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Total Cost of Fire in the United States

FINAL REPORT BY:

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FOREWORD

In August 2016, NFPA hosted *Economic Decision Making in Fire and Electrical Safety: A Workshop on Needs and Resources*. The workshop brought together the fire service, enforcers, economists, researchers, and others to discuss the information and research needs around economics and fire and electrical safety. One of the major areas identified for further study is the data and information related to the total economic impact of fire. It was noted by participants that there is a need to compile and update available information on this topic and to introduce consistency on the economic data around fire. This information would be used for fact sheets or similar communications about the cost of fire.

NFPA has provided information about the total cost of fire (i.e. losses plus the costs of protection) for several years with the latest report published in March 2014 (www.nfpa.org/totalcost). This analysis combines the losses caused by fire and the money spent for fire prevention, protection, and mitigation to prevent larger losses. While the workshop participants noted that this is an important analysis and report, they identified a need to better address indirect loss. This includes business interruption, employment, impact on real estate values, information on the indirect costs of injury (both occupant and first responder), etc.

The Foundation initiated this project to revisit the data, methodologies and approach used in NFPA's report *The Total Cost of Fire in the United States* published in March of 2014. This report is an update of this report with the most recent data available in the United States and highlights gaps where additional work is needed to improve the estimates.

The Fire Protection Research Foundation expresses gratitude to the report authors Jun Zhuang, Vineet M. Payyappalli, Adam Behrendt, and Kathryn Lukasiewicz, who are with the Department of Industrial and Systems Engineering, University at Buffalo located in Buffalo, NY, USA. The Research Foundation appreciates the guidance provided by the Project Technical Panelists and all others that contributed to this research effort. Thanks are also expressed to the National Fire Protection Association (NFPA) for providing the project funding.

About the Fire Protection Research Foundation

RESEARCH FOUNDATION
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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.

Keywords: fire statistics, cost, economic losses, loss estimates, fire losses, economic impact

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Total Cost of Fire in the United States

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Abstract: This report presents the total cost of fire in the United States for the years 1980 to 2014. The cost of fire for the years 2015 and later are not calculated as most of the data sources used are available only until 2014. The total cost of fire is defined as the collective of all net expenditure on fire protection and all net losses due to fire incidents. For 2014, the total is $328.5 billion, which was 1.9% of the U.S. Gross Domestic Product (GDP). The expenditures constitute $273.1 billion (83.1% of total) and the losses constitute $55.4 billion (16.9% of total). The fire safety costs in building construction is the largest component at $57.4 billion (17.5% of total). This report provides updated prevention, protection, and mitigation costs. This has been achieved through (a) creating a taxonomy for mutually exclusive expenditures and losses based on findings from extensive literature review to ensure a complete accounting of the cost of fire, and (b) using analytical methodologies from literature review of fire and other hazard impacts to account for each defined facet of cost and loss. These methods will guide the calculation of the total cost of fire in being complete, precise, and standardized for future application by the National Fire Protection Association (NFPA) community. Future research directions, including regression analysis to find relationships between quantifiable factors of costs and losses, are also provided.

Acknowledgments: We are thankful to many colleagues for providing support and constructive feedback on all phases of this project. Firstly, we thank Amanda Kimball (Fire Protection Research Foundation) for administering meetings and coordinating the communication and feedback between the research team and the project panel. We are also grateful to Amanda for connecting us with experts from fire protection and insurance sectors, who provided highly valuable information and comments. Next, we thank our project panel members for sharing their valuable expertises and experiences: Marty Ahrens (NFPA Research), Brian Ashe (Australian Building Codes Board), Brett Brenner (Electrical Safety Foundation International), Dave Butry (National Institute of Standards and Technology), Jeff Case (Phoenix Fire Department), Gregg Cleveland (City of Lacrosse Fire Department, WI), Butch Diekemper (City of Lenexa Fire Department, KS), Dr. Bill Jenaway (Volunteer Firemen's Insurance Service, Inc.), Larry Krasner (FM Global), Jeff Prestemon (U.S. Forest Service), Russ Sanders (NFPA Metro Chief Liaison), and Dave Waterhouse (Montreal Fire Department). We extend our gratitude to the project sponsor representatives: Kathleen Almand (NFPA), Ray Bizal (NFPA), and Meghan Housewright (NFPA). The panel members as well as the project sponsor representatives provided valuable information, suggestions, and feedback, which played a significant role in shaping this report. We also thank other contacts for the project including Dave Finger (National Volunteer Fire Council), Mary-Anne Firneno (Insurance Information Institute), and Nancy A. Narisi (Insurance Services Office), for sharing information that was pivotal in developing the section on the value of time donated by volunteer firefighters as well as net fire insurance expenditure. Finally, we thank Robert Polk (National Association of State Fire Marshals) and Kenneth E. Bush (Maryland State Fire Marshal's Office) for providing valuable comments on the report. The authors assume all errors.

Contents

Executive Summary and Illustrations

In response to an increased demand for data to aid decision making in fire protection at the strategic and operational levels, this report aims to provide data on the cost of fire[1] in the United States to anyone with an interest in understanding or using this data. This report is an update of a previous version (*The Total Cost of Fire in the United States*; NFPA, 2014b, which calculated the total cost of fire from 1980 to 2011) to provide more updated prevention, protection, and mitigation costs, with critical attention on estimating the economic impact of fire. In addition to providing updated methodologies for calculating the total cost of fire and its components, this report also identifies the areas where more future work is needed to improve the accuracy of estimating the total cost of fire.

The total cost of fire in the United States in 2014 was $328.5 billion, which was 1.9% of the U.S. Gross Domestic Product (GDP). The components of the total cost of fire are given in Table 1. The total cost of fire has been broken down into mutually exclusive categories of “expenditure" and “loss" and their sub-categories. The expenditures constitute $273.1 billion (83.1% of total) and the losses constitute $55.4 billion (16.9% of total).

Table 1: Components of the total cost of fire in the U.S. in 2014. All values are in billion U.S. dollars.

<table>
<tr><th colspan="4">Breakdown of the total cost of fire in the U.S., 2014</th><th>Value
(in billion $)</th></tr>
<tr><td rowspan="10">Expenditure
(273.1)</td><td rowspan="3">Direct
(90.1)</td><td rowspan="3">Active fire protection expenditure
(90.1)</td><td>Local fire department expenditures</td><td>41.9</td></tr>
<tr><td>Value of donated time of volunteer firefighters</td><td>46.9</td></tr>
<tr><td>Donations to fire departments</td><td>1.3</td></tr>
<tr><td rowspan="7">Indirect
(183.0)</td><td rowspan="6">Passive fire protection expenditure
(159.4)</td><td>Fire safety costs in building construction</td><td>57.4</td></tr>
<tr><td>Fire grade products</td><td>54.0</td></tr>
<tr><td>Fire maintenance</td><td>36.5</td></tr>
<tr><td>Fire retardants</td><td>7.5</td></tr>
<tr><td>Disaster planning</td><td>3.4</td></tr>
<tr><td>Preparing/maintaining standards</td><td>0.6</td></tr>
<tr><td colspan="2">Net fire insurance</td><td>23.6</td></tr>
<tr><td rowspan="4">Loss
(55.4)</td><td rowspan="3">Direct
(53.5)</td><td rowspan="2">Human loss
(40.4)</td><td>Cost of statistical deaths</td><td>31.4</td></tr>
<tr><td>Cost of statistical injuries</td><td>9.0</td></tr>
<tr><td colspan="2">Property loss</td><td>13.2</td></tr>
<tr><td colspan="3">Indirect losses</td><td>1.9</td></tr>
<tr><td colspan="4">Total</td><td>328.5</td></tr>
</table>

Some important highlights/findings from the analysis presented in this report are:

- For each cost component and for all the years from 1980 to 2014, the actual dollar values as well as the 2014 dollar equivalent have been calculated. The 2014 dollar values are estimated from the actual values, using inflation rates in Table 4. The costs discussed in this summary are inflation-adjusted values.

- Over the years 1980 to 2014, the total cost of fire has increased by 50.3%. However, over the same period of time, the total cost of fire as a percentage of U.S. GDP has decreased by 75.3% (from 7.6% in 1980 to 1.9% in 2014).

[1]This report only considers structural fires; wildfires and vehicle fires are excluded from analysis. Some other costs that are not considered are: the cost of industry-owned-fire-departments; the cost of water for firefighting; and the costs of enhancing the fire protection features of already constructed buildings.

- The fire safety costs in building construction ($57.4 billion) constitute the largest share (17.5%) of the total cost in 2014. Cost of fire grade products, the value of donated time of volunteer firefighters, and local fire department expenditure are the second, third, and fourth largest shares (16.4% at $54.0 billion, 14.3% at $46.9 billion, and 12.8% at $41.9 billion, respectively).

- Due to a significant decrease in the number of deaths and injuries (civilian and firefighter) over the years 1980 to 2014, the cost of statistical deaths and injuries has decreased by 49.7% (from $62.4 billion to $31.4 billion) and 50.3% (from $18.1 billion to $9.0 billion), respectively.

- This report documents multiple calculation methods for certain cost components. In such cases, we selected the most reasonable methods in which the data required was the most readily available. For example, five different methods are presented in Section 2.1 to calculate the value of donated time of firefighters. Since unavailability of accurate data hinders estimation of donated time, this report adopts the most reasonable method (in terms of data availability), which defines the value of donated time as the "cost to replace all volunteer fire departments with career," rather than calculating "the actual value of the donated time of volunteer firefighters." Adoption of this method should not be interpreted as an acknowledgment that eventually all volunteer firefighters would be replaced by career firefighters. The most important and the most difficult-to-estimate value of volunteer firefighters is their availability in the community and their readiness to respond at any hour of the day without being compensated.

- This report defines the 'economic impact of fire' as the net monetary downstream effects of fires on the economy. In other words,the economic impact of fire is the sum of all indirect losses due to fire incidents, which is a subset of the total cost of fire. Indirect losses, especially from large-loss fires, are expected to be significantly high and hence would impact the regional economy considerably. However, lack of adequate data on indirect losses makes it difficult to quantify the actual economic impact of fire.

