Economic Impact of Codes and Standards: A Workshop on Needs and Resources

FINAL PROCEEDINGS BY:

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Executive Summary

Decision making in the public policy arena is increasingly being based on economic indicators. Both the National Fire Protection Association (NFPA) and the International Code Council (ICC) have been approached by stakeholders wanting more information about the cost-benefit information for code changes or code adoption related to fire or electrical safety.

In today’s environment of extreme economic pressures on local jurisdictions, our enviable success in reducing fire losses has turned the focus more toward the costs of protection. Today’s fire departments and other fire and electrical safety advocates are focused on reducing the overall risk through a combination of protection, prevention, and other programs. They seek tools to evaluate the socio-economic benefit of these interventions to inform policy decisions with cost-benefit information on this aspect of safety.

On 4 October 2017, NFPA and ICC hosted “Economic Impact of Codes and Standards: A Workshop on Needs and Resources”, a one day workshop with the purpose to review case studies, data, and methodologies measuring economic impacts from various industries and sectors and assess how they can inform similar studies related to codes and standards. The goal was to develop a list of key methodologies, tools, and data sources to inform economic impact studies related to codes and standards as well as identify next steps related to needs related to this issue.

Based on the presentations and the discussions from the break out groups, the following summary observations are made and should be used to guide future work on this topic.

- **Code Adoption and Enforcement**
  - What is the true impact of a code adoption or code change on individuals? What is the recovery time from a disaster/event? The building industry needs more information on societal cost.
  - What are the top issues that are not enforced and what is the associated risk? More information on the link of code violations/noncompliance and role in an event is needed. This could include gathering this information from the fire data.
  - Need some sort of prioritization list for the issues to sort out short term and long term efforts – where do we get the most “bang for our buck”? Target problem areas (e.g. causes of fires, etc.). In the longer term, look at overall impact of codes on costs.
  - Need argument for code enforcement – litigation, safety, societal impacts, etc.

- **Economic Analysis**
  - Need a more standard/consistent methodology for cost-benefit analysis (CBA). It is done inconsistently now. Need to consider whole system evaluations.
    - Need to be able to extrapolate data between states. Need a method applicable nationwide.
- There is support for a consensus document related to CBA methodology and related data.
  - What is the true cost of using poor quality materials and/or construction methods?
  - Create a suite of different types of buildings to demonstrate the cost/benefit of changes and to eliminate the variable costs being used in different analyses. Develop CBAs around high priority issues.
    - Need case studies to highlight issues – what has been successful in the past?
  - Need more information on how to incorporate risk assessments.

- Data
  - Need for neutral data without bias. Data can be manipulated. A clearinghouse of data for construction data to be used in these types of economic analyses is needed.
  - There is a need for more data around benefits and the best way to quantify benefits.
    - What are the social benefits in terms of avoided costs of an event?

- General
  - More collaboration of building industry groups is needed.
  - More academic involvement would be valuable.
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The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.
About the National Fire Protection Association (NFPA)
Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. All NFPA codes and standards can be viewed online for free. NFPA’s membership totals more than 65,000 individuals around the world.

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1) Background and Overview

Decision making in the public policy arena is increasingly being based on economic indicators. Both the National Fire Protection Association (NFPA) and the International Code Council (ICC) have been approached by stakeholders wanting more information about the cost-benefit information for code changes or code adoption related to fire or electrical safety.

In today’s environment of extreme economic pressures on local jurisdictions, our enviable success in reducing fire losses has turned the focus more toward the costs of protection. Today’s fire departments and other fire and electrical safety advocates are focused on reducing the overall risk through a combination of protection, prevention, and other programs. They seek tools to evaluate the socio-economic benefit of these interventions to inform policy decisions with cost-benefit information on this aspect of safety.

On 4 October 2017, NFPA and ICC hosted “Economic Impact of Codes and Standards: A Workshop on Needs and Resources”, a one day workshop with the purpose to review case studies, data, and methodologies measuring economic impacts from various industries and sectors and assess how they can inform similar studies related to codes and standards. The goal was to develop a list of key methodologies, tools, and data sources to inform economic impact studies related to codes and standards as well as identify next steps related to needs related to this issue.

The agenda of the one-day workshop is below. Workshop attendance included federal government agencies, the fire and electrical safety enforcement community, economists, the building industry, insurers, and code and standard developers. A full attendance list is provided in Attachment A.

Agenda:
8:30am - Welcome, Workshop Purpose

Review of Economic Case Studies – 20 minute presentations with Panel discussion/Q&A

8:40am – Case Studies from Government Agencies

David Cohan, DOE – DOE’s Lifecycle Cost-Effectiveness Methodology

Lori Parris, DCRA – Economic Analysis Perspective from an Authority Having Jurisdiction

Alistair Mcfarlane and Michael Holler, HUD – Case Studies of HUD Cost Benefit Analyses and Challenges Faced

Edward Laatsch, FEMA – Economic Impact of Mitigation

10:00am – 15-minute Break
Chuck Smith, CPSC – Methodology used by CPSC for Benefits Estimation and Associated Data Needs

Marie Suding and Eli Harpst, GAO – How to Integrate Climate Information into Design Standards

Robert Stone, OSHA – OSHA’s Experience with Developing Cost-Benefit Analyses

11:15am - Panel Discussion/Q&A

11:45am – Lunch

12:45pm - Industry and Academic Studies

William Fay, Energy Efficient Codes Coalition – Economic Studies of Efficiency Investments

David Butry, Ph.D., NIST – Case Studies of Economic Analyses at NIST Related to Fire and Building Codes

Economic Effectiveness of Implementing a Statewide Building Code: The Case of Florida

Jeffrey Czajkowski, Ph.D., Wharton Risk Management and Decision Processes Center, University of Pennsylvania

Kevin M. Simmons, Ph.D., Austin College

Jun Zhuang, Ph.D., University at Buffalo - The Total Cost of Fire

2:05pm - Panel Discussion/Q&A

2:35pm – 10-minute Break

2:45pm – Breakouts (two discussion areas)

1. How can economic decision tools be applied to evaluate the impact of codes and standards?

2. What are the best practices for developing cost/benefit analyses in the code adoption process?

4:00pm - Breakout Reports

4:45pm - Conclusion, Next Steps
2) Presentations Overview

The following summarizes the presentations given during the workshop. Presentation slides are provided in Annex B.

The workshop started with a series of presentations on case studies of economic impact analyses from government agencies.

David Cohan from the Department of Energy (DOE) provided an overview of DOE’s Lifecycle Cost-Effectiveness Methodology. They seek to answer three questions when assessing cost effectiveness:

• How much energy is being saved?
• How much did it cost to save it?
• How long will the savings last?

He noted that there is a wide range in costs/time/energy savings, but people like having one number. The methods used by the DOE include life-cycle cost, mortgage cash flow, and simple payback. David then reviewed the pros and cons of each approach.

A key feature of the life-cycle cost approach is that it sums up costs and benefits over time. Specifically, the DOE compares all the costs and benefits accruing to the home/building owner over 30 years. The pros of this approach are: encompasses all benefits/costs over the life of a building, it is a standardized method, and it takes a long-term view. Some of the cons are that it requires a relatively complex analysis, it uses a lot of government sourced numbers (from census, etc.) and requires many assumptions about macro-economic variables over time. Another concern is that most people only stay in a house for 8 years and this type of analysis is based on 30 years.

The simple payback method calculates how long it takes for savings to pay back an initial investment. The pros of this method are that it is simple and intuitive and it is applied widely in the private-sector. The cons of this method are that it accounts for all costs up front but not all benefits, it assumes cash transactions rather than financing, and does not account for time value of money.

The mortgage cash flow method compares the monthly payments of the home/building owner with and without the energy efficiency investment. It seeks to answer the owner’s question if they are better or worse off on a monthly/yearly basis. The pro is that this method represents a practical, meaningful perspective. The cons are that it requires relatively complex calculations and it does not account for the down payment portion of the initial investment.

While all three methods are calculated and published by the DOE, in the end the life-cycle cost determines what DOE supports and does not support. This is because it is consistent with methods used at other federal agencies and private organizations, it is publicly reviewed, and it takes a long-term view appropriate for the federal government.
Lori Parris, Deputy Director of the Department of Consumer and Regulatory Affairs (DCRA), provided an economic analysis perspective from an Authority Having Jurisdiction (AHJ). The DCRA is the AHJ for the District of Columbia and issues permits, conducts plan reviews and inspections, and enforces zoning regulation. DCRA supplements its resources with a third party construction inspection and plan review program. This has an economic impact on how quickly a building can be built and occupied.

The Construction Codes Coordinating Board (CCCB) of the District of Colombia considers code change proposals and any changes to the model codes must be justified by a specific set of criteria and the anticipated impact of costs of construction must also be identified. An example of costs of building regulation was provided using CO detectors. It was determined that due to the health and life safety concerns of carbon monoxide poisoning that the added costs associated with installing CO detectors was justified. However, due to concerns of owners of existing buildings, a 3-year transition period was provided.

Alistair Mcfarlane from the U.S. Department of Housing and Urban Development (HUD), discussed HUD’s initiative to implement smoke-free public housing. The rule is that there not be lit tobacco products within 25 feet of the property. Generally, there are health benefits to tenants and benefits to housing authorities in reduced fire risk and maintenance costs. However, HUD found that there were a lot of uncertainties when quantifying the impact of this rule.

Alistair noted that a good study on reducing smoke exposure to an individual in a building does not exist. Most studies focus on family. Therefore, they ended up focusing on housing economics. This simplifies the analysis in that they only need to provide one measure for the net benefit to tenants. There is no need to know why someone will pay more, just how much they will pay. Through a survey, they found that people are on average willing to pay 5% more to live in a smoke free building.

Another challenge faced was to quantify the inconvenience cost to smokers, so again, they adopted a simple approach by calculating the opportunity cost of time to travel to the designated smoking areas. The HUD analysis also considered the impact of the rule on catastrophic fires and found that this smoke-free policy would reduce risk with an expectation of averting 170 fires, 3.4 civilian deaths, 12 injuries, and $3 million of property damages annually (total cost of $34 million annually when accounting for deaths and injuries).

Michael Holler from HUD provided an example related to manufactured housing standards. The Manufactured Housing Construction and Safety Standards Act of 1974 requires HUD to establish and enforce standards for the construction, design, performance, and installation of manufactured homes. The intent is to provide uniformity among manufacturers producing homes for multiple states. The rules are primarily based on the International Residential Code (IRC) and industry best practices.

Michael reviewed some of the more recent updates to the Act that had cost benefit impacts including: anti-scale shower and bath valves, updated roof truss testing procedures, revised requirements for ground anchor installations, requirement for CO detectors, and establishing a
He then spent some time discussing the challenges with this type of analysis. A major issue is the comparison of upfront costs to uncertain long-term benefits including payback period for energy saving requirements, reduced injuries/deaths, and damage from infrequent disasters (e.g. floods, hurricanes). He also noted that there are limited sources for cost data and medical costs, a lack of data on homes in different climate zones (i.e. have state data, but not by county, which is what is needed), and the annual production fluctuates. Another major issue highlighted is that the hours to produce a Rule Impact Analysis (RIA) can be greater than the compliance costs.

Edward Laatsch from the Federal Emergency Management Agency (FEMA) provided a presentation on the economic impact of mitigation. He discussed two specific studies. The first study presented was Mitigation Saves 2.0, which is an update to a 2005 study that found for every public dollar spent on mitigation, society saves $4. As with the first study, the updated study was undertaken by the National Institute of Building Sciences (NIBS). The current study was funded in part by FEMA, HUD, and private partners. At the time of the workshop, this study was underway, but an interim report was released in Fall of 2017 that found that every dollar spent on hazard mitigation can save the nation $6 in future disaster costs. The interim report is available here: https://www.nibs.org/page/mitigationsaves.

The updated study looked more broadly at the issue and considered both federal and private investment. The value of this study included identification of mitigation opportunities that provide the best value, creation of a common methodology for quantifying future losses, and the ability of the new administration to see the value in mitigation programs soon after taking office, which could impact funding decisions.

The second study highlighted was the Nationwide Hazus Building Code Loss Avoidance Study (LAS), which is currently in Phase 4 – National Study (previous studies were regional). This is an 18 month study that was just starting at the time of the workshop. This study focuses on comparing losses vs losses avoided vs average annual loss (AAL) for buildings constructed after I-Code adoption in areas of growth and exposure (i.e. flood, wind, and/or seismic events). Edward reviewed some of the modeling challenges associated with conducting a loss avoidance study. The benefits of this type of study is that it incentivizes priority code adoption and mitigation opportunities, identifies key loss drivers, quantifies the return on investment of building codes, and provides a national perspective that compares growth patterns, hazard exposures, and loss drivers.

