster

Disaster will likely occur frequently.			Disaster will likely occur only once or rarely.
4	3	2	1

Severity of Problem

Problem is widespread in buildings.			Problem is not widespread in buildings.
4	3	2	1

Life or Property Protection

Evidence is strong that lives or property would be saved if change is implemented.			Evidence is weak that lives or property would be saved if change is implemented.
4	3	2	1

Ease of Implementation

Does not require major material or structural changes.			Requires major material or structural changes.
4	3	2	1

Cost

Cost is low or moderate.			Cost is high.
4	3	2	1

Total score: _____