Figure 1 shows the breakdown of the total cost of fire in the U.S. in 2014 into various components. The components are sorted from largest to smallest (top to bottom) in Figure 2. Although highly dependent on the parameters[2] used for calculation, the cost of statistical deaths and the cost of statistical injuries form almost 12.3% of the total cost, or $40.4 billion. Fire maintenance costs ($36.5 billion) and net fire insurance costs ($23.6 billion) also have significant shares of the total cost (11.1% and 7.2%, respectively). Interestingly, direct and indirect property losses ($13.2 billion and $1.9 billion respectively) together constitute only 4.6% of the total cost of fire. Moreover, all of the loss components ($55.4 billion) add up to only 16.9% of the total cost, while the expenditure components ($273.1 billion) add up to the remaining 83.1%. While at first, this may appear imbalanced, in a counterintuitive sense, this highlights the importance of savings provided by the active and passive fire protection efforts, including the fire service. Nevertheless, a conventional cost-benefit analysis may not be practical in the case of fire protection as the potential losses of the resources that are at stake are immense.

Figure 3 shows the trend of the total cost of fire in the U.S. for the years 1980 to 2014. Over the years 1980 to 2014, the total cost has increased by 50.3%. However, an increase in the total cost is expected due to economic factors such as increases in manufacturing, construction, population, and technological improvements. GDP is the best indicator of these changes in the economy. Hence, the total cost of fire is calculated and plotted as a percentage of U.S. GDP for the period of 1980 to 2014. It is seen that this percentage has decreased by 75.3% (from 7.6% in 1980 to 1.9% in 2014). Figure 4 uses the same data as in Figure 3, to show that the total cost as a percentage of GDP has an exponentially decreasing trend in the total cost. During the period 1980-2014, the total losses have

[2]For details on parameters such as the value of statistical life and the value of statistical injury, refer Section 3.1.

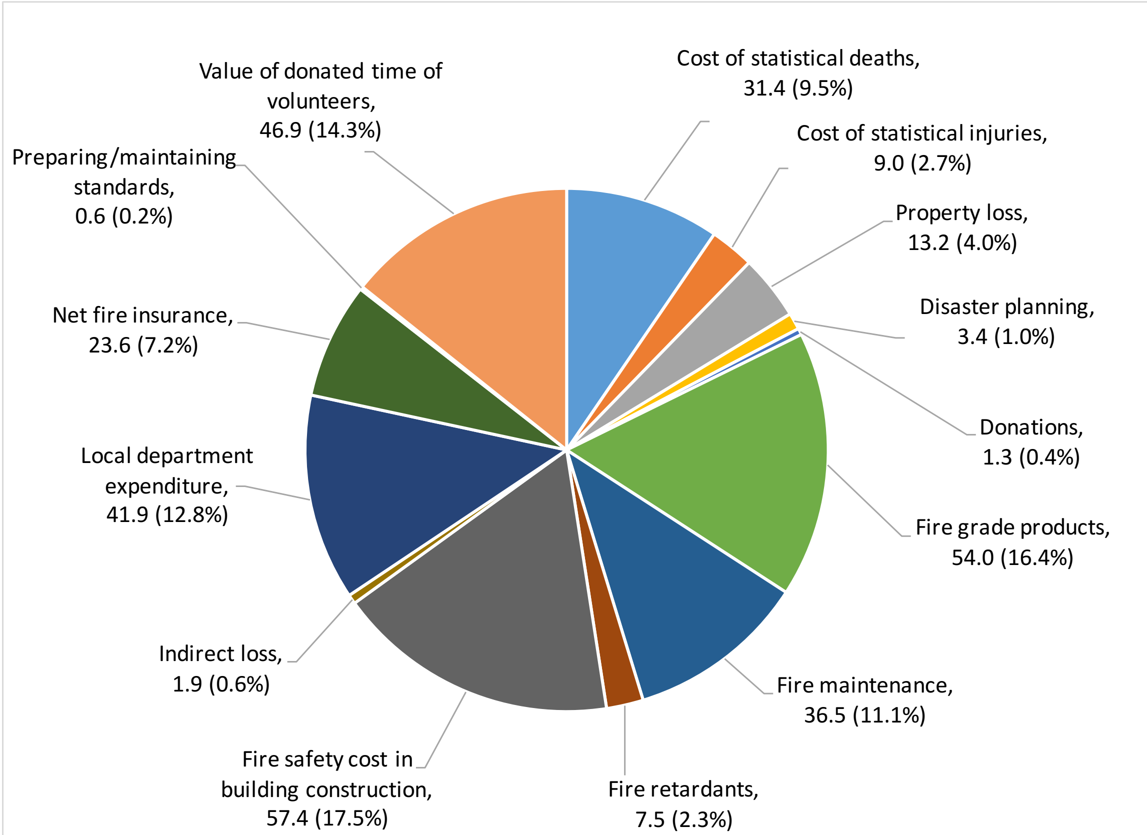

Figure 1: Values (in billion $) and percentage shares of the components of the total cost of fire ($328.5 billion) in the U.S. in 2014.

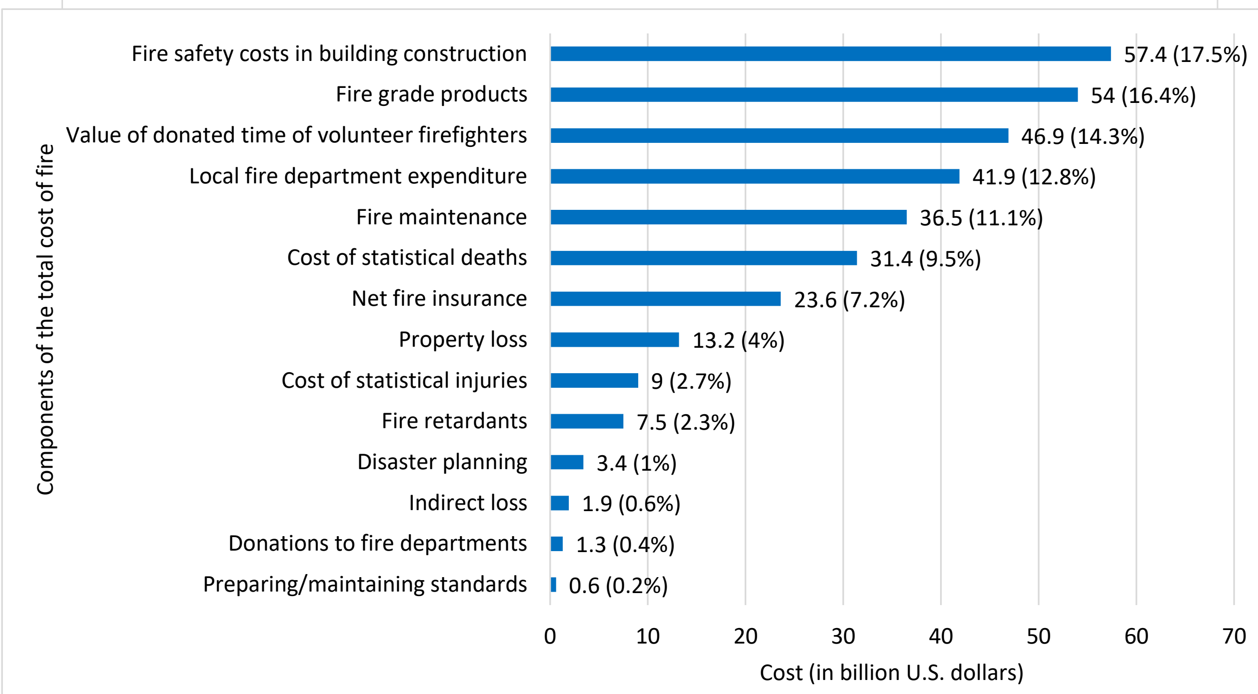

Figure 2: Values (in billion $) and percentage shares of the components of the total cost of fire ($328.5 billion) in the U.S. in 2014, arranged in decreasing order from top to bottom.

decreased by $49.6 billion (47.2%) from $105.0 billion to $55.4 billion, while the total expenditures have increased by $159.6 billion (140.6%) from $113.5 billion to $273.1 billion (Figure 5). Figure 6 shows that the ratio of the total losses to the total expenditures have decreased from 0.93 in 1980 to 0.20 in 2014 (see Table 2 for these ratios). This is attributed to the increased in expenditure over the years, and also to the savings from fire protection efforts, which are impossible to calculate but are very large. Figure 7 shows that losses have decreased in expenditure with decreasing marginal losses.

In summary, this report presents a comprehensive analysis of the total cost of fire in the United States for the years 1980 to 2014, and describes the impact of fire on various sectors of the U.S. economy.

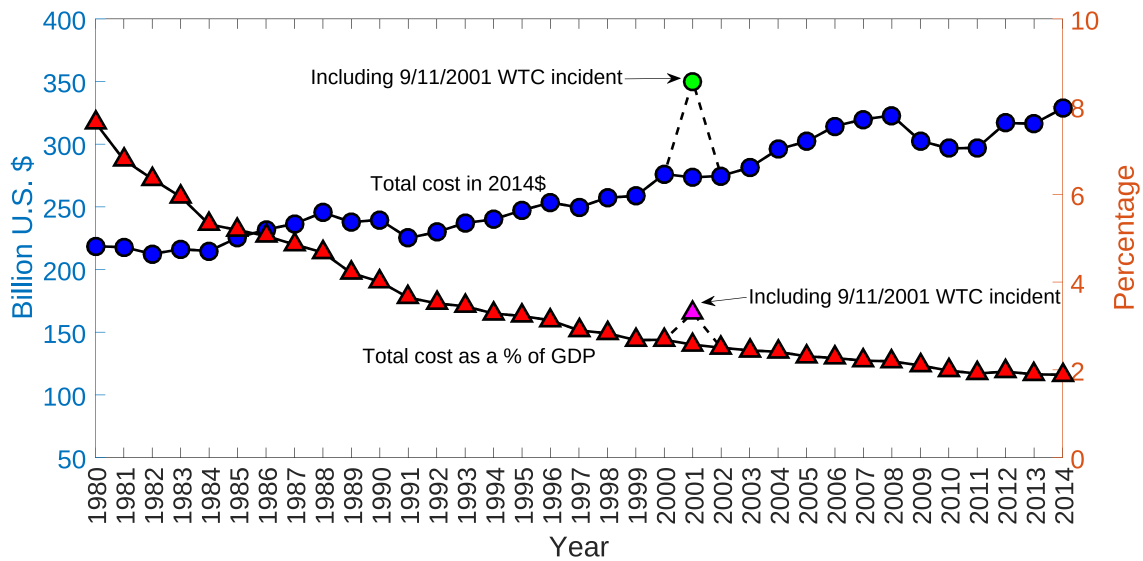

Figure 3: Changes in the total cost of fire in the U.S., for the years 1980 to 2014 (in 2014 dollars), compared with U.S. GDP. For each trend line, the spike point with dotted lines shows the corresponding value when the losses associated with the World Trade Center incident of September 11, 2001 are included.