Chuck Smith from the Consumer Product Safety Commission (CPSC) provided an overview of the methodology used by CPSC for benefits estimation. He noted that much of their analysis uses the “value of a statistical life” (VSL), which is based on studies of “willingness to pay”. The value used by CPSC is consistent with EPA and other federal agencies. He then provided an overview of the National Electronic Injury Surveillance System (NEISS) maintained by CPSC. This is a national probability sample of approximately 100 US hospital emergency departments (ED) that reports all product-related injuries treated. It is the main source of injuries related to consumer products. Information related to age and sex of victim, diagnosis and body part affected, disposition, and products involved are recorded, which enables CPSC to
make national estimates of consumer product injuries treated in hospitals by EDs by type of product.

Chuck described the injury cost model (ICM) that is used by CPSC and integrated with NEISS. The ICM estimates costs of injuries differentiated by age, sex, diagnosis, etc. The basic components of the costs are medical costs, work costs, and intangible costs (i.e. pain and suffering). Medical costs include the costs at the time of the injury as well as the cost of any follow-up care. Work costs include both short and long term effects as well as effects on family and friends and employer. Intangible costs value lost quality of life and is estimated from the difference between total compensatory damage awards, medical costs and lost wages.

He then described the process of estimating benefits of CPSC rules. First, they start with the estimated value of societal costs in the absence of a rule. Then, the impact of the rule on expected societal costs is assessed. The estimated hazard reduction is based on analyses by CPSC engineering, epidemiology, health sciences, and human factors personnel. The projected gross benefits are then the present value of baseline societal costs minus the present value of projected societal costs under the safety rule.

Chuck then provided two examples of CPSC rules where this type of analysis was completed: portable generators and table saw blades. Portable generators were noted as the cause of 659 CO deaths from 2004 to 2012 and more than 25,000 estimated medically-treated CO injuries. Based on the number of deaths and injuries, the expected societal costs of CO poisoning for all types of generators was determined to be $682/unit. The draft standard from CPSC was to address the CO emission rate based on engine type. The expected benefit based on the reduction of addressable societal costs of CO poisoning was $227/unit. Based on the number of units sold, the rule would reduce societal costs by $314.5 million. He then presented a similar case for table saw blades. He highlighted the need for collaboration between economists and epidemiologists for this type of study.

Marie Suding and Eli Harpst, from the Government Accountability Office (GAO), provided a presentation on how to integrate climate information into design standards. Limiting the federal government’s fiscal exposure by better managing climate change risks was added to GAO’s high risk list in 2013 (https://www.gao.gov/products/GAO-17-317). GAO’s work on climate change and federal fiscal exposure includes the following components: federal government as the leader of the strategic plan, federal property and resources, federal flood and crop insurance programs, disaster assistance and resilience, and technical assistance to federal, state, local, and private sector. High risk components are affected by building codes, design standards, and voluntary certifications. GAO calculated that the federal government paid $320 billion in damages due to extreme weather events.

GAO also completed analysis on climate information and risk management and found that reducing the risks associated with climate change requires reliable and appropriate information about past, present, and future climate. There is a need for information about observed climate conditions and climate impacts, projections from climate models on future climate, and technical assistance and translation of climate information based on sector and geographic area (e.g. the need for higher bridges or seawalls in certain areas). Based on the evaluation of three other
countries with this type of program, GAO’s recommendation is to develop and update a set of authoritative climate change observations and projections and create a climate information system (https://www.gao.gov/products/GAO-16-37).

In addition, GAO found that improved federal coordination could facilitate use of forward-looking climate information (http://www.gao.gov/products/GAO-17-3). Standard Development Organizations (SDOs) have not generally used forward-looking climate information in design standards, building codes, and voluntary certifications because there are institutional and technical challenges facing SDOs use of such information. Their recommendation is that the National Institute of Standards and Technology (NIST), in consultation with Mitigation Framework Leadership Group (MitFLG) and the US Global Change Resource Program (USGCRP), convene federal agencies for an ongoing government-wide effort to provide best available forward-looking climate information to SDOs.

Robert Stone from OSHA provided OSHA’s experience with developing cost-benefit analyses. OSHA started adopting consensus codes and standards in 1971 and many new OSHA regulations are to be older regulations up to date with newer consensus standards. Their focus is on worker safety and health and regulating employers. He provided a summary of OSHA’s methods for economic impact analysis. Some of the methods/tools employed by OSHA include:

- Incremental analysis – approach is the state of the world without standard vs state of the world with standard. It assumes full compliance with new regulation in order to calculate impact.
- Side-by-side analysis – this is a tool in setting up the incremental analysis. It involves identifying all the factors under consideration for modification, which is typically done by the rulemaking team (not the economists). It presents the current revision against the proposed revisions, since many regulations simplify or update existing regulations, and takes into account the timing of when the standard would take effect.
- Industry profile – who is covered by the standard and potentially impacted? Since many regulations have an exceptionally wide reach, the challenge here is identifying all of the industries that a regulation could cover.
- Baseline compliance – noted that this type of analysis can be complicated and needs to be done state by state (or even by locality) to measure compliance, so there is a need to make assumptions.
- Incremental costs – focus on industry and interested parties and can include safety features or some sort of efficiency component. The advantages of this method is that once you have unit costs, it is easier to combine costs (e.g. labor, equipment, etc.), and it aids in resolution of issues between parties rather than focusing on total costs. One example given here was the combustible dust standard. There is no easy way to get one size fits all estimate, so OSHA provides estimates and then gets feedback from industry to adopt analysis. This is all integrated into the process.
- Benefits estimation – uses data that is available, however, the data is often lacking sufficient descriptions. OSHA has their own database with narratives, but there is no standardized method of recording. They also use CSB data, which is very detailed.
Consideration of regulatory alternatives – this involves the need to consider all alternatives that could be at a potentially lower cost and achieve the same level of safety. He noted that this could be a sound approach to follow for SDOs.

There was then an opportunity for general discussion and questions involving all the speakers from the various government agencies.

The presentations continued with case studies from industry and academia.

William Fay from the Energy Efficient Codes Coalition (IECC) provided an overview of economic studies of efficiency investments. He noted that energy is the highest cost of home ownership outside of mortgage and after a loss of income, energy is the largest contributor for foreclosure. The position of the coalition is that codes are essential to reducing wasted energy from buildings.

IECC conducted a survey that found that Americans will pay up to 3% more for efficient homes. They also found that home buyers often believe that the home that they are buying is energy efficient and that very few buy directly from a home builder. He highlighted three studies aimed at demonstrating the pay-off for homes designed to the 2012 IECC. This included a Department of Energy (DOE) cost-effectiveness study using life-cycle analysis that compared the 2006, 2009, and 2012 IECCs by region and on a national level (by climate zone). This method balanced first costs against 30 year energy savings.

William also summarized a Building Codes Assistance Project (BCAP) study that used a mortgage cash flow method. The analysis found a payback period of 7-11 months for increasing the energy value of exterior walls. The third study presented was a cost-effectiveness study from the National Association of Home Builders (NAHB). They found that the 2012 IECC could add up to $8,000 to a home depending on climate zone and then calculated the pay-back. This study used eight representative cities in different climate zones. The pay-back period was found to range from 7 to 13 years. He also noted that the impact of the IECC is heavily dependent on how it is adopted.

He also highlighted a comparison of cost effectiveness methodologies completed by BCAP/ICF International. Life-cycle cost (LCC) is the predominant methodology for buildings and both LCC and Mortgage Cash Flow (MCF) account for longevity of building efficient improvements. However, it was noted that simple payback does not recognize useful life of improvements, the way people buy homes (i.e. with mortgage), changes in energy bills, and discount rates.

David Butry, Ph.D., from the National Institute of Standards and Technology (NIST), provided case studies of economic analysis at NIST related to fire and building codes. He feels that we do not need new methodologies or techniques to measure impact of building codes. These tools already exist. However, he pointed out that we do need advancement in data. On the benefit side, he noted that you can perform analysis with just the major benefits. Better data regarding costs is what is really needed. He also pointed out that
there is a set of ASTM standards around building economics meant for users in the construction industry. Then, he highlighted four different analysis methods used at NIST:

- **Life-cycle cost (LCC)** – measures, in present value, the sum of all relevant costs associated with the ownership and operation of a building over time.
- **Present value net savings (PVNS)** – measures net savings from investing in a given alternative rather than the foregone alternative.
- **Savings-to-investment ratio (SIR)** – ratio whose value indicates the economic performance of a given alternative instead of the foregone opportunity.
- **Adjusted internal rate of return (AIRR)** – average annual yield from a project over the study period accounting for reinvestment of interim receipts.

He then discussed three NIST case studies: comparison of egress options in tall buildings, economic evaluation of arson risk mitigation options, and timing of wildfire prevention education. The first study presented a life-cycle cost comparison of egress stairs and occupant evacuation elevators in tall buildings. This analysis was related to the change in the International Building Code (IBC), 2009 edition, relating to egress provisions for very tall and large area buildings. They developed five prototypical building designs and cost estimates for both exit stairs and occupant evacuation elevators (OEEs) related to installation and recurring costs (e.g. lost rental space and maintenance). Then, the life-cycle costs between egress alternatives was compared. He noted some of the limitations of the study: configuration/layout and related cost elements were representative and did not reflect all available options. They found that the additional exit stair required for very tall buildings is cost-effective on a first-cost basis, but that OEEs are cost-effective on a LCC basis when discount rates are low or rental rates are high.

David then presented an economic evaluation of arson risk mitigation options. The focus of this study was mitigation for the Devil’s Night arsons in Detroit between the years of 1985 and 1998. Starting in 1985, the city took the following steps to try to prevent arsons: fire fighter stations at strategically located command posts, potential arson targets eliminated (i.e. abandoned buildings), residents helped guard and patrol at-risk areas, media campaign on the dangers, and set-up structured activities for youths. The modeling by NIST focused on three of these mitigation strategies. They performed economic analysis using present value net benefits (PVNB), benefit-to-cost ratio (BCR), and adjusted internal rate of return (AIRR). Analysis also included Monte Carlo sensitivity analysis. Their findings suggest to jointly expand mitigation efforts to achieve maximum net benefits, which were maximized at $243.6 million.

The third study focused on the optimal timing of wildfire prevention education. Previous research completed estimated the economic returns to wildfire prevention education. The question explored in this study was whether the timing of the messages changed the outcome. Typically messages are in response to an active fire problem. What is the impact if this is done before a spike in fires? The analysis showed that if the messages were timed before a spike in fires, it saves $4 million.
Jeffrey Czajkowski, Ph.D., Wharton Risk Management and Decision Processes Center, University of Pennsylvania, and Kevin M. Simmons, Ph.D., Austin College, presented a study that they completed on Economic Effectiveness of Implementing a Statewide Building Code: The Case of Florida.

Thirty-six percent of states do not adhere to uniform statewide residential building code standards. The increased cost of construction is often the key argument against more stringent codes. Their goal was to demonstrate the effectiveness of a strong statewide code updated to the most current editions.

From ISO, they found an average of $517 million in losses were incurred in Florida over the study period of 2001 to 2010. Ten years after Hurricane Andrew, the Florida Building Code (FBC) was implemented statewide. This study focuses on the impact of the implementation of the FBC by estimating the loss differences between pre and post 2000 construction by controlling for other relevant exposure and vulnerability aspects. Given the loss reductions, they evaluated the economic effectiveness of the FBC assuming that the homes built prior to 2000 had instead been constructed under the FBC. Their results show losses reduced by as much at 72 percent. This is true across multiple regression models and consistent with their earlier findings.

While this is good for Florida, is this good public policy? They highlighted a study done in Moore, Oklahoma that compares favorably with an ARA 2002 study that found a 2.67 reduced cost for each dollar spent in FL statewide. This is also comparable to the FEMA mitigation which saves numbers of a 4 to 1 cost/benefit ratio.

The researchers also investigated the market response to enhanced codes that compared the markets in Moore, OK to neighboring town Norman, OK. In 2014, Moore adopted a similar code to FL after a series of violent tornados. The study performed found no change on the real estate market.

Jun Zhuang, Ph.D., University at Buffalo, presented a study he completed for the Fire Protection Research Foundation and NFPA on The Total Cost of Fire. This is an update of a 2014 study. This presentation included a review of the data sources used along with highlighting where additional data is necessary. A set of standard definitions is also proposed as part of this study.

The issues considered in this study include local fire department expenditure, value of time of volunteer fire fighters, donations to fire departments, passive fire protection expenditures, fire safety costs in building construction (which has increased due to construction activity increasing), net fire insurance, and the losses: human loss, direct property loss, and indirect loss.

Some of the highlighted areas for future work include:

- Value of donated time of volunteer fire fighters – needs standard
- Inclusion of wildland fires
- Fire safety cost of building construction – updated multipliers with input from industry
• Indirect losses – updates to multipliers, relation between direct and indirect
• Revision of definitions of certain components of total cost

This report is available on the Foundation website: www.nfpa.org/foundation.

Jun also highlighted another study that compares the total investment vs vulnerability to fire loss in terms of optimizing investment. He also highlighted several other related studies in the area including zip code level analysis, population studies, and comparison of resource allocation models to AFG grants.
3) Discussion on Needs – Summary from Breakout Sessions

After the presentations, all workshop participants were split into four groups. Two groups (Group 1 and 4) covered the first discussion area and two groups (Group 2 and 3) covered the second discussion area below.

1. How can economic decision tools be applied to evaluate the impact of codes and standards?
   a. What resources (i.e. tools and data) are already available to undertake this type of evaluation?
   b. What tools are still needed?
   c. What data sets are needed?
   d. What are the next steps that need to be taken to develop a “toolkit” for these types of economic evaluations? How can NFPA and ICC help?
   e. Can/should we develop a standard methodology?

2. What are the best practices for developing cost/benefit analyses in the code adoption process?
   a. What resources (i.e. tools and data) are already available to undertake these analyses?
   b. What tools are still needed?
   c. What data sets are needed?
   d. What are the next steps that need to be taken to develop a “toolkit” for these types of cost/benefit analyses? How can NFPA and ICC help?
   e. Can we develop a standard methodology?

Group 1 (discussed Question 1)

- **Resources**
  - ASTM has a series of standards that cover measuring life-cycle costs and benefits for buildings and building systems – this can be a starting point

- **Challenges**
  - Diverse opinions exist on this topic
    - Variability in factors can lead to variability in analysis
    - What is the true impact of a factor?
    - Politics – state to local
    - No neutral data
      - Everyone has some level of bias
      - Data can be manipulated
    - Gaps in the existing data (participation in state fire data by fire departments)
    - The actual data used can lead to wide variance in results

- What needs to occur in order to effectively use economic tools for impact of codes?
Need a common basis for economic assumptions
Need to establish common variables
What is the cost of doing nothing?
What is the cost of supporting services for updating codes – what is cost of getting code books/training?
Overall economic analysis of updating codes – high level analysis – impact on society or issue based?
Need more data to calculate state/local costs
Demonstrate downside of using old codes/standards – what is cost of doing nothing?

- Needed improvements to process
  - Clearer guidelines on how to submit CBAs
  - Clearinghouse for data – one stop shop for construction data
  - Public access to codes/standards

Group 2 (discussed Question 2)

- Challenges
  - At this time there are no consistent methods being used
  - Need transparency (process)
  - Clear issue identification
  - CBA – articulation of all costs and benefits
    - Evaluation of impact
    - Whole systems evaluation
      - People
      - Profit
  - How to measure socioeconomic impacts?
  - Who pays/who benefits?
  - Need to be clear on benefits of anything with an associated costs

- To develop CBAs
  - Define a clear scope
  - Bottom up analysis
  - Include societal impact – net impacts on AHJ
  - Analysis needs to be explicit on what is and not included

- Resources
  - Analysis of current studies/data
    - There are good examples out there
  - Identify methodology and level of data needed
  - Federal database of fire data
  - Constructconnect tool
  - Autocase as a tool – way of monetizing societal costs and benefits

- Tools/data still needed
  - Structural templates – level the playing field for building industry – create a suite of buildings that are unbiased to demonstrate the cost/benefit of changes
  - Labor rates
  - Material costs
  - Better quantification of benefits/costs
  - Post disaster data analysis (imagery)
• Next steps
  o Compile government economic analysis examples in a literature summary format
  o Create a consistent analysis method for code changes so that a tool could calculate the costs/benefits
  o Need to educate/campaign around the other benefits of code changes as well (beyond economic)

• Standardization
  o All parties need to agree on a standard methodology
  o Basis for trade-offs related to safety in the codes

Group 3 (discussed Question 2)

• Resources
  o Have good fire data – but need a comprehensive analysis of all of the data required for an economic analysis.
  o Variety of analysis tools – at some point, what tool to use will need to be settled.

• Challenges
  o Selling codes to policy makers – ultimately code development leads to this.
  o Prioritization - What are the areas where we get the most “bang for our buck”?
    ▪ Cost/effect
    ▪ What should priorities be?
    ▪ Not all code changes are equal
  o Easier for fire – have good data as a starting point
    ▪ Have much less data on building side (e.g. GFCI, etc.)

• Data needs
  o What is causing problems? Is there a problem?
  o Need standard numbers for certain costs - can have impact on analysis.
  o Issues with variability of data and how it impacts the analysis.
  o Can we extrapolate data between states?
  o How to estimate how many lives will be saved by a measure/change? This has a large impact on the analysis.
  o Need information on code violations within fire data.
  o Individual vs societal costs – importance depends on your view/perception.

• Next steps
  o List of priorities – what is causing the problems, what are the problems, are there problems?
  o Need information on the role of noncompliance (if any) in an event/fire.
  o Get USFA involved (for past fire data) – this can help with priorities related to fire.
  o More academic involvement would be beneficial.

Group 4 (discussed Question 1)

• Resources
  o Office of Management and Budget (OMB), Office of Information and Regulatory Affairs (OIRA), OMB Circular A4 on Regulatory Analysis
  o General willingness to pay for safety

• Tools
  o Independent analysis
- Risk analysis
  - Case studies – what has been successful in the past
  - Analysis of alternatives
- Data
  - Requirements for a good set of data – need a consensus document
- Next steps
  - Consensus standard methodology for CBAs
  - Doing more workshops
  - Engaging partners
  - Analyzing some specific provisions in the codes as case studies
  - Educating policy makers
    - Issue with rolling back the current (and not adopting latest)
4) Summary Observations

Based on the presentations and the discussions of the break out groups, the following summary observations are made and should be used to guide future work on this topic.

- **Code Adoption and Enforcement**
  - What is the true impact of a code adoption or code change on individuals? What is the recovery time from a disaster/event? The building industry needs more information on societal cost.
  - What are the top issues that are not enforced and what is the associated risk? More information on the link of code violations/noncompliance and role in an event is needed. This could include gathering this information from the fire data.
  - Need some sort of prioritization list for the issues to sort out short term and long term efforts – where do we get the most “bang for our buck”? Target problem areas (e.g. causing fires, etc.). In the longer term, look at overall impact of codes on costs.
  - Need argument for code enforcement – litigation, safety, societal impacts, etc.

- **Economic Analysis**
  - Need a more standard/consistent methodology for cost-benefit analysis (CBA). It is done inconsistently now. Need to consider whole system evaluations.
    - Need to be able to extrapolate data between states. Need a method applicable nationwide.
    - There is support for a consensus document related to CBA methodology and related data.
  - What is the true cost of using poor quality materials and/or construction methods?
  - Create a suite of different types of buildings to demonstrate the cost/benefit of changes and to eliminate the variable costs being used in different analyses. Develop CBAs around high priority issues.
    - Need case studies to highlight issues – what has been successful in the past?
  - Need more information on how to incorporate risk assessments.

- **Data**
  - Need for neutral data without bias. Data can be manipulated. A clearinghouse of data for construction data to be used in these types of economic analyses is needed.
  - There is a need for more data around benefits and the best way to quantify benefits.
    - What are the social benefits in terms of avoided costs of an event?
• General
  o More collaboration of building industry groups is needed.
  o More academic involvement would be valuable.
Annex A: Workshop Participants

The following were the workshop presenters on “Economic Impact of Codes and Standards: A Workshop on Needs and Resources”, held at Capitol Place III Conference Center, Washington DC on 4 October 2017.

David Cohan, DOE
Lori Parris, DCRA
Alistair Mcfarlane and Michael Holler, HUD
Edward Laatsch, FEMA
Chuck Smith, CPSC
Marie Suding and Eli Harpst, GAO
Robert Stone, OSHA
William Fay, Energy Efficient Codes Coalition
David Butry, Ph.D., NIST
Jeffrey Czajkowski, Ph.D., Wharton Risk Management and Decision Processes Center, University of Pennsylvania
Kevin M. Simmons, Ph.D., Austin College
Jun Zhuang, Ph.D., University at Buffalo
The following were the full list of workshop attendees on “Economic Impact of Codes and Standards: A Workshop on Needs and Resources”, held at Capitol Place III Conference Center, Washington DC on 4 October 2017.

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US DOE Building Energy Codes Program
Overview of DOE Cost-Effectiveness Methodology

David Cohan, DOE
October 4, 2017 for ICC-NFPA Workshop

“The Secretary shall periodically review the technical and economic basis of voluntary building energy codes.”
(42USC§6836(b))

Three (Impossible) Questions

- How much energy is being saved?
- How much did it cost to save it?
- How long will the savings last?

How much energy is being saved?

Savings = (Current energy use - New energy use) x Hours of Use

Lightbulb example:
Current bulb = 100 watts
New bulb = 20 watts
Hours of Use = 1000 hours/year

Calculation:
100 current watts – 20 new watts = \( \Delta \) 80 watts
80 watts x 1000 hours = 80,000 watt-hours = 80 kWh
80 kWh @ 10¢/kWh = $8.00/year
3000 hours? 5000 hours? 8760 hours?

Single Family & Multifamily Prototype Models
How much did it cost to save it?

How long will it last?

Cost-Effectiveness Methods Used by DOE

- **Life-Cycle Cost (LCC)**
  Compares all the costs and benefits accruing to the home/building owner over 30 years.

- **Mortgage Cash Flow**
  Compares the monthly payments of the home/building owner with and without the energy efficiency investment.

- **Simple Payback**
  Calculates how long it takes for savings to pay back an initial investment.
Life-Cycle Cost

“If I invest in this project will I ultimately be better or worse off?”

Time Value of Money

Interest rate → money today is worth more in the future.
$100 @ 4% interest = $104 in one year.

Discount rate → money in the future is worth less today.
$104 next year @ 4% discount rate = $100 today.

<table>
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<td>Freddie Mac</td>
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<td>Loan Term</td>
<td>30 years</td>
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<td>Down Payment Rate</td>
<td>20% of home price</td>
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<td>Points and Loan Fees</td>
<td>Freddie Mac Weekly Primary Mortgage Market Survey</td>
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<td>Discount Rate</td>
<td>5% (equal to Mortgage Interest Rate)</td>
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<td>Period of Analysis</td>
<td>30 years</td>
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<td>Property Tax Rate</td>
<td>American Housing Survey, US Census Bureau</td>
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<td>Income Tax Rate</td>
<td>IRS, state values vary</td>
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<td>Home Price Escalation Rate</td>
<td>Equal to Inflation Rate</td>
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<td>Inflation Rate</td>
<td>Consumer Price Index</td>
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<tr>
<td>Energy Prices and Escalation Rates</td>
<td>National average prices from Energy Information Administration; escalation rates From Annual Energy Outlook</td>
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Simple Payback

“When am I going to get my money back?”

Initial Investment + Annual Savings

$1000 investment
Saves $200/year
$1000/$200/year = 5 year payback

Pros
Encompasses the full costs and benefits over the life of the building, as required in the IECC.
Standardized method widely used across the federal government.
Takes long-term view appropriate for the federal government

Cons
Requires relatively complex analysis.
Requires many assumptions about macro-economic variables over time.

Simple Payback

Pros
Simple to calculate and intuitive.
Applied widely in private-sector investment decision-making.

Cons
Accounts for all costs but not all benefits.
Assumes cash transactions rather than typical mortgage/loan financing
Does not account for time value of money.
Cash Flow

“Will I be better off or worse off on a monthly/yearly basis?”

- Investment in efficiency increases the loan amount which increases monthly mortgage payments.
- More efficiency lowers monthly bills.

Cash Flow

$5000 efficiency upgrade

- Monthly payment on a 30-year $200,000 loan at 4% = $955
- Monthly payment on a 30-year $205,000 loan at 4% = $979
- Difference in payments = $24/month.
- Positive cash flow if bill reduction is more than $24/month. Negative cash flow if less.

Cash Flow

Pros
Represents practical, meaningful perspective of a typical homebuyer/building owner.

Cons
Relatively complex calculations required.
 Doesn’t account for the down payment portion of the initial investment.

Summary

DOE calculates and publishes all three methods but uses LCC when making decisions.

- Consistent with methods used at other federal agencies and private organizations.
- Publicly reviewed.
- Takes long-term view appropriate for the federal government.