Table 2: Ratio of losses to expenditures. “2001a" represents 2001 value including the 9/11 Word Trade Center incident, and “2001b" represents 2001 value excluding the 9/11 Word Trade Center incident.

Year	Ratio	Year	Ratio	Year	Ratio	Year	Ratio
1980	0.93	1989	0.61	1998	0.37	2006	0.26
1981	0.94	1990	0.55	1999	0.35	2007	0.25
1982	0.83	1991	0.56	2000	0.35	2008	0.26
1983	0.80	1992	0.53	2001a	0.66	2009	0.25
1984	0.70	1993	0.51	2001b	0.32	2010	0.23
1985	0.76	1994	0.45	2002	0.32	2011	0.23
1986	0.66	1995	0.45	2003	0.30	2012	0.21
1987	0.65	1996	0.46	2004	0.28	2013	0.20
1988	0.68	1997	0.38	2005	0.28	2014	0.20

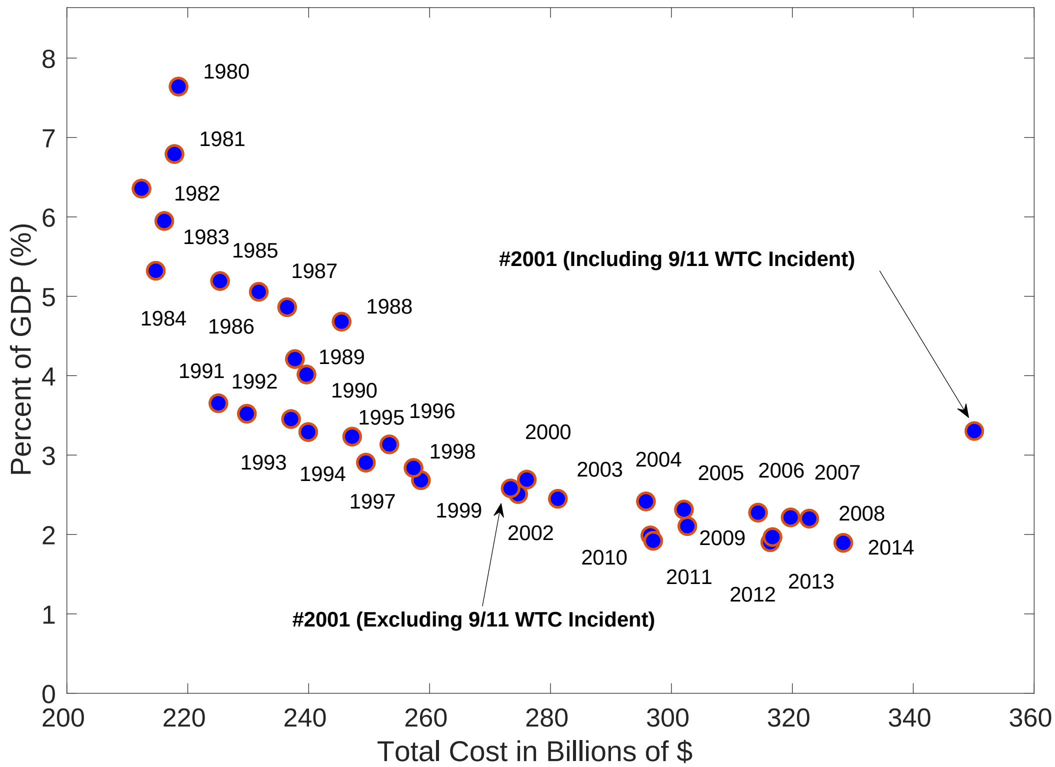

Figure 4: Scatter plot that compares the total cost of fire in the U.S. against the total cost as a function of GDP, for the years 1980 to 2014.

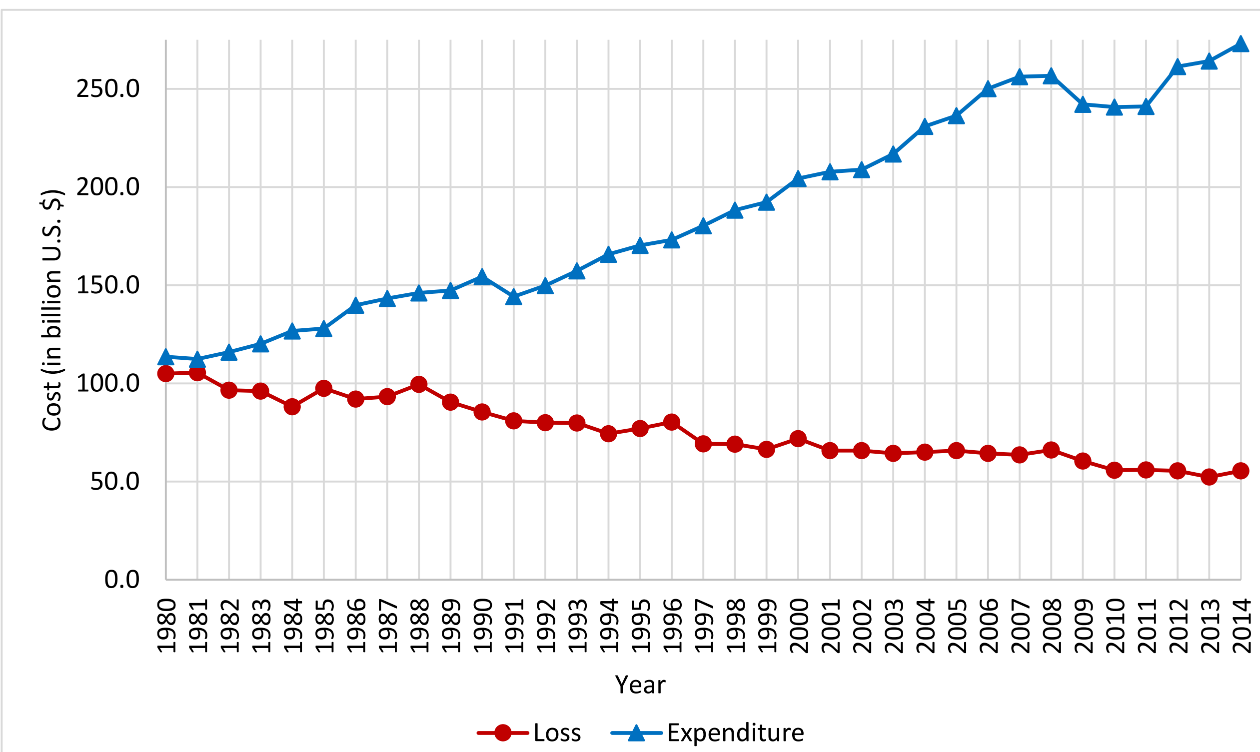

Figure 5: Trends of losses and expenditure, for 1980 to 2014. The value for the year 2001 excludes the 9/11 Word Trade Center incident.

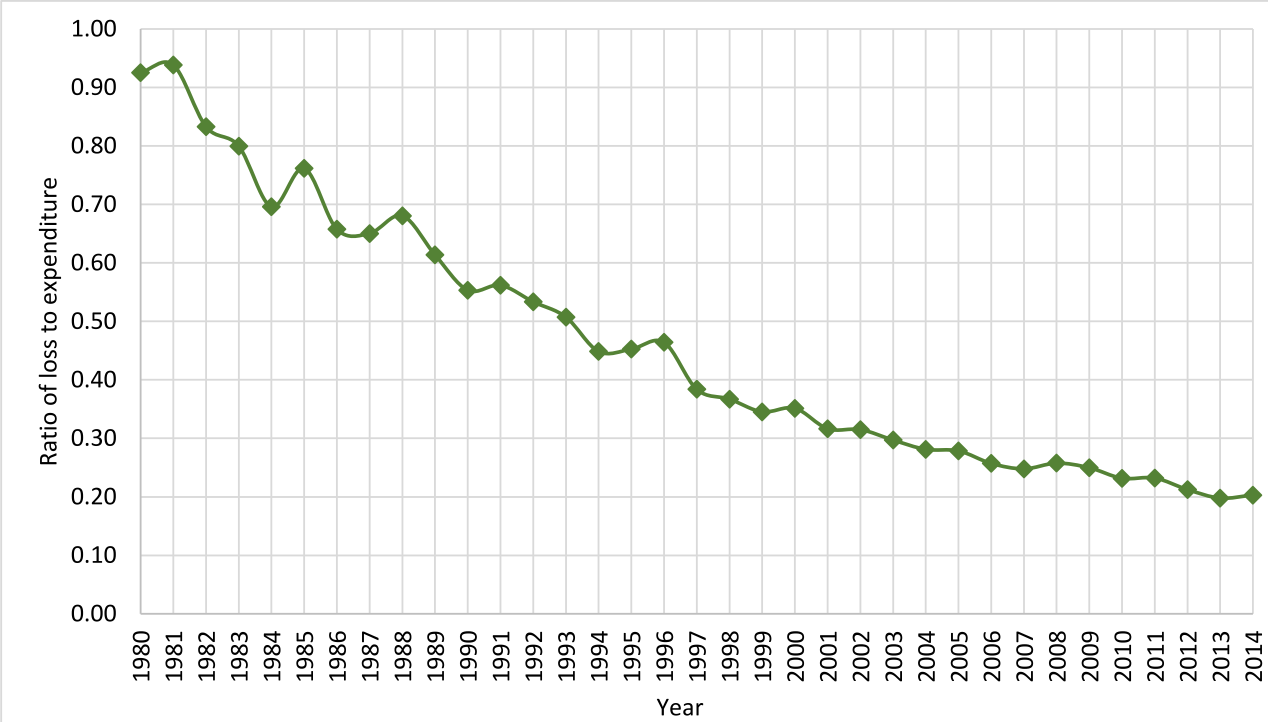

Figure 6: Ratio of losses to expenditure, for 1980 to 2014. The value for the year 2001 excludes the 9/11 Word Trade Center incident.