David Cohan
U.S. Department of Energy
david.cohan@ee.doe.gov
Economic Impact of Codes and Standards: A Workshop on Needs and Resources

Presented by Lori S. Parris
Deputy Director

THE DISTRICT OF COLUMBIA SNAPSHOT
- A cosmopolitan city with 646,449 residents
- Population density is 9,856.5 persons per square mile
- 140 million square feet of commercial space
- 302,947 total occupied housing units

DCRA MISSION
The mission of the Department of Consumer and Regulatory Affairs (DCRA) is to protect the health, safety, economic interests, and quality of life of residents, businesses and visitors in the District of Columbia by ensuring code compliance and regulating business.

WHO WE ARE & WHAT WE DO
- Permit Issuance & Plan Review
- Construction and Property Maintenance Inspections
- Zoning Regulation & Enforcement
- Vacant Property & Abatement
- Business & Professional Licensing Administration

CURRENT CODE CONSTRUCTION CODES
- Effective March 2014, DC adopted the 2013 District of Columbia Construction Codes, consisting of 13 of the 2012 ICC Codes and the 2011 National Electrical Code as modified by local DC Amendments (Title 12, DC Municipal Regulations)
  - 2012 International Building Code (IBC)
  - 2012 International Residential Code (IRC)
  - 2012 International Existing Building Code (IEBC)
  - 2012 International Energy Conservation Code (IECC)
  - 2012 International Green Construction Code (IgCC)
  - 2012 International Swimming Pool and Spa Code (ISPSC)
  - 2012 International Plumbing Code (IPC)
  - 2012 International Property Maintenance Code (IPMC)
  - 2012 International Fire Code (IFC)
  - 2012 International Fuel Gas Code (IFGC)
  - 2012 International Mechanical Code (IMC)
  - 2011 National Electrical Code (NEC)
COMMON PERMITS ISSUED BY DCRA

- Building Permits
  - Homeowners’ Center Jobs
  - Walk-through - Non Complex Jobs
  - ProjectDox - Complex Jobs
- Postcard Permits
  - Non-complex, common home improvement jobs, that are permitted online
- Supplemental Permits
  - Required for the installation of supplemental systems (plumbing, mechanical, and electrical) and related devices
- Certificates of Occupancy & Home Occupation Permits

DCRA and Third Party CONSTRUCTION INSPECTIONS

- Types of Inspections
  - Building
  - Electrical
  - Plumbing
  - Mechanical
  - Fire Protection
- Stages of Inspections
  - Site Development
  - Footings/Foundation/Slab
  - Framing/Rough-in
  - Insulation
  - Final

ADOPTION OF DISTRICT OF COLUMBIA CONSTRUCTION CODES

- In the District of Columbia, the Mayor is authorized to issue proposed rules to amend the Construction Codes and to adopt new editions of and supplements to the International Codes.
- The Mayor's authority has been delegated to the Construction Codes Coordinating Board (“CCCB”) pursuant to Mayor’s Order 2009-22, dated February 25, 2009, as amended.

CONSTRUCTION CODES COORDINATING BOARD

- The CCCB is a 13-person Board with members appointed by the Mayor of the District of Columbia for terms of three years.
- The CCCB is composed of the following persons:
  - CCCB Chair (ex officio member)
  - Office of the Construction Code Official (3 members)
  - Office of the Fire Marshall (1 member)
  - District Department of the Environment (1 member)
  - Mayor’s Delegate (1 member)
  - Council of the District of Columbia (1 member)
  - Building Industry-Commercial & Industrial (1 member)
  - Building Industry-Residential & Multi-Family (1 member)
  - Architectural Design Profession (1 member)
  - Mechanical Engineering Profession (1 member)
  - Structural Engineering Profession (1 member)
  - Private Citizen (1 member)
- The CCCB elected a new code development cycle in October 2015 to consider adoption of the 2015 I.C. Codes and the 2014 NEC.
CONSIDERATION OF CODE CHANGE PROPOSALS

- The CCCB considers code change proposals that are proposed by the TAGs, members of the public or by the CCCB Chair.
- Changes to the model codes must be justified by one or more of the following criteria:
  - To address a critical life/safety, health, general welfare need
  - To address a specific District of Columbia policy or statute
  - For consistency with federal law, or with reference to codes in neighboring jurisdictions (Maryland and Virginia)
  - To address a unique characteristic of the District of Columbia
  - To correct an error or omission
- The anticipated impact on costs of construction must also be identified.

ECONOMIC COSTS OF BUILDING REGULATION

- Economic costs of new building regulations are considered during the code development process.
- Code change proposals have to identify the anticipated impact of a code change proposal on cost of construction.
- CCCB and TAG membership includes stakeholders, such as developers, builders, and design professionals, who can provide input on potential costs that may be increased by a proposed code change.
- The requirement of public comment, and City Council review and approval of Construction Code revisions also allows for objections on the basis of cost impacts to be raised and considered.
- Code officials can allow for use of alternative methods of construction, materials, and equipment in specific projects pursuant to Section 104.11 of the District of Columbia Building Code.

EXAMPLE OF COSTS OF BUILDING REGULATION - CO DETECTORS

- In 2013 Construction Codes, DC adopted requirements for carbon monoxide detectors (CO detectors) in new and existing residential buildings.
- Added cost of CO detectors was considered and determined to be justified due to health and life safety concerns of carbon monoxide poisoning.

Economic Impact Considerations

- Concerns were expressed by owners of existing multi-family buildings about the costs of coming into compliance with the new CO rules and with the new smoke detector requirements (which required a smoke detector in each bedroom or sleeping area).
- Due to industry concerns, a 3-year transition period until March 2017 was provided for existing buildings to come into compliance with the new rules.

QUESTIONS?

Follow Us on Social Media
Instituting Smoke-Free Public Housing
Discussion of the Challenges of Performing an Economic Analysis
Alastair McFarlane, HUD
10/3/2017

Challenge: Tenant Benefits
- Multiplicity of benefits: adverse health events and conditions from SHS as measured by length of life, quality of health, or medical costs, as well as odor, reduced risk of fire. Others have counted productivity benefits – time lost at work for smoking
- For proposed rule, we used medical costs as a minimum and VSLY as a maximum. Focused on those illnesses that would be immediately affected by rule. Epidemiology
- Uncertainties: effect of rule on total exposure to smoke (inside and outside of residence), and change of exposure on health effects (RR data are for living with smoker or not), duration vs intensity, demographic distribution of smokers, filtration of smoke throughout the building, decided on half of overall impact.
- Benefits of Cessation – Whether to include cessation benefits? Initially decided not to because of variation of values, uncertainty of impact of cessation, and hesitance to address rationality of smokers

Solution: Tenant Benefits
- Housing Economics to the Rescue! Estimate willingness to pay for smoke-free housing instead of accounting for individual sources of benefits.
- Simplifies analysis by providing one measure for the entirety of tenants net benefits. Do not need to know why someone will pay more only how much
- Survey: 43 percent willing to pay more for smoke-free housing, on average 5 percent more (confirmed by empirical studies)
- Range of $165 to $472 per household OR $121 M - $346 M in aggregate (similar to other estimates)
- Smokers – the fraction that supports smoke-free are treated the same as nonsmokers, majority smokers (59%) are against so we attribute only the inconvenience costs

Challenge: Inconvenience Cost to Smokers
- Smokers bear the greatest burden of rule b/c have to alter behavior
- First: Difference between smoking and the least costly compliance method (ENDS) is theoretically appealing but met significant resistance from comments
- Second: Apply studies on behavioral response to smoking restrictions, but difficult to accurate and significant estimates for such an important study
- Third: Opportunity cost of time is a straightforward measure but may miss many of the compliance costs (discomfort, etc). Also how to value time of unemployed?
- Fourth, Cessation: lost pleasure vs irrationality of smokers

Solution: Inconvenience Cost to Smokers
- Adopt simplest approach: opportunity cost of time to travel to designated areas
- Some portion of that lost time is dedicated to the smoking of the cigarette (our way of handling lost pleasure)
- Value of time is taken from academic literature on commuting and travel to leisure destinations dependent on employment status
- Assumed inconvenience costs for the proportion of smokers "against"
- Aggregate Inconvenience cost is $101 million

Description of Rule and RIA - December 2016
- No lit tobacco products within 25 feet of property (ENDS optional)
- Smoke-free regulation already implemented by 570 of 3,100 PHAs
- Justification: reduces smoking-related damages to government-owned housing and protects nonsmokers from second hand smoke
- Benefits: health outcomes, less catastrophic fires, and lower maintenance costs
- Costs: administrative, infrastructure, and enforcement costs by PHAs and compliance burden on smokers
- Difficulty of Analysis: many impacts to analyze, methodologies (sometimes conflicting), and strong opinions concerning the result
Risk of Catastrophic Fires from Smoking

- 6% of all fires but leading cause of fire deaths in multi-unit properties (31%). Both injuries (11%) and property damage (15%) are disproportionately high.
- Evidence that fire and hazard premiums greater for every smoker in building and that smoke-free can result in 10 percent reduction.
- Smoke-free policies would reduce risk.
- Expected to avert 170 fires, 3.4 civilian deaths, 12 injuries, and $3 million of property damages annually (total $34 million).
- Assume that value of lower risk of deaths and injuries counted in the rent premium but attribute benefit of reducing property damages to PHAs.
Economic Analysis of Codes and Standards: Challenges Performing Economic Analysis of Manufacturing Housing Standards

October 4, 2017
Michael Hollar
Senior Economist
U.S. Department of Housing and Urban Development

Manufactured Housing Standards

- Construction and Safety Standards.
  - FR-5221: Required shower and bath valves use anti-scald mixing valves and increased minimum insulation levels for cross-under ducts.
  - FR-5222: Updated roof truss testing procedures.
  - FR-5631: Revised requirements for ground anchor installations and established standardized test methods.
  - FR-5739: Require CO detectors, exterior piping for water heater relief valves, extension to venting systems, and separate switches for ceiling/wall lights. Establish code for multi-story and attached homes to promote innovation.

Basic Wind Zone Map for Manufactured Housing

NOTE: See Section 3588.360(c)(2) for areas included in each Wind Zone.

Basic Roof Load Zone Map
### Manufactured Housing Standards

**Advantages:**

1. Limited number of manufacturers and designs.
2. In some cases, states have already implemented.
Economic Impact of Mitigation

Ed Laatsch
Director – Safety, Planning & Building Science Division

John Ingargiola
Lead Physical Scientist / PTS/AE Building Science Program Area Manager

Outline

“Mitigation Saves 2.0”
• An Independent Study on Savings Associated with Public and Private Mitigation

Nationwide Hazus Building Code Loss Avoidance Study
• Phase 4: National Study

Benefit-Cost Analysis
• Robert T. Stafford Disaster Relief and Emergency Act

“Mitigation Saves 2.0”
An Independent Study on Savings Associated with Public and Private Mitigation

Regarding the original Mitigation Saves study:
• In 2005, a study by the National Institute of Building Sciences (NIBS) titled "Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities" ("MSv1") quantified the future savings from FEMA’s natural hazard mitigation grant efforts.
• The study looked at hazard mitigation activities funded through FEMA’s Hazard Mitigation Grant Program, Project Impact program, and the Flood Mitigation Assistance Program.
• The original study demonstrated that on average, for every public dollar spent on mitigation, society saves $4.