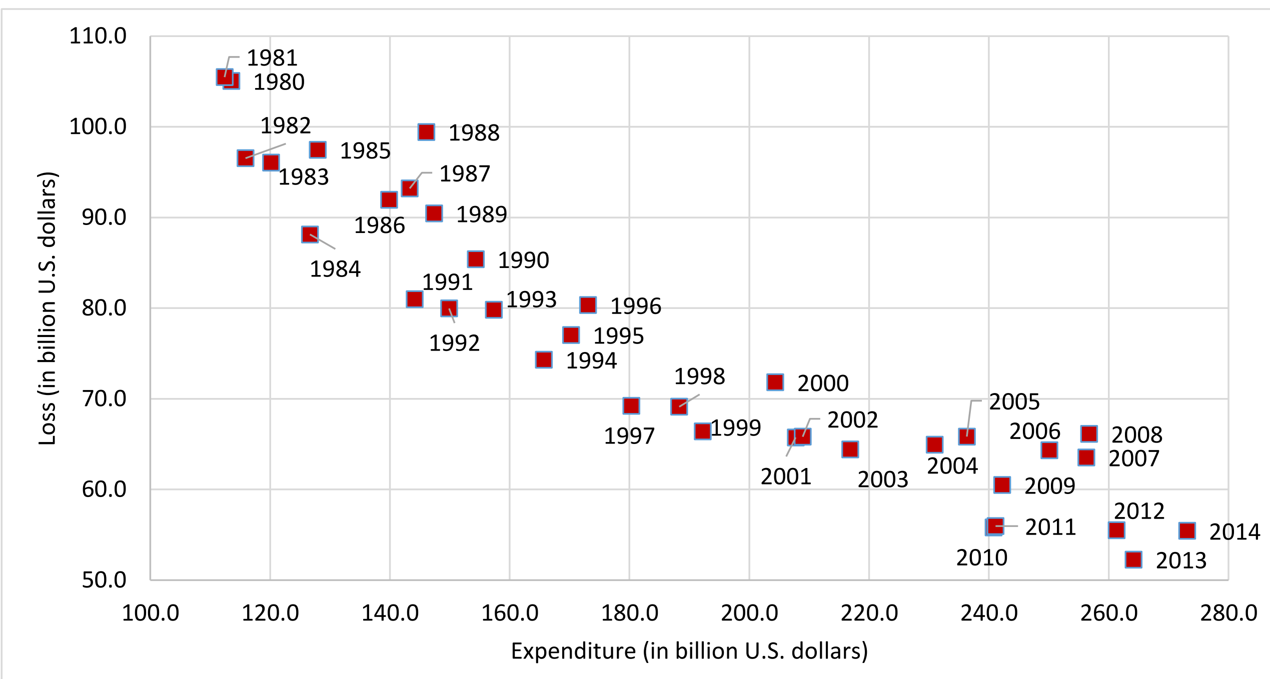

Figure 7: Losses versus expenditures diagram for 1980 to 2014, which shows that losses have decreased in expenditures, with decreasing marginal losses. The value for the year 2001 excludes the 9/11 Word Trade Center incident. Note that the X-axis (expenditure axis) and the Y-axis (loss axis) start from \$100 billion and \$50 billion respectively, and not from \$0 billion.

Total Cost of Fire in the United States

1 Introduction

The fire service and fire protection personnel in the United States rely on the analysis of fire incident and fire activity data for improving decision making at all levels. At the strategic end, government analysts may use this data to draft future policies. From an operations perspective, firefighters may use this data for designing community risk-reduction programs such as risk-based inspections. In light of this increased demand for data, this report aims to provide the cost of fire[3] in the U.S. to anyone with an interest in understanding or using this data.

This report provides definitions and calculations for accurate prevention, protection, and mitigation costs, with critical attention on estimating the economic impact of fire, or the combination of all indirect losses and downstream effects of fire incidents. The downstream effects are significant specifically for large fires with high losses. This report accounts for the total cost of fire (excluding wildland fires) in the U.S. to governmental and non-governmental organizations, fire departments, businesses, property owners, and the public at large, at various levels of the national economy. Two fundamental terms used in this report are defined below.

Definition 1 Total cost of fire: *This report defines the total cost of fire as the collective of all net expenditure on fire protection and all net losses due to fire incidents.*

The net expenditure on fire protection constitutes the money spent on fire prevention and suppression, and the components of net losses are direct and indirect losses. Direct losses include all losses to property, as well as losses due to deaths and injuries; and indirect losses include business interruptions as well as the inconvenience caused to individuals and the public at large as a result of fires. The breakdown of the total cost into its components is shown in Figure 8. A glossary that provides the definitions of these components is provided at the end of this section.

Definition 2 Economic impact of fire: *This report defines the economic impact of fire as the net monetary downstream effects of fires on the economy. In other words,the economic impact of fire is the sum of all indirect losses due to fire incidents, which is a subset of the total cost of fire.*

Indirect losses may refer to a reduction in turnover dollars for an interrupted or closed business, or jobs that are lost. In the case of lost business, it must be acknowledged that the losses to one party may be gains to another. For example, an interrupted business loses turnover dollars whereas another competing business can use this opportunity to increase its turnover dollars. In this way, illustrating the loss to one business as a loss to the community would be incorrect. While it may be possible at a microlevel (e.g., a city) to use input-output models or other econometric models to calculate the economic impact of fire with high accuracy, to our best knowledge, it appears to be very complicated to perform a similar calculation at the national level. Hence, indirect losses are a single component, although further subdivisions, such as business interruption costs, lost jobs and salaries, and economic impact on real estate, are possible.

As we define the economic impact of fire as the indirect losses, the challenges in estimating these indirect losses must first be enumerated. Lack of available and applicable data heavily constrains this effort. Also, beyond simply the values involved, indirect loss estimation methodology, some of which

[3]This report only considers structural fires; wildfires and vehicle fires are excluded from analysis. Some other costs that are not considered are: the cost of industry-owned-fire-departments; the cost of water for firefighting; and the costs of enhancing the fire protection features of already constructed buildings.

is used in other hazard/disaster contexts, is not often appropriate to be adapted in the context of fire. The issue of scalability plays a large role in making it difficult to adapt existing models. For example, methods such as REMI and RIMSII that some researchers have used to calculate the effect of fire on the economy (see Section 3.2 for details), are not able to be applied at a national level, primarily because those methods require case-to-case analyses of thousands of fire incidents that would be nearly impossible to complete. Furthermore, large loss fires (that result in mass damage) are statistical outliers in loss/cost calculations, because the losses are hundreds or thousands of times more than other fires. We acknowledge that the economic impact of (indirect losses from) such fires could be significantly high. NFPA (2016b) documented 27 large-loss fires and explosions (defined as an event in which the property damage amounts to at least $10 million) in 2015, which totaled $2.5 billion in property losses. That report categorizes 260 fire incidents that occurred during 2006-2015 as large-loss fires. These fires had a combined property damage of $13.3 billion (adjusted to inflation, in 2014 dollars). Transposing this to the national level to attempt to quantify the indirect losses due to large-loss fires would require extensive case studies of statistical samples to represent not only the overall list of incidents, but also to represent the various (e.g., manufacturing, public assembly, educational) sectors affected. An approximation would be possible by assigning proper weights to various sub-groups within the statistical sample selected from the 260 incidents. Moreover, the indirect loss value is estimated as $1.9 billion, which is only 0.6% of the total cost. We would expect a larger value, especially because the economic impact of large-loss fires and all small fires summed together is expected to be significant.

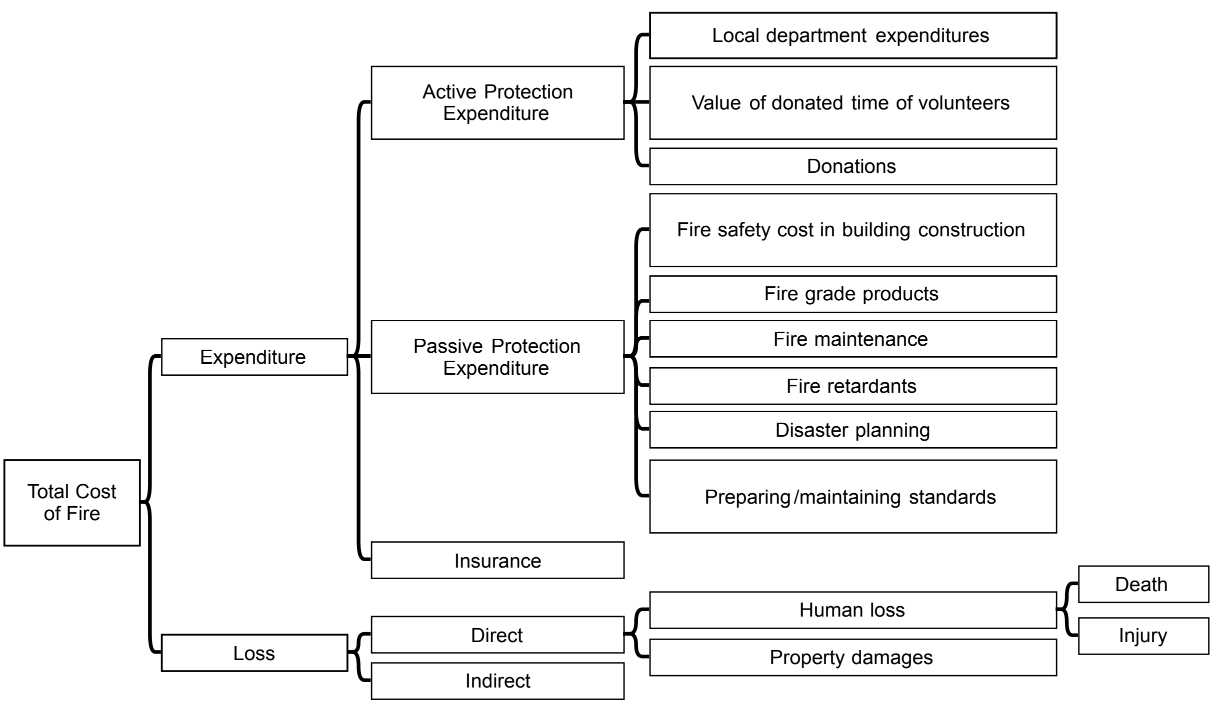

Figure 8: The taxonomy organizes and illustrates the expenditures and losses associated with the total cost of fire in the U.S. Each component shown is addressed in the calculations in Sections 2 and 3 to determine the 2014 total.