Module 1: Overall Framework and Integration requirements

• Objective: to provide a framework for integrating mitigation strategy modules into an overall statement of the benefits of mitigation efforts
• Module 1 includes the following tasks:
  • Initial Meeting
  • Identify & document common procedures that apply across multiple modules
  • Perform the cost-benefit analysis using input form other modules
  • Develop the Report and disseminate to project sponsors and archival journals

Module 2A: Enhanced flood, wind, seismic and wildfire-urban interface design requirements

• Objective: quantify the benefits & costs of above code design (in new construction)
• Stakeholders may include lenders, insurers, Small Business Administration, local, state and federal government (FEMA is investing in Module 2A)
• This module involves calculating risk under current code requirements and under assumed enhancements to those code requirements. NIBS will then estimate the potential aggregate benefits and costs from widespread adoption of above-code design requirements.
Module 6A: Cost-Benefit Analysis of Public-Sector Mitigation Grants and Loans

• Objective: benefits & costs of public sector mitigation grants & loans
• Stakeholders: Agencies with particular interest would include those whose programs are being addressed including DHS, FEMA, HUD, SBA, DOT, USACE, Commerce and Interior.
  - Image: Lower Manhattan Project and Connect Project (US Department of Housing and Urban Development 2016)

Current Status of the Mitigation Saves 2.0 Study

• FEMA-funded portion of Study began in October of 2016 (Modules 1, 2A and 6A)
• Analyses are complete and results and conclusions have been gathered and formulated
• Report has gone through a 70% draft review by Stakeholders and Oversight Committee
• 95% draft review comments are currently being incorporated into report
• FEMA-funded portion of report to be delivered Fall of 2017
• Active outreach and fundraising efforts are currently taking place to complete the remaining study modules

Value of the Study

• Identifying mitigation opportunities that provide the best value
• Creation of a common methodology for quantifying future losses in both the public and private sectors.
• New administration will be able to see the value in mitigation programs very soon after taking office, which could effect funding decisions

Nationwide Hazus Building Code Loss Avoidance Study

Phase 4: National Study

Nationwide Hazus LAS in progress
• 6 step process, 18 month schedule
  - Challenges by hazard (flood, wind, seismic)
  - Data gaps
  - Damage function modifications
• Meta data management
Results Analytics
• Losses vs losses avoided vs AAL
• Data enhancements - dynamic economics, recovery analytics
• C/B/A, scenarios, sensitivity analysis, code adoption priorities
• Other decision tools

Hazus Building Code LAS to date

• Background: Purpose of Hazus Losses Avoided Study (LAS): Quantify economic impact of modern building code adoption in losses avoided.
• Concept: Model losses avoided at the parcel level where modern hazard-resistant building codes are adopted in areas of high wind, flood, seismic hazard
• Phase 1 Pilot Study 2011: Charleston County, SC, and Salt Lake County, UT
• Phase 2 Regional Study 2012: FEMA Region IV, used as demonstration study area
• Phase 3 National Methodology 2013: Develop National methodology including lessons learned from Phase 1 & 2
• Phase 4 National Study 2017: Underway

Phase 2 Regional Study Results

Results Summary

<table>
<thead>
<tr>
<th>Building</th>
<th>Contents</th>
<th>Building + Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-I-Code</td>
<td>Pre-I-Code</td>
<td>Pre-I-Code</td>
</tr>
<tr>
<td>Florida</td>
<td>$888,463</td>
<td>404,796</td>
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<tr>
<td>Losses Avoided ($M)</td>
<td>483,667</td>
<td>230,188</td>
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<tr>
<td>Losses Avoided (%)</td>
<td>-54%</td>
<td>-78%</td>
</tr>
</tbody>
</table>

Note: For Simplicity, Modeling assumes all post-2000 Florida construction was built to current codes
Calibration example: Hurricane Charley Phase 2 study
Proposed Methodology
• Step 1. Perform data collection and screening (CoreLogic & ISO)
• Step 2. Input data into Hazus (v4.1)
• Step 3. Adapt damage curves (flood, wind, seismic)
• Step 4. Compute and analyze losses avoided
• Step 5. Evaluate findings
• Step 6. Perform QA

Schedule ~6mos per step pairs.

E/W Teams sweep to Miss River

Study Focus
• Areas of growth and exposure
• Buildings constructed after I-Code adoption

Post 2000 growth
Ref: CoreLogic data

LAS Modeling Challenges
• Flood
  • Determining FFE & freeboard
  • Confirming regulatory vs non-reg maps & BFE for construction
  • Confirming regulatory boundaries (in vs out)
  • Calibrating new coastal and riverine DF's in Hazus
• Wind
  • Determining wind building characteristics (WBCs).
  • Determining wind map adoption history (prob vs determ; WBDR)
  • Damage function mods to code & wind map versions (transitional)
• Seismic:
  (6 western states, use Hazus AEBM)
  • Determining code adoption history & design level maps
  • Assign/create model building type (interviews)
  • Damage function mods (design category A-E & post 2008 new fragilities- fundamental research). Automate AAL(8 return periods)

Benefits
What are the benefits of performing a nationwide parcel level study?
• Incentivizes priority code adoption and mitigation opportunities
• Identifies key loss drivers of community hazard profiles and buildings
• Quantifies substantial return on investment of building codes
• Encourages innovation on code enhancements and parcel data
• Provides clear national perspective comparing growth patterns, hazard exposures and loss drivers

Measuring economic impacts
• Results Analytics: Quantification of risk and impacts
  • Losses vs losses avoided vs AAL
  • C/B A
  • Decision tools – code adoption, scenarios, critical facilities
  • Data enhancements, benchmarking (exist Hazus use)
• Hindcasting: DRR, enforcement effects
• Forecasting / resilience and capital planning
• Investment / Private sector partnerships
• Monitoring & Evaluation- periodic updates

Benefit-Cost Analysis
Robert T. Stafford Disaster Relief and Emergency Act

The Stafford Act authorizes the President to establish a program to provide technical and financial assistance to state and local governments to assist in the implementation of hazard mitigation measures that are cost effective and designed to substantially reduce injuries, loss of life, hardship, or the risk of future damage and destruction of property.

• The BCA program consists of guidelines, methodologies and software modules for a range of major natural hazards including:
  • Flood (Riverine, Coastal Zone A, Coastal Zone V)
  • (551, Job Aid No. 1.3: Elevation)
  • Hurricane Wind (P-804)
  • Hurricane Safe Room (P-320, P-361)
  • Damage-Frequency Assessment
  • Tornado Safe Room (P-320, P-361)
  • Earthquake
  • Wildfire
  • Drought
Valuing the Societal Costs of Deaths

- “Value of a Statistical Life” (VSL)
- Based on studies of “willingness to pay”
- Consistent with EPA & other federal agencies

Injury Cost Model (ICM)

- Computer model fully integrated with NEISS; estimates costs of ED injuries.
- Primary costs include medical costs, work loss, and the intangible costs of injury (i.e., pain & suffering).
- Cost estimates differentiated by age and sex of victim, diagnosis, disposition and body part affected.
- Also estimates the number & costs of medically attended injuries treated outside of hospital EDs (e.g., physicians’ offices, clinics, ambulatory surgery centers)

Basic Components of the ICM

- Medical Costs
- Work Loss
- Intangibles

Valuing the Societal Costs of Injuries:
National Electronic Injury Surveillance System (NEISS)

- National probability sample of ~100 US hospital emergency departments (ED)
- Reports all product-related injuries treated
- Provides information on age and sex of victim, diagnosis and body part affected, disposition, and products involved
- Enables CPSC to make national estimates of consumer product injuries treated in hospital EDs, by type of product

CPSC Jurisdiction
ICM: Medical Costs
- Professional fees
- Hospital costs
- Transportation
- Diagnostic procedures
- Prescriptions
- Equipment
- Follow-up care
- Administrative costs

ICM: Work Loss
- Short-term (acute phase)
- Long-term (permanent full-or-partial disability)
- Costs to family & friends
- Effects on employer

ICM: Intangibles (Pain & Suffering)
- Values lost quality of life rather than monetary aspects of injury
- Estimated from the difference between total compensatory damage awards and medical costs and lost wages
- Uses regression equation to control for influence of damage caps, type of defendant, and the injury type

ICM: Data Sources
- Federal, state, private
- National survey data: MEPS, NNHS, PPS
- BLS Annual Survey
- Hospital discharge data: HCUP-NIS
- Workers’ compensation: DCI
- Jury verdicts
- Published studies

Estimating Benefits of CPSC Rules
Starting Point: Estimated value of societal costs in the absence of a rule.
- Estimate annual societal costs per unit in use
  - With consideration of different risks/expected costs depending on product characteristics
- Project unit sales (by relevant characteristics)
- Consider expected societal costs over the useful lives of products; discounted to present value.
Case 1: Portable Generators, Notice of a Proposed Rule (NPR)

- 659 CO deaths, 2004 - 2012 (average 73 deaths/year)
- More than 25,000 estimated medically-treated CO Injuries (about 3,000 injuries per year)
- 25% of fatal incidents involved multiple fatalities... accounted for 44% of all the deaths.

<table>
<thead>
<tr>
<th>Class I Engines</th>
<th>Class II Engines</th>
<th>Class III Engines</th>
<th>All Units</th>
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<tbody>
<tr>
<td>Estimated Deaths / Year (Percent)</td>
<td>8.5 %</td>
<td>25.6 %</td>
<td>46.2 %</td>
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<tr>
<td>Estimated Nonfatal Injuries / Year</td>
<td>21</td>
<td>96</td>
<td>1,176</td>
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<tr>
<td>Aggregate Annual Societal Costs of Deaths and Injuries (million $)</td>
<td>8.0</td>
<td>$287.6</td>
<td>$517.8</td>
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<table>
<thead>
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<th>Engine Class</th>
<th>Estimated Deaths / Year</th>
<th>Estimated Nonfatal Injuries / Year</th>
<th>Aggregate Annual Societal Costs of Deaths and Injuries (million $)</th>
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</thead>
<tbody>
<tr>
<td>1-Cylinder</td>
<td>0.5</td>
<td>21</td>
<td>$6.0</td>
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<tr>
<td>2-Cylinder</td>
<td>25.6</td>
<td>96</td>
<td>$287.6</td>
</tr>
<tr>
<td>All Units</td>
<td>46.2</td>
<td>1,176</td>
<td>$517.8</td>
</tr>
</tbody>
</table>

Expected Societal Costs of CO Poisoning, by Generator Engine Class

Expected Benefits Under the Draft Standard, by Generator Engine Class & Characteristics

Active Injury Mitigation (AIM)

Active injury mitigation (AIM) system technology is supplement to existing safety features, blade guard and riving knife; mitigate injury from blade contact.

AIM consists of:
1) Detection of contact between saw blade and human finger/body. Detection could be based on:
   - Electrical
   - Thermal
   - Optical
   - Etc.
2) Reaction to mitigate injury.
Preliminary Regulatory Analysis

Expected Benefits

• The draft proposed rule would reduce blade-contact injuries by an estimated 70% to 90% annually.

• The expected gross benefits range from about $2,300 to $4,300 per table saw over its expected product life, or an aggregate of about $970 million to $2,450 million over the product life of 1 year of sales.

Thank you
The Economic Impact of the IECC

The Only I-Code That Pays For Itself in Cash . . . And Then Some.

WHEN IT COMES TO NATIONAL ENERGY POLICY, BUILDINGS ARE THE “ELEPHANT IN THE ROOM”

America’s Homes & Commercial Buildings

- 42% of all energy
- 71% of natural gas
- 71% of electricity

. . . And account for 39% of US manmade GHGs

WHY SIX NATIONAL LOW-INCOME HOUSING GROUPS ARE EECC SUPPORTERS

AFTER MORTGAGE, PRINCIPAL & INTEREST, ENERGY IS THE HIGHEST COST OF HOME OWNERSHIP

Average U.S. Homeowner Costs 2007-2008

AFTER LOSS OF INCOME, ENERGY IS ALSO THE LEADING REASON FOR FORECLOSURE

Buildings Energy Codes Are the Most Effective Way to Boost Efficiency

( . . . and reduce CO2)

CODES ARE ESSENTIAL TO REDUCING WASTED ENERGY FROM BUILDINGS
So Who Cares?

OUR BROAD - & UNLIKELY - SUPPORT BASE

- Government
- National Association of State Energy Officials
- ICLEI

Broad-Based Energy Efficiency Groups
- The Alliance to Save Energy
- American Council for an Energy Efficient Economy (ACEEE)
- United Nations Foundation

Regional Energy Alliances
- Midwest Energy Efficiency Alliance (MEEA)
- Northeast Energy Efficiency Partnerships (NEEP)
- Northwest Energy Codes Group
- NW Energy Coalition
- South-central Partnership for Energy Efficiency as a Resource (SPEER)
- Southeast Energy Efficiency Alliance (SEEA)
- Southwest Energy Efficiency Project (SWEEP)

Academia/Think Tanks
- American College and University Presidents Climate Commitment
- Institute for Market Transformation
- New Buildings Institute
- Affordable Housing Advocates
- Enterprise Community Partners
- Global Green USA
- LISC – Local Initiatives Support Corp.
- National Housing Institute
- National Low Income Housing Coalition

Energy Consumers
- Consumers Federation of America
- Public Citizen

Business/Insurance
- American Chemistry Council
- Bayer
- Business Council for Sustainable Energy
- Cardinal Glass
- Current Energy
- Extruded Polystyrene Foam Association (XPSA)
- Fireman’s Fund
- Green Chamber of Commerce
- North American Insulation Manufacturers Assn (NAIMA)
- Northwest Environmental Business Council
- Polyisocyanurate Insulation Manufacturers Assn (PIMA)
- Structural Insulated Panel Association (SIPA)
- Vinyl Siding Institute (VSI)

Environmental Groups
- Center for Environment, Commerce & Energy
- Climate Crisis Coalition
- Environment America
- National Wildlife Federation
- Natural Resources Defense Council (NRDC)
- Sierra Club
- 2020 Vision

Labor
- Blue Green Alliance

Utilities
- American Public Power Association
- Edison Electric Institute
- National Rural Electric Cooperative Association

2008: Mayors Join Campaign for Dynamic IECC Efficiency Gains

- Endorse "30% Solution" & "Builder Flex"
- Oppose Rollbacks and Trade-Offs that Weaken the Stringency of gains
- Encourage Municipal Support for All Eligible Code Officials to attend code hearings and
- Vote in favor of continued efficiency gains for America's model energy code, the IECC.

Americans WANT – & Will Pay More For – Efficient homes

Nine out of ten buyers would rather buy an energy-efficient home... and they are willing to pay up to 3% more!
(Source: National Association of Home Builders)

But, Paraphrasing Hamlet
“Here’s the Rub”

NW Survey: “Home buyers believe the home they’re buying is energy efficient... And we can presume they also believe it’s safe.

Very few home buyers purchase a home from a homebuilder. By the time we buy, the home is already safe or unsafe, efficient or inefficient, and there’s nothing we can do about it.
So How Do We Know When We’re Choosing an Energy Efficient New Home?

No evident difference to a new homebuyer, but...

These Homes Look – And Are – Identical . . . Except for the Code They Meet!

No evident difference to a new homebuyer, but...

2006 IECC
2012/2015 IECC

This House Cost $1,250 More...
...Far Less Than 2-3%!

Which Home Would You Choose?
Better Codes = Better Homes

38% more efficient

$10,081

in energy savings over a typical 30-year mortgage after fully recouping $1,250 added cost.

Savings will continue to accrue over the home’s 80- to 100-year life.

HOW MUCH DO OWNERS OF 2012 or 2015 IECC HOMES POCKET IN NET ENERGY SAVINGS?

TWO ANALYSES OF HOW QUICKLY LOWER ENERGY BILLS MATCH UP TO THE INCREMENTAL OUTLAY FOR EFFICIENCY IMPROVEMENTS.

1. The US Department of Energy

DOE COST-EFFECTIVENESS STUDY

• Study covering the 2009 and 2012 IECC for new single- and multi-family homes against 2006 IECC baseline taking specific code amendments into consideration.
• National Cost Analysis: An overview of cost-effectiveness by climate zone
• State-level analyses for 43 states and DC.
**DOE Cost-Effectiveness Study**

- Uses a life-cycle approach, balancing first costs against longer-term energy savings over the life of the home.
- Energy analysis is conducted using the DOE EnergyPlus™ software.

**How Much Do Owners of 2012 IECC Homes Pocket in Net Energy Savings?**

**2. BCAP/ICF International Analyses**

**Mortgage Payback: Assumptions**

- Methodology: Mortgage Cash Flow
- Mortgage Term: 30 years
- Down Payment: 20%
- Interest Rate: 4.03% (based on current national average)
- With a lower down payment—such as 10% down or less—consumers will break even on their investment even sooner.

**Mortgage Payback: Results**

- Additional down payment: $292 to $459
- Additional monthly mortgage cost: $5.55 to $8.72.
- Break-even point: 7 months to 11 months
- Annual profit after breakeven: $516 to $544

**ICF-BCAP Confirm Savings Everywhere**

<table>
<thead>
<tr>
<th>Where</th>
<th>Net Savings</th>
<th>Added Cost</th>
<th>Break Even</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>$2,400 - $4,220</td>
<td>$970 - $1,070</td>
<td>7 months</td>
</tr>
<tr>
<td>Maine</td>
<td>$5,300 - $5,700</td>
<td>$840 - $1,140</td>
<td>16 - 17 months</td>
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<tr>
<td>Illinois</td>
<td>$5,400 - $5,930</td>
<td>$898 - $1,200</td>
<td>6 - 13 months</td>
</tr>
<tr>
<td>New York City</td>
<td>$3,495 - $6,230</td>
<td>$810 - $1,440</td>
<td>4 - 9 months</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>$5,400 - $5,830</td>
<td>$1,215 - $1,640</td>
<td>5 - 23 months</td>
</tr>
<tr>
<td>Philadelphia</td>
<td>$2,480 - $3,800</td>
<td>$810 - $1,240</td>
<td>22 - 46 months</td>
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<table>
<thead>
<tr>
<th>Where</th>
<th>Net Savings</th>
<th>Added Cost</th>
<th>Break Even</th>
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</thead>
<tbody>
<tr>
<td>Texas</td>
<td>$2,580 - $4,070</td>
<td>$2,350 - $3,480</td>
<td>11 - 17 months</td>
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<tr>
<td>Indiana</td>
<td>$4,500</td>
<td>$840 - $1,070</td>
<td>22 months</td>
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<td>North Carolina</td>
<td>$2,660</td>
<td>$930</td>
<td>11 months</td>
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<td>Ohio</td>
<td>$3,650 - $5,240</td>
<td>$830 - $1,280</td>
<td>18 - 23 months</td>
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<td>New England City</td>
<td>$6,720 - $7,840</td>
<td>$810 - $1,240</td>
<td>17 - 22 months</td>
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<tr>
<td>Virginia</td>
<td>$2,502 - $7,644</td>
<td>$8,542 - $12,803</td>
<td>15 months</td>
</tr>
</tbody>
</table>

**Resource: Fact Sheet Handout**
How Much Do Owners of 2012 IECC Homes Pocket in Net Energy Savings?

3. National Association of Homebuilders

NAHB Cost-Effectiveness Study

- 2006 IECC baseline vs. 2009 IECC and 2012 IECC
- Standard Reference House and methodology developed by NAHB Research Center’s 2008 and 2009 Annual Builder Practices Survey (ABPS)

2012 IECC Cost Effectiveness Analysis

Comparing Cost-Effectiveness Methodologies – ICF

- Life Cycle Cost (LCC) is predominant methodology for buildings.
- Roughly comparable energy savings figures.
- Significantly higher cost figures than BCAP or DOE studies.
- Simple payback method used.

But What’s the Impact of America’s Model Energy Code?

It Depends on Adoption!
Codes Stabilize Grids; Delay the Need For New Power Plants

The 2011 Prediction:
Continued savings of the magnitude of recent efficiency gains in building energy codes and appliance standards appear to have broken the traditional connection between electricity demand & economic growth, eliminating the need for additional power plants to serve these sectors through 2025.


The 2014 Evidence:
"Improvements in energy efficiency for buildings & appliances appear to have broken the traditional connection between electricity demand & economic growth."

Building Energy Codes Reduce CO2 Emissions
How Much? EECC Code/CO2 Calculator

EECC’s CO2 Calculator is an easy to use, but extremely powerful tool that determines the carbon saved based on:
- Climate Zone
- Current IECC Version in Force
- Code Compliance %

What Do Building Energy Codes Mean to Our Nation

Alliance to Save Energy: “If all states had adopted the 2012 IECC in 2012 and achieved full compliance by 2013 ...”
- 3.5 quadrillion Btu annual energy savings by 2030.
- $40 billion annual energy cost savings by 2030.
- 200 million metric tons of carbon dioxide emissions avoided annually by 2030.

Equivalents

3.5 quadrillion Btu = Enough to heat 3.5 million average homes each year

$40 billion energy cost savings by 2030.

200 million metric tons of carbon dioxide emissions avoided annually by 2030.

CODES ARE THE MOST COST EFFECTIVE MEANS OF GREENHOUSE GAS REDUCTION

IECC ISN’T LIFE SAFETY CODE per se BUT IT HELPS

- IECC, IgCC included in ICC’s Resiliency Initiative
- SWEEP Analysis IECC IS A Life-Safety Code
  - Moisture Management
  - Indoor Air Quality
  - Fire Safety
  - Strong Envelope Performs Best in Extreme Temperatures
  - Tighter Construction/Better Windows Help in Storms

THAT SAID, IECC IS THE BANK FOR LIFE SAFETY CODES

- The entire suite of codes is essential
- IECC developed by ICC’s governmental members in tandem with plumbing, electrical, fire, and mechanical codes.
- Of these, only the IECC generates thousands of dollars of homeowner savings that not only pay for its efficiency elements, but recoup costs for fire and safety codes to boot.
THANK YOU!

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Case Studies of Economic Analyses at NIST

David T. Butry
Chief, Applied Economics Office
Engineering Laboratory (EL)
National Institute of Standards and Technology (NIST)

Select Economic Case-Studies

- A Life-Cycle Cost Comparison of Exit Stairs and Occupant Evacuation Elevators in Tall Buildings
- Economic Evaluation of Arson Risk Mitigation Options
- Optimal Timing of Wildfire Prevention Education

ASTM Building Economics Standards

- Develops standards that serve as guidelines for making building and infrastructure choice, design, construction, operations, cleanup, and disposal decisions based on economic analysis.
- Provides the building and construction community with standard terminology and evaluation practices that will guide economic evaluations of all types of investment over a project's life cycle—ranging from the planning, programming, and design phases through all the construction, operations, decommissioning, disposal, and caretaking phases.
- Users: manufacturers, producers, government agencies, building owners, contractors, building codes bodies, architectural/engineering firms, consumer groups, trade associations, research groups, consulting firms, and universities

Economic Evaluation Methods (Examples)

- Life-Cycle Cost (LCC) Method
  - Measures, in present value, the sum of all relevant costs associated with owning and operating a building over a specified period of time
- Present Value Net Savings (PVNS)
  - Measures the net savings from investing in a given alternative instead of investing in the foregone alternative
- Savings-to-Investment Ratio (SIR)
  - Ratio whose value indicates the economic performance of a given alternative instead of investing in the foregone opportunity
- Adjusted Internal Rate of Return (AIRR)
  - Average annual yield from a project over the study period, taking into account reinvestment of interim receipts

A Life-Cycle Cost Comparison of Exit Stairs and Occupant Evacuation Elevators in Tall Buildings

When are egress-related building code options cost effective?

- Changes to 2009 International Building Code (IBC) related to key egress-related equipment defined analysis framework
  - Key changes to the 2009 IBC required:
    1. An additional exit stairway for buildings more than 420 ft high;
    2. An increase of 50 percent in the width of exit stairways in new sprinklered building with floor areas exceeding 15,000 ft²;
    3. Permitting the use of elevators for occupant evacuation in fires and other emergencies for all buildings, and as an alternative to the required addition of an exit stairway for buildings more than 420 ft high; and
    4. A minimum of one fire service access elevator for buildings more than 120 ft high.

Background

- Changes to 2009 International Building Code (IBC) related to key egress-related equipment defined analysis framework
  - Key changes to the 2009 IBC required:
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    4. A minimum of one fire service access elevator for buildings more than 120 ft high.
Study Design

- Five prototypical building designs:
  - 13-floor (156 ft high)
  - 28-floor (336 ft high)
  - 42-floor (504 ft high)
  - 75-floor (900 ft high)

- Developed exit stair cost estimates
  - Installation costs
  - Recurring costs: lost rental space (Washington, DC rates)

- Developed occupant evacuation elevator (OEE) costs
  - Installation costs
  - Recurring costs: maintenance & repair

- Developed fire service access elevator costs

- Compared life-cycle costs between egress alternatives
  - An additional exit stair compared to occupant evacuation elevators
  - Per 2009 IBC requirements

- Exception: evaluated comparison for prototypical buildings greater than 120 ft

- Used sensitivity analysis to examine robustness of results

<table>
<thead>
<tr>
<th>Building No.</th>
<th>No. of Floors</th>
<th>Building Height (ft)</th>
<th>Per Floor Area (ft²)</th>
<th>Total Floorspace (ft²)</th>
<th>Cost ($ millions)</th>
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</thead>
<tbody>
<tr>
<td>Building 2</td>
<td>13</td>
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<tr>
<td>Building 3</td>
<td>28</td>
<td>336</td>
<td>30,000</td>
<td>840,000</td>
<td>147</td>
</tr>
<tr>
<td>Building 4</td>
<td>42</td>
<td>504</td>
<td>40,000</td>
<td>1,680,000</td>
<td>504</td>
</tr>
<tr>
<td>Building 5</td>
<td>75</td>
<td>900</td>
<td>45,000</td>
<td>3,375,000</td>
<td>1,215</td>
</tr>
</tbody>
</table>

Study Parameters

- Study period: 25 years
- Discount rate: 2.7%
  - Time value of money
  - Used to adjust costs occurring at different times
  - 2.7% is the 25-year real interest rate on Treasury Notes and Bonds
    - Source: Office and Management and Budget Circular A-94, Appendix C

Assumptions & Limitations

- The specifications, assumptions, and cost estimating relationships of the occupant evacuation elevators were developed in consultation with industry experts
  - The elevator configuration & related cost elements are representative, but not exhaustive
  - Represent one design possibility

Key Findings

- For the prototypical buildings over 120 ft in height:
  - Additional exit stair is cost-effective on a first-cost basis
  - Occupant evacuation elevators are a cost-effective alternative on a life-cycle cost basis when:
    - Discount rates are low
    - Rental rates are high

Results: Break-Even Analysis

<table>
<thead>
<tr>
<th>Building No.</th>
<th>Floors</th>
<th>Stair Width (in)</th>
<th>Break-Even Discount Rate (%)</th>
<th>Break-Even Rental Rate ($/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building 2</td>
<td>13</td>
<td>44</td>
<td>20.9</td>
<td>11.63</td>
</tr>
<tr>
<td>Building 3</td>
<td>28</td>
<td>44</td>
<td>10.4</td>
<td>14.58</td>
</tr>
<tr>
<td>Building 4</td>
<td>42</td>
<td>44</td>
<td>9.4</td>
<td>20.74</td>
</tr>
<tr>
<td>Building 5</td>
<td>75</td>
<td>44</td>
<td>5.0</td>
<td>15.79</td>
</tr>
</tbody>
</table>

Results: Break-Even Analysis

Example Graphical Comparison w/ Uncertainty
Economic Evaluation of Arson Risk Mitigation Options

How economic are arson mitigation options?