Uniform Protocol: One key contribution of this report is the development of a uniform protocol with the goal of clarifying fire economics language into mutually exclusive and quantifiable divisions. A uniform protocol is established to (a) define mutually exclusive costs and losses as well as ensure complete accounting of the cost of fire; and (b) highlight the need for calculating human loss values (injury and death) in the specific context of fire to create Value of Statistical Life (VSL) figures for firefighters and civilians. Firstly, the taxonomy in Figure 8 provides definitive categories and subsets of the total cost of fire which allows for a uniform distinction to be made between different types of cost. The breakdown of the total cost of fire into mutually exclusive expenditure and loss components are shown. In this taxonomy, expenditures reflect proactive spending on prevention, mitigation, and response while losses represent the damages caused by fire incidents. Direct losses are defined as stock values of tangible damage caused by fire. Indirect costs are defined as flow values which reflect intangible economic effects on the micro- and macroeconomic scales. Another aspect of the uniform protocol is the calculation of human losses. As explained in Section 3.1, this report develops a new term called the value of statistical injury (VSI). In addition, Section 3.1 also highlights the need for calculating the value of statistical life (VSL) specifically for the fire protection context. Current calculations of human losses are based on U.S. Consumer Product Safety Commission (CPSC) and the Department of Transportation (DoT), which may not always be fit to be used in cost-benefit analysis specific to fire protection. With regards to the methodology being used to calculate the values of the various subsets of costs, each section in the report provides the computation, along with the explanation and sample calculations, of each category allowing for these methods to be reproducible in coming years. Table 3 summarizes the various data sources used for calculating the total cost of fire. The “Remarks" column mentions the methods followed to estimate missing data, if any, from available data using extrapolation. The “Uncertainty score" column provides a relative uncertainty score, which is discussed in detail in Section 4.1.

Table 3: Data sources used for calculating the total cost of fire. Simple linear trend extrapolation was used to estimate missing data values. The uncertainty score represents a relative index of data availability, calculation convenience, and availability of uncertainty estimates of data sources. A score of 1 indicates lowest uncertainty and a score of 5 represents the highest uncertainty.

Components of cost	Data sources	Years	Uncertainty score	Remarks
Local fire department expenditure	NFPA, "The Total Cost of Fire in the United States"	1980-2011	2	Data for 1992 to 2011 is also available for download from U.S. Census Bureau's website.
	U.S. Census Bureau, "State & Local Government Finance: Historical data"	2012-2014		
Value of donated time of volunteer firefighters	NFPA, "U.S. Fire Department Profile"	1986-2014	3	Data for 1980-1985 was estimated using extrapolation
	NVFC provided the following estimates: Number of recruitments for all-volunteer and mostly-volunteer departments, FICA, Medicare, pension, and health insurance.	2017		The recruitment numbers were assumed the same for all years. Other estimates were reverse-calculated using percentage of salary estimates.
	Independent Sector, "The Value of Volunteer Time"	2001-2016		Data for 1980-2001 was estimated using extrapolation
	Bureau of Labor Statistics, "Occupational Outlook Handbook"	1996-2014		Data for 1980-1995 was estimated using extrapolation
Donations to fire departments	NFPA, "U.S. Fire Department Profile"	1986-2014	4	Data for 1980-1985 was estimated using extrapolation
Fire safety costs in building construction	U.S. Census Bureau, "Value of Construction Put in Place"	1993-2015	3	NFPA report has been used to obtain values for 1980-2011. For 2012-2014, the census data is used.
	NFPA, "The Total Cost of Fire in the United States"	1980-2011		
Fire maintenance	Meade, William P., "A first pass at computing the cost of fire in a modern society"; Local fire department expenditure	1993; 1980-2014	5	Meade's estimates for 1980-2014 were estimated based on the 1993 estimate and the local fire department expenses for 1980-2014.
Disaster planning			5	
Fire grade products	Meade, William P., "A first pass at computing the cost of fire in a modern society"; Federal Reserve Bank of St. Louis, "Manufacturing Sector: Real Output"	1993; 1987-2016	5	Meade's estimates for 1980-2014 were estimated based on the 1993 estimate and the US manufacturing outputs for 1980-2014. The manufacturing output values for 1980-1986 were estimated using extrapolation.
Fire retardants			5	
Preparing/maintaining standards			5	
Net fire insurance	NFPA, "The Total Cost of Fire in the United States"	1980-2011	4	Data for 2012-2014 was extrapolated from 1980-2011
Property loss	NFPA, "Fire loss in the United States"	2003-2015	3	Data for 1980-2002 was extrapolated from 2003-2015 data
Cost of statistical deaths	NFPA, "Fire loss in the United States"	2003-2015	2	Data for 1980-2002 was extrapolated from 2003-2015 data
	U.S. Department of Transportation, "Revised departmental guidance on valuation of a statistical life in economic analysis"	2010-2016		Data for 1980-2009 was estimated using extrapolation
Cost of statistical injuries	NFPA, "US Firefighter injuries"	1981-2014	2	Data for 1980 was estimated using extrapolation
	U.S. Department of Transportation, "Revised departmental guidance on valuation of a statistical life in economic analysis"	2010-2016		Data for 1980-2009 was estimated using extrapolation
Indirect loss	NFPA, "Fire loss in the United States"	2003-2015	5	Data for 1980-2002 was extrapolated from 2003-2015 data

Inflation Rate Calculation and Adjustment

For adjusting the actual costs to inflation, the Consumer Price Index inflation calculator provided by the Bureau of Labor Statistics (2017a) is used. Inflation rates calculated using the CPI are shown in Table 4.

Table 4: Inflation rates calculated using the Consumer Price Index. The inflation rate for each year shows the 2014 dollar equivalent of one dollar in that year, with the base month for each year being July. Source: Bureau of Labor Statistics (2017a).

Year	Inflation rate	Year	Inflation rate	Year	Inflation rate	Year	Inflation rate
1980	2.88	1989	1.92	1998	1.46	2007	1.14
1981	2.60	1990	1.83	1999	1.43	2008	1.08
1982	2.44	1991	1.75	2000	1.38	2009	1.11
1983	2.38	1992	1.70	2001	1.34	2010	1.09
1984	2.29	1993	1.65	2002	1.32	2011	1.05
1985	2.21	1994	1.61	2003	1.30	2012	1.04
1986	2.18	1995	1.56	2004	1.26	2013	1.02
1987	2.09	1996	1.52	2005	1.22	2014	1.00
1988	2.01	1997	1.48	2006	1.17		

Glossary of Definitions: Components of the Total Cost of Fire

This section provides concise definitions for the components of the total cost of fire. Detailed calculation methods and references to those methods are presented in Sections 2 and 3.

- **Local fire department expenditure:** The U.S. Census Bureau, provides the estimates the fire protection expenditure of local and state governments, which is presumably the sum of "all costs of local career fire departments and direct purchases by volunteer fire departments using funds from special taxes or transfers from other local agencies" (NFPA, 2014b). 95% of this estimated expenditure is presented in this report as the local fire department expenditure. The remaining 5% of the expenditure is assumed to be for non-fire-related incidents, e.g., medical emergencies.

- **Value of donated time of volunteer firefighters:** This is the cost of replacing the volunteer services with career services. This definition makes it clear that the objective of calculating the value of donated time of volunteer firefighters not to assign a dollar value to the donated number of hours, instead, is to calculate the value of the volunteer firefighters to the community. The actual value is derived not only from the services offered when volunteer firefighters are on duty, but from their availability in the community and their readiness to respond at any hour of the day without being compensated.

- **Donations to fire departments:** This includes all donations and support grants to fire departments from non-governmental organizations.

- **Fire safety costs in building construction:** This refers to new building "construction expenditures that are needed solely because of fire safety and fire protection considerations, such as compartmentalization features, built-in fire protection systems, and treatments of or limitations on exterior surfaces" (NFPA, 2014b). The costs of enhancing the fire protection features of already constructed buildings are not considered, however, these are expected to be captured to an extent by the 'fire maintenance' component.

- **Expenditure on fire grade products:** This is the “cost of meeting ‘fire grade’ standards in the manufacture of equipment, particularly electrical systems equipment and ‘smart’ equipment with its greater use of computer components" NFPA (2014b). A fire grade product is “an equipment that complied with Underwriters Laboratories or other standards designed to reduce the propensity of products to contribute to fires as a heat source or fuel source" (Meade, 1991).
- **Expenditure on fire maintenance:** This includes the “costs of fire maintenance, which was defined to include system maintenance, industrial fire brigades, and training programs for occupational fire protection and fire safety" (NFPA, 2014b).
- **Expenditure on fire retardants:** This is defined as the “costs of fire retardants and all product testing associated with design for fire safety" (NFPA, 2014b).
- **Expenditure on disaster planning:** This component represents the “costs of disaster recovery plans and backups" (NFPA, 2014b).
- **Expenditure on preparing/maintaining standards:** This includes the “costs of preparing and maintaining standards" (NFPA, 2014b).
- **Net fire insurance expenditure:** This is defined as the difference between the insurance premiums paid by property owners (personal and commercial) for insuring their property from fire and the damages claimed from insurers. There are multiple insurance types considered, such as exclusive fire insurances as well as homeowner, commercial, and farm owner multi-peril insurances. The fire insurance part of multi-peril premiums are estimated as a fraction of the total multi-peril premiums, and the damages claimed are estimated as a fraction of the total property losses (direct and indirect).
- **Direct property loss:** This represents the dollar value of the total damages to properties and contents, due to fires.
- **Cost of statistical deaths:** This is defined as a monetary equivalent of all deaths due to fire, and is calculated using the value of statistical life (VSL). The concept of VSL is to quantify the monetary value of increased safety, and in particular, the value of reducing the risk of mortality (Andersson and Treich, 2011). Also sometimes referred to as the “value of life," VSL is “the monetary value of a mortality risk reduction that would prevent one statistical death." The (U.S. Department of Transportation, 2017) defines VSL as “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," and calculates VSL using the Willingness to Pay (WTP) approach. In short, each death due to fire is considered to be associated with a cost equivalent to the VSL value.
- **Cost of statistical injuries:** This is defined as a monetary equivalent of all injuries due to fire, and is calculated using the value of statistical life (VSI). The VSI is a new term created in this report, which is constructed based on the Department of Transportation’s (DoT) term: ‘value of preventing injuries.’ The concept of this term, and in turn that of the VSI, is to assign a monetary value to an injury that would be a fraction of the VSL, based on the severity of the injury.
- **Indirect loss:** Also defined as the ‘economic impact of fire,’ indirect losses represent the net monetary downstream effects of fires on the economy. Indirect losses from commercial/industrial building fires may refer to a reduction in turnover dollars for an interrupted or closed business, or jobs that are lost, due to fires. Indirect losses in the context of residential building fires may refer

to the various inconvenience-related costs to primarily the residents and also the public, due to fire.