Detroit: Devil’s Night Arson

Devil’s Night (Detroit, MI) 1985-1998
- 4,489 fires in metro area
  - 42-night period
  - 115 fires per night

Mitigation: Angel’s Night

City response (partial) from 1985 onward:
1. Firefighters stationed at strategically located command posts.
2. Potential arson targets eliminated (e.g., abandoned buildings and vehicles, trash cans).
3. Residents served as volunteers and guarded and patrolled at-risk areas.
4. Media campaign on dangers of arson.
5. Structured activities for youths.

Modeling

- Risk Model
  - Statistical Poisson model
  - Consequence of intentionally-set fires
  - National Fire Incident Reporting System data
- Mitigation Strategies
  - Increase in policing
  - Decrease in vacant structures
- Economic Analysis with Monte Carlo Sensitivity Analysis
  - Present value net benefits
  - Benefit-to-cost ratio
  - Adjusted internal rate of return

Cost-Effectiveness of Mitigation Strategies

Deterring arson by increasing mitigation effort

Optimizing Mitigation Effort

- Jointly expand mitigation effort to achieve maximum present value net benefits
- Maximum achieved by:
  - 24% decrease in disorder
  - 18% decrease in vacant buildings
  - 0% change in policing
- Net benefits maximized at $243.6 million
Optimal Timing of Wildfire Prevention Education

Does the timing of prevention matter?

Research Approach

• We explore how changes in prevention reduce the economic impact of wildfire management:
  - Timing
  - Budget
  - Timing & Budget
• Hold fuel management effort constant
  - Quite a lot fuel management occurs in Florida and it might be difficult to expand operations.
• Assume shifts in prevention effort are feasible
  - Staffing constraints might make it difficult to reduce effort beyond some level.

Scenarios

1. Constant prevention budget
   - Only changes in prevention timing can affect economic impact
   • A "what can be done" scenario
   • Possible without current budget reallocation
2. Flexible prevention budget
   - Changes to prevention timing and overall effort level can affect economic impact
   • A "what could be done" scenario
   - Possible with given budget flexibility
• Scenarios require:
  - Individual regions can change their spending patterns across months differently
  - All regions must change their spending patterns equally, by the same percentage across all months, state-wide

Previous Research Findings

• Estimated the economic returns to wildfire prevention education
  - Marginal Benefit/Cost Ratios:
    - Prevention: 35/1
    - Fuels Management: 4/1
• Evaluated the coordination of prevention activities to minimize economic impact
  - Optimal allocation:
    - Saves: $23 million
    - Prevention: +168%
    - Fuels Management: +74%

Research Approach

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  - Timing
  - Budget
  - Timing & Budget
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Scenarios

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Economic Impact w/no Budget Flexibility

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Economic Impact w/no Budget Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Table 3: Economics of altering the timing of wildfire prevention effort with no change in prevention spending (shown in thousands of U.S. dollars), totals earned over 2003 to 2007

<table>
<thead>
<tr>
<th>Region</th>
<th>Total spent (in thousands)</th>
<th>Total cost (in thousands)</th>
<th>Net benefit (in thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>323,580</td>
<td>315,730</td>
<td>7,850</td>
</tr>
<tr>
<td>2</td>
<td>323,580</td>
<td>315,730</td>
<td>7,850</td>
</tr>
<tr>
<td>3</td>
<td>323,580</td>
<td>315,730</td>
<td>7,850</td>
</tr>
<tr>
<td>4</td>
<td>323,580</td>
<td>315,730</td>
<td>7,850</td>
</tr>
</tbody>
</table>

Just altering the timing of prevention effort saves $34 million.
Economic Impact w/Budget Flexibility

Table 4: Economics of altering the timing of wildfire prevention effort with an increase in prevention spending (shown in thousands of U.S. dollars), totals summed over 2003 to 2007.

<table>
<thead>
<tr>
<th>Region</th>
<th>Total spending change</th>
<th>Net to date</th>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
<th>Region 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide</td>
<td>1,001</td>
<td>187</td>
<td>204</td>
<td>64</td>
<td>312</td>
<td></td>
</tr>
<tr>
<td>Rx. for spending</td>
<td>12,550</td>
<td>5,796</td>
<td>1,715</td>
<td>2,769</td>
<td>2,533</td>
<td></td>
</tr>
<tr>
<td>Wildfire losses</td>
<td>351,144</td>
<td>16,974</td>
<td>68,104</td>
<td>21,131</td>
<td>192,092</td>
<td></td>
</tr>
<tr>
<td>Total cost + loss</td>
<td>321,624</td>
<td>25,333</td>
<td>70,620</td>
<td>31,301</td>
<td>193,092</td>
<td></td>
</tr>
<tr>
<td>Total cost - loss</td>
<td>321,823</td>
<td>25,673</td>
<td>74,327</td>
<td>31,776</td>
<td>196,549</td>
<td></td>
</tr>
</tbody>
</table>

- Altering only the timing of wildfire prevention activities can be used to further reduce the economic impact.
  - When fuels management and budget constraints exist.
  - Altering only the timing produced expected net benefits of $3.9 million:
    - Required a shift of effort from summer/early-winter months to late-winter and early-spring months.
    - Benefit-cost ratio: infinite (there's no cost!)

- With budget flexibility, altering the timing and intensity of prevention effort produced net benefits of $4.4 million:
  - Again, a shift towards late-winter/early-spring months.
  - Benefit/cost ratio of additional investment: 7.3/1

- The timing of wildfire management matters!

Contact Information

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ECONOMIC VALUE OF STRONGER BUILDING CODES

Jeffrey Czajkowski
Wharton Risk Management & Decision Processes Center
University of Pennsylvania

Kevin M. Simmons
Austin College

(joint work with James Done & supported by the State of Florida Division of Emergency Management and Verisk, Inc.)

Economic Impact of Codes and Standards – A Workshop on Needs and Resources
October 4, 2017
NFPA and International Code Council

Outline

• Research Context and Approach
• Methodology & Results
  □ Florida statewide code implementation statistical loss estimation
  □ Benefit-cost analysis of Florida statewide code
  □ Market Effect of Enhanced Building Codes
• Questions for Discussion

Despite strong building codes frequently touted as a key natural disaster risk reduction strategy & cornerstone of resiliency … we often witness

Enhanced emphasis on movement toward uniform statewide codes using most current code edition

• For 1- and 2-family dwellings:
  □ 32 states utilize the model International Residential Code (IRC) effective statewide
  □ Or, 36 percent of states do not adhere to uniform statewide residential building code standards

• As per May 2016, whether local or statewide IRC:
  □ 40 percent of states are using the 2009 IRC edition or earlier

Increased costs of construction are often the key argument against more stringent codes – thus, it is critical to highlight the economic effectiveness of a strong statewide code.

Leverage our previous research

Insurance Services Office (ISO) annualized ZIP Code (~ 950 per year) loss data from Florida over the period 2001-2010

Across all years, an average of $517 million in losses ($5.17 billion total) and 31,701 claims (317,005 total) are incurred each year from 836,935 exposures, with an average windstorm claim being $150,009 incurred at the rate of 32.4 claims per 1000 insured exposures.
Statewide Florida Building Code (FBC)

FBC Timeline
- 1992 – Hurricane Andrew exposes low standards of construction
- 1996 – Florida Building Code Commission begins to study enhanced statewide codes
- 1998 – Commission recommendations approved by the state legislature
- 2002 – After all legal challenges were exhausted, the FBC was implemented statewide on March 1, 2002

Isolate the impact of the implementation of statewide FBC
- ISO loss data accounts for decade of construction
- Estimate loss differences from pre vs. post 2000 construction

Methodology
1) From the ISO data, estimate series of statistical models relating the impact of post-2000 construction on 2001 to 2010 windstorm losses controlling for other relevant exposure and vulnerability aspects
2) Given these loss FBC loss reductions, evaluate the economic effectiveness of the FBC assuming that the homes built prior to 2000 had instead been constructed under the FBC

That better construction practices lead to lower wind damage is not necessarily a surprise in Florida, but is it good public policy?

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Number of customers by ZIP, decade of construction and by year</td>
</tr>
<tr>
<td>CCCL</td>
<td>Natural log of median household income for the ZIP and year. Adjusted to 2010 dollars</td>
</tr>
<tr>
<td>Deductibles</td>
<td>Natural log of total insurance premiums. Adjusted to 2010 dollars</td>
</tr>
<tr>
<td>Gross</td>
<td>Natural log of losses from pre vs. post 2000 construction</td>
</tr>
<tr>
<td>Income</td>
<td>Number of residential structures divided by the size of the ZIP code in miles, By ZIP and year</td>
</tr>
<tr>
<td>Loss Reduction</td>
<td>The percent of brick and brick/masonry homes for the ZIP and year</td>
</tr>
<tr>
<td>Population</td>
<td>The percent of brick and brick/masonry homes for the ZIP and year</td>
</tr>
<tr>
<td>Post FBC</td>
<td>Natural log of median household income for the ZIP and year</td>
</tr>
<tr>
<td>Post FBC</td>
<td>Natural log of losses from pre vs. post 2000 construction</td>
</tr>
<tr>
<td>Post FBC</td>
<td>Number of customers using the state insurer, Citizens</td>
</tr>
<tr>
<td>Post FBC</td>
<td>Natural log of total insurance premiums. Adjusted to 2010 dollars</td>
</tr>
<tr>
<td>Post FBC</td>
<td>Natural log of total insurance premiums. Adjusted to 2010 dollars</td>
</tr>
<tr>
<td>Post FBC</td>
<td>Natural log of total insurance premiums. Adjusted to 2010 dollars</td>
</tr>
</tbody>
</table>

Overall, our results show the strong effect the statewide FBC had on losses from wind storms during this timeframe with losses shown to be reduced by as much as 72 percent. The loss reduction in robust across multiple regression models & consistent with other previous findings.

BC Ratios > 1 robust across multiple scenarios

- Cost data from ARA 2002 study of the enactment of the FBC for three related housing types constructed to FBC standards
- Weighted across wind borne design regions and adjusted to 2010
- Cost comparison favorable with a similar building code enhancement adopted by the City of Moore, OK - $1.00 per square foot
- Comparing the per unit cost of $3,254 to the various estimates of damage reduction and different samples we have benefit to cost ratios ranging from 2.67 to 7.93.
- That is, for every dollar spent on the implementation of the statewide FBC, up to $7.93 dollars are saved in the form of reduced windstorm losses
BC Ratios > 1 robust across multiple scenarios

<table>
<thead>
<tr>
<th></th>
<th>FBC Direct</th>
<th>FBC Full</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO Sample</td>
<td>3,254</td>
<td>9,207</td>
</tr>
<tr>
<td>All Florida</td>
<td>3,254</td>
<td>7,306</td>
</tr>
<tr>
<td>With Deductibles</td>
<td>3,254</td>
<td>16,509</td>
</tr>
</tbody>
</table>

- Results are consistent with the multi-hazard mitigation council "4 to 1" BC ratio (our work highlighted in their updating process)

- Assuming a 72% reduction in loss and including deductibles, the BCA ratio of 6.06 translates to a payback of between 8 and 9 years.

Research Extensions

- Examine how the BCA performs under different Florida wind regions. Additionally, consider how future varying climate change scenarios affects the BCA

- Examine how real estate market react when one municipality adopts stronger codes while neighboring communities do not

Market Response to Enhanced Codes

- In 2013 Moore, OK suffered it's 3rd violent tornado in 14 years
- Fatalities were 24 including 7 children at Plaza Towers Elementary School
- In 2014, Moore adopted a similar building code as Florida while no other municipality in OK followed suit
- This creates an isolated regulatory action which raises production cost
- The fear of many communities is that such an action would drive development to lower cost communities
Market Response to Enhanced Codes

• Using a D-I-D approach we examine how price per square foot, weekly sales and new permits compared to a neighboring town, Norman
• We find no change in any of the variables when compared to Norman suggesting that demand for homes in Moore were unaffected by implementing the new code
• Paper is forthcoming in the *International Journal for Disaster Risk Reduction*

Questions for Discussion

• Why does building code adoption and enforcement vary significantly throughout the country?
• Will Florida BCA results hold in different parts of the country? And for other types of hazards?
• Will demonstrating the economic effectiveness of building codes encourage statewide adoption of up-to-date standards? What non-economic factors might matter?
• What role can the insurance industry play in the adoption of strong and well-enforced codes?
Total Cost of Fire in the United States

Dr. Jun Zhuang
Associate Professor and Director of Undergraduate Studies
Department of Industrial & Systems Engineering
University at Buffalo

NFPA Workshop on Economic Impact of Codes and Standards
October 4, 2017
Washington, D.C.