2 Expenditure Components of the Total Cost of Fire

Expenditure is defined as the money spent by society (including governments, fire departments, and others) on fire protection. There are three expenditure components: active fire protection expenditure, passive fire protection expenditure, and net fire insurance. It is agreed that there could be differences in passive/active fire protection measures for different types of fires (such as residential or commercial). However, to our best knowledge, sufficient data is not currently available to segregate these expenditure components into fire types.

The definitions used for active and passive fire protection expenditures in this report differ slightly from their conventional definitions. In this report, active fire protection expenditure is defined as society's expenditure on human-led prevention and suppression efforts, or in other words, fire department activities. Passive fire protection expenditure is the expenditure on static or non-human-led prevention and suppression devices and programs. Conventionally, "active fire protection" encompasses the electrical/mechanical suppression systems that are activated only when fire is present (e.g., fire sensors and alarms, notification systems, sprinklers, water supplies, and smoke management systems). A "passive fire protection" system is an integral part of the building layout and materials of construction (e.g., partitions to confine the fire or fire-resistive materials used for construction).

Also, some other expenditures (e.g., cost of water for firefighting) are either partially or completely excluded from the calculations in this report. These are discussed in Section 4.1.

2.1 Active Protection Expenditure

Active protection expenditure includes local department expenditures, the value of donated time of volunteer firefighters, and donations to fire departments. The local department expenditures are directly reported by fire-departments, and thus require no estimation, unlike the donated time of volunteers and donations to fire departments.

Local Fire Department Expenditure

Most fire departments are funded by local governments. Industrial fire departments and forest fire departments are exceptions, as the former is funded by private companies and the latter is funded by federal/state governments. The former is excluded from this report as they are very few in number, and the latter is not considered as wildfires are excluded from the analysis. All previous reports on the total cost of fire in the U.S. have used the Statistical Abstract of the United States (U.S. Census Bureau, 2017e) as the source for local fire department expenditure. However, the Census Bureau discontinued the publishing of the Statistical Abstract of the United States in 2012, thus, in this report, the Census Bureau's reports[4] on State & Local Government Finance (U.S. Census Bureau, 2017c) are used as the alternate source of data for calculating the local fire department expenditure.

The expenditures of fire departments are not solely for providing fire protection services. Fire departments provide emergency medical services (EMS) including ambulance and other specialty services such as for emergency management, hazardous materials, and technical rescue. These services together may be represented using the term 'non-fire-related,' and the corresponding expenses need to be subtracted from the Census-Bureau-reported expenditure values, to calculate the 'fire-related' expenses. The potential significance of non-fire-related expenses in relation to the total fire department

[4]This data is available for download from the Census Bureau's website for the years 1992-2014 (U.S. Census Bureau, 2017c). For years prior to 1992, the data is available upon request (U.S. Census Bureau, 2017d).

expenses is underlined by: (i) the total number of fire-related calls to fire departments has dropped from 2.3 million to 1.3 million (40.8%); and (ii) the total number of non-fire-related calls (that include calls for medical aid, false alarms, mutual aid, hazardous materials, and other reasons) has increased from 9.6 million to 32.3 million (235.7%) (NFPA, 2017a). Of all the non-fire-related services, EMS is inevitable and the most prominent, and the provision of EMS incurs operational expenses that are already accounted for in the local government funding. Only 39% of fire departments do not offer EMS (NFPA, 2016d). Furthermore, NFPA (2016a) reports that out of the $\approx$ 33.6 million calls received by fire departments across the U.S. in 2015, $\approx$ 21.5 million (64%) were for medical aid responses (ambulance, EMS, and rescue). USFA (2017a) also reports that 64% of the fire department calls in 2014 required EMS and rescue services. However, this information is not sufficient to estimate the expenses on EMS and other medical-aid-related services that fire departments provide. Reviewing the annual budgets of all fire departments (or at least a representative sample) would help estimate the non-fire-related expenditure of fire departments across the U.S., however this is beyond the scope of this report. Nevertheless, we present three cases: (i) In 2013, roughly 5% of the expenditures of the City of Burlington Fire Department's (Vermont) were EMS-related (City of Burlington Fire Department, Vermont, 2013); (ii) in 2016, nearly 8% of the total expenditures of the City of Seattle Fire Department's were for EMS responses, wages, and equipment maintenance (Seattle Fire Department, 2016); and (iii) San Diego Fire Department's 2012 expenditures show that 8% of expenses were for lifeguard services (San Diego Fire Department, 2012). These three examples indicate that the percentage expenditure of fire departments on non-fire-related (primarily medical-aid-related) services are significant (at least 5%), however, not necessarily as high as the percentage of non-fire-related calls (64% as per USFA, 2017a). Thus, we propose that 95% of the expenditure on fire protection as listed by the U.S. Census Bureau is fire-related, whereas the remaining 5% is spent on non-fire related services. It may be possible that a review of annual budgets of more fire departments would reveal a higher percentage figure for the non-fire-related expenses, however we do not want to overestimate without any solid evidence. Arguably, the 5% figure for non-fire-related services is large enough to be significant (compared with 0% in the previous version of this report; NFPA, 2014b) and small enough to be a safe first step towards more accurate calculation. Future works could explore fire department budgets extensively and provide a more accurate estimate of fire-related and non-fire-related expenditures.

Sample calculation on local fire department expenditures:
State & local government expenditure on fire protection (from US Census) = \$44.1 billion;
Net fire protection expenditure = \$44.1 billion$\times$ 0.95 = \$41.9 billion.

Value of Donated Time of Volunteer Firefighters

Volunteer fire services form an indispensable component of fire protection in the U.S. While it is extremely important to measure the value of time donated by volunteer firefighters, this valuation is not easily tractable. This report identifies two broad approaches to calculate the value of donated time of volunteer firefighters. The first approach attempts to assess the value of the volunteer services. The second approach calculates the cost of replacing the volunteer services with career services. The National Volunteer Fire Council (NVFC) strongly supports the second approach, which is thus used in this report. Adoption of this method should not be interpreted as an acknowledgment that eventually all volunteer firefighters would be replaced by career firefighters. If the quantity of time is the sole measure of the value of time donated by volunteer firefighters, and these hours are used in the calculations explicitly (e.g., by estimating the value of services each hour on the call, using the median annual salary of a firefighter of \$45,970 provided by the Bureau of Labor Statistics (Bureau of Labor Statistics, 2017b)) it will underestimate the actual value of the volunteer services. For example, if a volunteer firefighter responds to an emergency from 2:00 A.M. to 4:00 A.M., assigning an hourly dollar value to to those two hours of volunteer time is futile. The actual value is derived not only from the services offered when volunteer firefighters are on duty, but from their availability in the community and their readiness to respond at any hour of the day without being compensated. Moreover, considering that this report is intended to act as a resource to policymakers and decision makers in fire protection, the more meaningful approach from a public policy perspective should account for the value of volunteer services as well as the value of availability and readiness. Nevertheless, the following paragraphs list the various methodologies broadly classified into the two approaches, as mentioned earlier, and present pros and cons of each method.

The methodology (Method 1) used in NFPA (2014b) follows the second approach. In that report, the value of donated time of volunteer firefighters is defined as "the alternative cost if all communities currently covered by volunteer fire departments were to be protected by career firefighters." However, calculating the number of firefighters needed to cover a particular region based only on its population density may not give the best results. The reasons are: (i) the distribution of population varies largely across the country, due to terrain and other geographical features; and (ii) the average time donated by a volunteer firefighter is far less compared to the average full time that a career firefighter works.

Another potential method (Method 2) that follows the second approach is using the rates of career firefighters per 1000 people protected for different population sizes ($<$2,500, 2,500 to 4,999, ... 500,000 to 999,999, and $>$1,000,000) (NFPA, 2016d). These rates could be extrapolated to find the population groups currently being served by volunteer firefighters, in order to get the number of career firefighters needed to replace volunteer firefighters. The expenditure on these career firefighters would be the value of volunteer firefighters' donated time. Although reasonable, this also may not be the most appropriate method, as most career firefighters serve urban or semi-urban areas that have high population densities. The high career firefighter rates for these areas cannot be applied to rural areas with low population densities.

An alternative (Method 3) using the first approach is to estimate the actual donated time by all volunteer firefighters, and then calculate the number of career firefighters needed to cover this total time. This will require more data (e.g., from NFPA Fire Service Survey or from NFPA Survey of Fire Departments for U.S. Fire Experience). In the absence of data, the next best option is to use estimates for the average number of hours donated by a volunteer firefighter as well as for the average number of working hours of a career firefighter. Based on the input from NVFC, it is estimated that a volunteer firefighter donates 10 hours per week. Also, it is safe to assume that a career firefighter works for at least 50 hours per week (Bureau of Labor Statistics, 2017c). Using these estimates, the number of career firefighters needed to cover the total time donated by volunteer firefighters is 788,250$\times$ 10/50 = 157,650. The corresponding cost is calculated as 157,650$\times$ 41.9/346,150 = $19.0 billion, which is far less than the $140 billion estimated by NFPA (2014b). Our report uses an alternate and simple approach, which replaces the existing volunteer firefighters with the same number of career firefighters. The corresponding cost, although almost 30% less compared to NFPA (2014b) estimate, could be reasonable since as mentioned previously, volunteer firefighters donate far less time than career firefighters. Here, we use the cost of local fire department expenditure for fire-related incidents = $41.9 billion (instead of the personnel expenses = 0.85$\times$ $44.1 = $37.4 billion), because replacing 788,250 volunteer firefighters with career firefighters would require relocating many existing fire departments and/or locating new fire departments, which would incur much more than personnel expenses.

Another method (Method 4), along the first approach, is to use the 'national value of volunteer time,' which is $24.14 per hour in 2016, as given by Independent Sector (2017). Multiplying this hourly rate with the estimated national total of hours contributed by all volunteer firefighters will give the value of donated time of volunteer firefighters. For example, for the year 2014, the value of volunteer time is $23.07 per hour (Independent Sector, 2017). The number of volunteer firefighters in 2014 was 788,250 (NFPA, 2016d). Using the NVFC estimate of 10 hours per week donated by a volunteer firefighter, the total value for 2014 would be: $\$23.07 \times 788{,}250 \times 10 \times 52$ = \$9.4 billion. A 1993 study (Pilsworth, 1993) estimates the “economic worth or the value of volunteer labor used in the provision of fire protection services to the State of Montana" to be \$12.4 million. That study mentions that there were 8,845 estimated volunteer firefighters in Montana in 1993. The corresponding national figure was 795,400 (NFPA, 2016d). Extrapolating the data given in Independent Sector (2017), the national value of volunteer time (\$11.89 per hour) is estimated to be 3.07 times that of Montana (\$3.87 per hour)[5]. Hence, the \$12.4 million figure of Montana in 1993 could be extrapolated to find the national figure as \$12.4 million $\times 795{,}400/8{,}845 \times 3.07$ = \$3.4 billion for 1993, assuming that the average number of hours contributed by volunteer firefighters was the same for all states. The previous methodology that uses the 10 hours per week estimate gives a corresponding value of $\$11.89 \times 795{,}400 \times 10 \times 52$ = \$4.9 billion. Although this is about 44% greater than the value extrapolated from the Montana study result of \$3.4 billion, these two calculations are closer when compared with the other methodologies that provide values in the order of \$100 billion. However, the value of volunteer hours methodology is not adopted in this report.

Finally, based on detailed inputs from NVFC, we find the following method (Method 5) to be the most comprehensive and meaningful. This method is along the second approach, and hence estimates the cost of replacing volunteer firefighters with career firefighters. NVFC points out that the Bureau of Labor Statistics (BLS) estimate of the median annual firefighter salary (\$45,970 in 2014) does not include benefits or taxes. After adding Federal Insurance Contributions Act (FICA) taxes at 6.20%, Medicare at 1.45%, workers compensations insurance (WCI) at 5.00%, with a \$2,500 pension, and \$14,000 health insurance, the revised median annual salary is \$68,285. The calculation of how many new firefighters need to be recruited needs to be based on the four tiers of departments and personnel demography: all-volunteer, mostly-volunteer, mostly-career, and all-career (NFPA, 2016d). We consider only all-volunteer and mostly-volunteer departments for our calculation. Again, based on NVFC inputs, every department ideally would have a minimum of eight firefighters available per shift to respond. However, it is very likely that all-volunteer and mostly-volunteer departments have lower call volumes and protect communities with small tax bases. Hence the NVFC estimates an average of six firefighters needed per shift. They also conclude that mostly-volunteer departments already have half of the career personnel in place that they need. The NVFC suggest using a standard 4.2 shift system and a 5:1 member-to-officer ratio. Hence, the respective personnel requirements are calculated as 6×4.2 = 25.2 + 5 officers = 30 career personnel for all-volunteer and 3×4.2 = 12.6 + 3 officers = 16 career personnel for mostly-volunteer. The 19,915 all-volunteer and 5,580 mostly-volunteer fire departments (NFPA, 2016d) would require 686,730 ($19{,}915 \times 30 + 5{,}580 \times 16$) newly recruited career firefighters to replace the existing volunteer firefighters. With a median annual salary of \$45,970, the total cost of replacement is \$46.9 billion.

The \$46.9 billion calculated using Method 5, although significantly less than Method 1’s estimate of about \$140 billion, presents a more reasonable figure based on the number of volunteer fire departments that could be replaced with career personnel, also accounting for existing career personnel in mostly-volunteer fire departments. Method 5 calculates that 686,730 career firefighters need to be recruited in 2014 (to add to the 346,150 on payroll) to replace the 788,250 volunteer firefighters. Method 1 estimates the actual need of the community in terms of response time, by calculating the cost to replace volunteer firefighters with four times the number of career firefighters (which is 1,384,600 in addition to the existing 346,150 in 2014). This is two times the number proposed in Method 5.

While Method 5 is the most reasonable, we would like to note that: (i) All of the career firefighters hired will be full-time, when in fact, many departments may rely on part-time career personnel. (ii) The number of active volunteer firefighters who are available for service could be less than the number of

[5]It is unclear whether Independent Sector (2017) gives 2016 dollar values for all years or the actual dollar values.

volunteers on the fire departments' roster. (iii) The staffing formula used to calculate the number of career firefighters needed to replace volunteers may not be necessarily representative for all career fire departments. (iv) The average firefighter salary may not be the best choice for the salary of a career firefighter who would replace a volunteer firefighter, since career firefighters are mostly from large urban cities and population centers, in which the number of volunteer firefighters is very few. (v) There will be no department consolidation, which is actually likely to occur if smaller departments were to hire career personnel. (vi) All departments are considered to have only one station, when there could be some that have multiple stations, particularly in areas where consolidation has already occurred. (vii) Replacing volunteers in mostly-career departments are not considered. (viii) The cost of upgrading stations, equipment, and vehicles, which would be necessary in departments in many states in order to meet Occupational Safety and Health Administration requirements, is ignored. (ix) The 2017 estimates for insurance and pension benefits have been used for all years from 1980 to 2014. Some of these benefit plans may not have been instated from 1980, and the benefit numbers vary. As these benefits constitute about 50% of the final estimate of salary, a considerable margin of uncertainty could be expected, although less for the recent years.

In summary, this report presents Method 5 as the most reasonable method. Other methods too offer many valid contributions, and may be used if supplemented with more accurate data which is currently difficult to obtain. Methods 1 through 5 clearly present the trade-off between the definitions of "cost to replace all volunteer fire departments with career" and "the actual value of the donated time of volunteer firefighters." This report documents an exhaustive description of all these methods in order to motivate more research that could fill the existing gaps in methodology and data required to calculate the value of donated time of volunteer firefighters.

Sample calculation for the value of time donated by volunteer firefighters (using Method 5):

$$
\begin{aligned}
\text{Number of all-volunteer departments} &= 19,915 \\
\text{Number of mostly-volunteer departments} &= 5,580 \\
\text{Member to officer ratio for each department} &= 5:1
\end{aligned}
$$

$$
\begin{aligned}
&\text{Number of career personnel needed for each} \\
&\text{all-volunteer department, based on a 4.2 shift system} = 6 \times 4.2 = 25.2 \text{ members} \\
&\qquad + 5 \text{ officers} \approx 30
\end{aligned}
$$

$$
\begin{aligned}
&\text{Number of career personnel needed for each} \\
&\text{mostly-volunteer department, based on a 4.2 shift system} = 3 \times 4.2 = 12.6 \text{ members} \\
&\qquad + 3 \text{ officers} \approx 16
\end{aligned}
$$

$$
\begin{aligned}
&\text{Total number of career personnel needed} \\
&\text{to replace volunteer personnel} = (19,915 \times 30) + (5,580 \times 16) \\
&\qquad = 686,730
\end{aligned}
$$

$$
\text{BLS estimate of a firefighter's annual salary} = \$45,970
$$

$$
\begin{aligned}
&\text{NVFC estimate of a firefighter's annual salary adding 6.2\%} \\
&\text{FICA, 1.45\% Medicare, 5\% WCI, \$2,500 pension, and} \\
&\text{\$14,000 health insurance to the BLS estimate} = \$68,285
\end{aligned}
$$

$$
\begin{aligned}
\text{Total cost of replacement} &= 686,730 \times 68,285 \\
&= \$46.9 \text{ billion.}
\end{aligned}
$$

Donations to Fire Departments

As the value of donated time of volunteer firefighters is included as a component in the total cost of fire, it should follow that all fire-related donations be included. Although donations are just an operational need of the fire departments and are not expenditure from the point of view of fire departments, it could be seen as the community's expenditure. That is why in the taxonomy in Figure 8, “donations" is a component of “active protection expenditure," instead of merging with “local department expenditure." Due to lack of funding, these fire departments rely on donations and support grants from non-governmental organizations such as Firefighters Support Foundation (FSF), as many fire departments in the U.S. are underfunded and volunteer-based (FSF, 2017). The extent of donations may vary between different regions. In Tennessee, roughly one-quarter of fire departments (181 out of 730) rely on donations for more than 50% of their revenue (TACIR, 2013). Almost all of these (177 out of 181) are volunteer fire departments. Lack of publicized reports of these donations makes it difficult to perform a nationwide analysis. However, there are some articles about substantially large donations: (1) Local firefighter associations donated equipment worth $36,000 to Canton Fire Department, Connecticut; (2) The Clayton and Katherine Dockstader Foundation donated $500,000 to the Galway Volunteer Fire Department, New York, to break ground on a new fire station (FireChief.com, 2016); (3) A local nonprofit organization donated $245,000 to Lincolnville Fire Department, Maine, for a “Fire Truck Fund" reserve account, for building a new fire station, and for personnel recruitment and retention (FireApparatusMagazine.com, 2011); (4) Duracell committed to donate a minimum of 20 million batteries to volunteer fire departments through the “Power Those Who Protect Us" program (Fire Engineering, 2011).