Outline

Part 1: Overview
- Taxonomy, total cost and components
- Trends and data sources

Part 2: Cost components & calculation
- Expenditure components
- Loss components

Part 3: Discussion & future work
- Discussion
- Uncertainty
- Regression Analysis
- Future work

Taxonomy

Cost Components: Breakdown

Total cost of fire in the U.S. in 2014 = $328.5 billion

Graph showing breakdown of costs and percentages.

Regret Analysis

Chart showing total cost of fire as a percentage of GDP.

Graph showing cost over time with markers for significant incidents.
Expenditure
Definition: Money spent by society (including governments, fire departments, and others) on fire protection.

Components:
1. Active fire protection expenditure
2. Passive fire protection expenditure
3. Net fire insurance

Active fire protection expenditure
Definition: The society's expenditure on human-led prevention and suppression efforts, or fire department activities.

Components:
1. Local fire department expenditure
2. Value of donated time of volunteer firefighters
3. Donations to fire departments
Local fire department expenditure
Definition: 95% of the fire protection expenditure of local and state governments
• ≈ 95% of "the sum of all costs of local career FDs and direct purchases by volunteer FDs using funds from special taxes or transfers from other local agencies" (NFPA, 2014).
• The remaining 5% of the expenditure is assumed to be for non-fire-related incidents, e.g., medical emergencies.
Sample calculation:
• State & local government expenditure on fire protection (US Census) = $44.1 billion
• Net fire protection expenditure = $44.1 billion x 0.95 = $41.9 billion.

Value of donated time of volunteer firefighters (1 of 2)
Definition: This is the cost of replacing the volunteer services with paid services.
Objective:
• To calculate the value of the volunteer firefighters to the community.
• Not to assign a dollar value to the donated number of hours.
• Value of services offered on duty = availability in the community & readiness to respond at any hour of the day without being compensated.
Possible calculation approaches:
1. Using the estimated donated hours of volunteer FFs and working hours of career FFs
2. Using rates of career firefighters for different population sizes protected

Donations to fire departments
Definition: All donations and support grants to fire departments from non-governmental organizations.
Sample calculation (based on Tennessee data TACIR, 2013, which says roughly one-quarter of fire departments (181 out of 730) rely on donations for more than 50% of their revenue):
Number of fire departments = 29,380
Local fire department expenditures = $41.9 billion
Sum of expenditure of a quarter of fire departments = $2.9 billion
(assuming an arithmetic progression of expenditure)
Lower bound on donations is 50% of the above = $1.4 billion

Passive fire protection expenditure
Definition: Expenditure on static or non-human-led prevention and suppression devices and programs
Components:
1. Fire safety costs in building construction
2. Expenditure on fire grade products
3. Expenditure on fire maintenance
4. Expenditure on fire retardants
5. Expenditure on disaster planning
6. Expenditure on preparing/maintaining standards
7. Net fire insurance expenditure

Fire safety costs in building construction (1 of 2)
Definition: New building construction expenditures that are needed solely because of fire safety and fire protection considerations
• E.g., compartmentalization features, built-in fire protection systems, and treatments of or limitations on exterior surfaces (NFPA, 2014).
• The costs of enhancing the fire protection features of already constructed buildings are not considered, (these are expected to be captured to an extent by the "fire maintenance" component).
Formula (NFPA, 2014):
Cost of building fire protection = 0.10% x [value of commercial residential building construction + 0.10% x [value of noncommercial construction including commercial, government, and residential] + 0.00% x [value of existing and local governmental construction, excluding campuses, roadways, bridges and streets, parking areas, and schools, airports, and parks]]
Expenditure > Passive > Building construction

Fire safety costs in building construction (2 of 2)

Sample calculation (using the formula on previous page):

Value of construction put in place (private residential) = $869,793 million
Value of construction put in place (private non-residential) = $353,707 million
Value of construction put in place (public total) = $976,128 million

Fire safety costs in building construction = 2.5% of $869,793 million
+ 12.0% of $353,707 million
+ 4.0% of $976,128 million
= $57.4 billion.

Expenditure > Passive > Other

Expenditure on fire grade products, fire maintenance, fire retardants, disaster planning, & preparing/maintaining standards

Sample calculation:

Expenditure on fire grade products, fire maintenance, fire retardants, disaster planning, & preparing/maintaining standards

Expenditure > Passive > Net fire insurance

Net fire insurance (1 of 2)

Definition: Difference between the insurance premiums paid by property owners (personal and commercial) for insuring their property from fire and the damages claimed from insurers.

- Insurance types:
  - Exclusive fire insurances,
  - Multi-peril insurances: homeowner, commercial, and farm owners.
- The fire insurance part of multi-peril premiums are estimated as a fraction of the total multi-peril premiums.
- Damages claimed are estimated as a fraction of the total property losses (direct and indirect).

Formula (NFPA, 2014):

Net fire insurance = [(Premiums paid for fire insurance) - (Damages claimed)]

Expenditure > Passive > Net fire insurance

Net fire insurance (2 of 2)

Sample calculation (using formula from previous page):

Total fire-related premiums for 2014 = $37.7 billion
Direct property loss in 2014 = $13.8 billion
Indirect property loss in 2014 = $2.0 billion
Net fire insurance = ($37.7 - $13.8 - $2.0) billion
= $23.6 billion.

Loss

Definition: Monetary equivalent of property losses, human losses, and indirect losses.

Components:
1. Human loss
2. Direct property loss
3. Indirect property loss
Human loss (1 of 2)

Definition: Monetary equivalent of deaths and injuries, using the willingness to pay (WTP)

Components:
- Cost of statistical death
- Monetary equivalent of deaths (civilians and firefighters) due to fires, calculated using the value of statistical life (VSL)
- Definition of VSL (also known as value of life):
  - The monetary value of a mortality risk reduction that would prevent one statistical death (Andersson and Treich, 2011)
  - The additional cost that individuals would be willing to bear for improvements in safety (that is, reductions in risks) that, in the aggregate, reduce the expected number of fatalities by one (U.S. Department of Transportation, 2017)
- Using U.S. DOT’s VSL value of $9.6 billion for 2016 as the baseline value
- Cost of statistical injury:
- Monetary equivalent of injuries (civilians and firefighters) due to fires, calculated using the VSL as well as newly defined value of statistical injury (VSI)
- VSI: the monetary value that would prevent one statistical injury

Direct property loss

Definition: Monetary losses due to damages to property and contents.

Types of properties, as classified by NFPA (2016):
- public assembly;
- educational;
- institutional;
- residential;
- stores and offices;
- industry, utility, and defense;
- storage in structures; and
- special structures.

Sample calculation: Property loss = $13.2 billion (NFPA, 2016)

Indirect loss

Definition:
- Also as “economic impact of fire” the net monetary downstream effects of fires on the economy.
- Indirect losses from commercial/industrial building fires
  - reduction in turnover dollars for an interrupted or closed business,
  - jobs that are lost, due to fires.
- Indirect losses in the context of residential building fires
  - Inconvenience-related costs to primarily the residents and also to the public, due to fire.

Potential estimation approaches
- Econometric input-output models
- Regional Economic Models Inc. (REMI), Regional Input-Output Modeling System (RIMS II).
- Recent regional studies on estimating the savings that fire protection services provide to the economy (savings from successful fire interventions)
  - Phoenix, AZ (Evans, 2017)
  - Montreal, Canada (Delorme & Waterhouse, 2017)
- Challenge: These models are primarily for regional studies. Expanding to national level will require significant amount of work.
- Using NFPA’s multipliers to estimate indirect loss as a percentage of direct loss (NFPA, 2014)

Total cost & components: calculated values (1980-2014)

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>$75.9</td>
<td>$218.6</td>
<td>$83.8</td>
<td>$217.9</td>
<td>$87.1</td>
<td>$212.4</td>
<td>$90.8</td>
<td>$216.2</td>
<td>$93.8</td>
<td>$214.8</td>
<td></td>
<td></td>
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</tbody>
</table>

Total human loss: $91.4 billion; $90.2 billion; $89.4 billion; $88.1 billion; $86.9 billion; $85.6 billion; $84.4 billion; $83.2 billion; $82.0 billion; $80.8 billion; $79.6 billion; $78.4 billion; $77.2 billion; $76.0 billion; $74.8 billion; $73.6 billion; $72.4 billion; $71.2 billion; $70.0 billion; $68.8 billion; $67.6 billion; $66.4 billion; $65.2 billion; $64.0 billion; $62.8 billion; $61.6 billion; $60.4 billion; $59.2 billion; $58.0 billion; $56.8 billion; $55.6 billion; $54.4 billion; $53.2 billion; $52.0 billion; $50.8 billion; $49.6 billion; $48.4 billion; $47.2 billion; $46.0 billion; $44.8 billion; $43.6 billion; $42.4 billion; $41.2 billion; $40.0 billion; $38.8 billion; $37.6 billion; $36.4 billion; $35.2 billion; $34.0 billion; $32.8 billion; $31.6 billion; $30.4 billion; $29.2 billion; $28.0 billion; $26.8 billion; $25.6 billion; $24.4 billion; $23.2 billion; $22.0 billion; $20.8 billion; $19.6 billion; $18.4 billion; $17.2 billion; $16.0 billion; $14.8 billion; $13.6 billion; $12.4 billion; $11.2 billion; $10.0 billion; $8.8 billion; $7.6 billion; $6.4 billion; $5.2 billion; $4.0 billion; $2.8 billion; $1.6 billion; $0.4 billion; |
Total cost v/s GDP: calculated values (1980-2014)

<table>
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<tr>
<th>Year</th>
<th>Total Cost of Fire</th>
<th>U.S. GDP</th>
<th>Total Cost of Fire as a Percentage of GDP</th>
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Regression analysis: selected expenditure components

Discussion

Acknowledgements:
- Cost of water for fire protection
  - Quantity of water used for fire protection (from fire hydrants, etc.) account for about 0.5 to 1.0% of total water supplied by water utilities (AWWA, 2012), hence is ignored in many studies.
  - 0.75% of total revenue of 294 water utilities = $0.18 billion
  - Worth acknowledging, as the cost of water is expected to increase over time.
- Problems in data reporting
  - Property loss estimation – standardized loss estimation tools would be helpful
    - E.g., Property Loss Estimation Tool (PLET), developed by Kansas State Fire Marshal’s Office.
- Building codes – determinant of fire losses and protection expenditures
  - No uniform building code across U.S.
- Future work
  - Value of donated time of volunteer firefighters:
    - Create standard definition
    - Calculation of value of volunteer hour, specifically in the fire protection context
  - Wildland fires
    - Integrate economic and environmental costs of wildfires into the total cost of fire
  - Fire safety cost of building construction
    - Calculate updated multipliers, with inputs from builders, architect, fire protection equipment manufacturers
  - Indirect losses
    - Analyze relation between direct and indirect losses
    - Calculate updated multipliers (indirect as a function of direct) using regression
  - Expand regional econometric input-output models to national level
  - Revise definitions of certain components of total cost
    - E.g., expenditures on fire grade products, fire maintenance, fire retardants, disaster planning, and preparing/maintaining standards - nearly 25-years old
Other related work – Investment v/s losses

\[
\text{Vulnerability to Fire Loss C}_{\text{fire}}(Q) = f_1(Q) + f_2(Q) \\
\text{Total Investment in Billions of Dollars (B)} \\
\text{Population}
\]

Data sources: NFIRS, NFPA reports, fire department websites, fire protection articles

Other related work: Loss v/s weather, expenditure v/s population

Data sources: NFIRS, NFPA reports, fire department websites, fire protection articles

Other related work: ZIP code level analysis of FD resources

Number of Firefighters per Annual population

- [0 to 329)
- [329 to 895)
- [895 to 1,900)
- [1,900 to 4,153)
- [4,153 to 10,108)
- [10,108 to 23,717)
- [23,717 to 115,538)

Data sources: NFIRS

References


Thank you for your time! Any questions/comments?

Collaborations are welcome!

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Web: http://www.eng.buffalo.edu/~zhuang/