Although it is very likely that donations would be only a small fraction of the total cost of fire, this report documents an estimation method as follows. Estimating this component helps not only in improving accuracy in the measurement of the total cost, but also in understanding by how much the volunteer fire departments are underfunded. If the Tennessee data (TACIR, 2013) is extrapolated to get a rough estimate for the lower bound for donations to fire departments in the U.S., a quarter of the fire departments in the U.S. (29,980/4 = 7,495, in the year 2014) depend on donations for 50% of their revenue. Assuming that these fire departments receiving donations are the ones with the lowest expenditures, it is possible to approximate the lower bound on the donations if the distribution of fire departments' expenditures is available. However, as that data is not available, we assume that the fire department expenditures follow a 'truncated normal distribution.' The truncated normal function has characteristics similar to that of the popularly used normal distribution (Burkardt, 2014), with the advantage that truncation enables defining appropriate lower bound (≥ 0) and upper bound ($\leq$ total expenditure). In this way, we generated simulated distributions for the expenditures of 29,980 departments in the U.S. for the years 1980-2014, such that the mean and the standard deviation of individual fire department expenditures are 3.3% and 5% of the total expenditure. For each year, the total donations were estimated as 50% of the sum of the lowest quarter of fire departments expenditures. For example, for 2014, the estimated total amount of donations to fire departments is $1.3 billion.

Sample calculation for donations to fire departments:

$$\begin{aligned}
\text{Number of fire departments} &= 29,980 \\
\text{Local fire department expenditures} &= \$41.9 \text{ billion} \\
\text{Sum of expenditures of a quarter of fire departments} &= \$2.6 \text{ billion} \\
\text{(assuming a truncated normal distribution of expenditures)} & \\
\\
\text{Lower bound on donations} &= 50\% \text{ of } \$2.6 \text{ billion} \\
&= \$1.3 \text{ billion}
\end{aligned}$$

2.2 Passive Protection Expenditure

Passive expenditure consists of all “non-active" expenditure components which include the fire protection part of building construction expenditure and the “costs of fire protection not included in building construction part of core" as explained in NFPA (2014b).

Fire Safety Costs in Building Construction

The objective is to estimate the national-level cost of building construction for fire safety. All previous NFPA reports on the Total Cost of Fire in the U.S. have used the Statistical Abstract of the United States (U.S. Census Bureau, 2017e) as the source for getting the annual building construction costs in the U.S. These costs were grouped into four categories (private residential, public building, private non-residential, and other private building). Then, multipliers based on Apostolow et al. (1978) and Meade (1991) were used to calculate what fraction of these costs were due to fire protection. The formula used by NFPA (2014b) is:

$$\begin{aligned}\text{Cost of building fire protection} = {} & [2.5\% \text{ x value of private residential building construction})] \\ & + [12.0\% \text{ x (value of nonresidential construction excluding} \\ & \text{communications, power, and railroad)]} \\ & + [4.0\% \text{ x (value of state and local government construction} \\ & \text{excluding runways, railroads, power, highways and streets,} \\ & \text{sewage and waste disposal, water supply, conservation and} \\ & \text{development)]}\end{aligned}$$

We use an alternate method for calculating the building construction costs for fire protection, as it is very likely that the multipliers used in the nearly 40-year-old WPI study need updating. In this report, the Census Bureau's Value of Construction Put in Place Survey (VIP) (U.S. Census Bureau, 2017b) is the source of data for calculating the building construction costs for each year.[6] We use the same methodology in NFPA (2014b) to calculate the building safety costs in fire protection. The data for 2012 to 2014 is updated using U.S. Census Bureau (2017a) data. There is some discontinuity observed in the 2011 to 2013 values. Also, not all states have adopted current codes or editions of codes, which introduces variability in the calculations since independent state-level analyses are aggregated to form a national-level estimate. However, as the scope of this report is to estimate an average at the national level, not necessarily on a state level, performing an analysis of every state to estimate the corresponding fire safety costs in building construction is beyond the scope of this project. In the sample calculation below, 'value of construction put in place' is the term used by the Census Bureau to denote the value of construction in the United States, as the calculation is done at the national level.

Sample calculation for fire safety costs in building construction:

$$\begin{aligned}\text{Value of construction put in place (private residential)} &= \$369,793 \text{ million} \\ \text{Value of construction put in place (private non-residential)} &= \$359,707 \text{ million} \\ \text{Value of construction put in place (public total)} &= \$276,128 \text{ million} \\ \text{Fire safety costs in building construction} &= 2.5\% \text{ of } \$369,793 \text{ million} \\ &+ 12.0\% \text{ of } \$359,707 \text{ million} \\ &+ 4.0\% \text{ of } \$276,128 \text{ million} \\ &= \$57.4 \text{ billion.}\end{aligned}$$

Expenditure on Fire Grade Products, Fire Maintenance, Fire Retardants, Disaster Planning, and Preparing/Maintaining Standards

These components of costs are compiled in the section titled "Other Economic Costs" in NFPA (2014b), and named as "Costs of Fire Protection Not Included in Building Construction Part of Core." For each of these components, the same definitions used in NFPA (2014b) are supported in this report, as given below:

- Expenditure on Fire Grade Products: "Costs of meeting 'fire grade' standards in the manufacture of equipment, particularly electrical systems equipment and 'smart' equipment with its greater use of computer components. 'Fire grade' is the term used in Meade (1991) for equipment that complied with Underwriters Laboratories or other standards designed to reduce the propensity of products to contribute to fires as a heat source or fuel source."

[6]This data is available for download from U.S. Census Bureau's website for the years 1993-2016 (U.S. Census Bureau, 2017a).

- Expenditure on Fire Maintenance: “Costs of fire maintenance, which was defined to include system maintenance, industrial fire brigades, and training programs for occupational fire protection and fire safety."

- Expenditure on Fire Retardants: “Costs of fire retardants and all product testing associated with design for fire safety."

- Expenditure on Disaster Planning: “Costs of disaster recovery plans and backups."

- Expenditure on Preparing/Maintaining Standards: “Costs of preparing and maintaining standards."

For estimating five miscellaneous categories (fire grade products, fire maintenance, fire retardants, disaster planning, and preparing/maintaining standards) of passive fire protection expenditure, Meade (1991) remains by far the best available data source. However, this study calculated the expenditure for the year 1991, and this value had been used as a constant ($27.8 billion, which is equivalent to $45.9 billion in 2011 dollars using the Consumer Price Index) for every year (1980-2011), in (NFPA, 2014b). Adjustment of these values with respect to inflation does not accurately reflect the actual changes in these values since or prior to the 1991 study. In order to standardize the calculation of passive protection costs, the expenditure on fire grade products, fire retardants, and preparing/maintaining standards have been adjusted to the U.S. manufacturing output (Federal Reserve Bank of St. Louis, 2017). This has been done so as the production and consumption of fire grade products and fire retardants, as well as the expenditure on standards are all expected to be related to the manufacturing output. The expenditure on fire maintenance and disaster planning are adjusted to the fire department expenditure calculated in Section 2.1. This has been done so as maintenance activities and disaster planning are expected to be related to fire department activities. These five categories of passive fire protection expenditure have similar calculation methodologies, and hence could be merged into a single category. This has been left for future work, as the definitions of these five categories may need to be revised as well, as explained in Section 4.1.

Sample calculation for passive protection expenditure:

$$
\begin{aligned}
\text{U.S. Manufacturing ouput indicator in 1991} &= 74.3\\
\text{U.S. Manufacturing ouput indicator in 2014} &= 127.4\\
\text{Fire department expenses in 1991} &= \$13.0 \text{ billion}\\
\text{Fire department expenses in 2014} &= \$41.9 \text{ billion}\\
\text{Consumer Price Index for 2014 based on 1991} &= 1.8\\
\text{Expenditure on Fire Grade Products in 1991} &= \$18.0 \text{ billion}\\
\text{Expenditure on Fire Grade Products in 2014} &= \$18.0 \times 1.8 \times 127.4/74.3 = \$54.0 \text{ billion}\\
\text{Expenditure on Fire Maintenance in 1991} &= \$6.5 \text{ billion}\\
\text{Expenditure on Fire Maintenance in 2014} &= \$6.5 \times 1.8 \times 41.9/13.0 = \$36.5 \text{ billion}\\
\text{Expenditure on Fire Retardants in 1991} &= \$2.5 \text{ billion}\\
\text{Expenditure on Fire Retardants in 2014} &= \$2.5 \times 1.8 \times 127.4/74.3 = \$7.5 \text{ billion}\\
\text{Expenditure on Disaster Planning in 1991} &= \$0.6 \text{ billion}\\
\text{Expenditure on Disaster Planning in 2014} &= \$0.6 \times 1.8 \times 41.9/13.0 = \$3.4 \text{ billion}
\end{aligned}
$$

$$
\begin{aligned}
\text{Expenditure on Preparing/}&\\
\text{Maintaining Standards in 1991} &= \$0.2 \text{ billion}
\end{aligned}
$$

$$
\begin{aligned}
\text{Expenditure on Preparing/}&\\
\text{Maintaining Standards in 2014} &= \$0.2 \times 1.8 \times 127.4/74.3 = \$0.6 \text{ billion}
\end{aligned}
$$

$$
\begin{aligned}
\text{Total} &= \$(54.0 + 36.5 + 7.5 + 3.4 + 0.6) \text{ billion}\\
&= \$102.0 \text{ billion}
\end{aligned}
$$

2.3 Net Fire Insurance Expenditure

We use the same formula used in (NFPA, 2014b) to calculate the net fire insurance expenditure:

$$
\begin{aligned}
\text{Net fire insurance} = &\{(\text{Premiums}) \text{ estimated as [Fire insurance premiums]}\\
&+ [21\% \times (\text{homeowner, commercial, \& farm owner multi-peril premiums})]\}\\
&- \{(\text{Losses}) \text{ estimated as [NFPA estimate of direct property damage in fires}\\
&\quad \text{reported to fire departments, excluding vehicle and outdoor properties]}\\
&- [50\% \times (\text{NFPA estimate of indirect loss})]\}
\end{aligned}
$$

The National Association of Insurance Commissioners (NAIC) 2015 report NAIC (2015) gives information about homeownersâĂŹ, commercial, and farm ownersâĂŹ multiple peril property and casualty premium values as $86.3 billion, $38.9 billion and $13.6 billion, respectively, in the US in 2014. The 2014 report (NFPA, 2014b) estimated that 21% of these multi-peril premiums were for fire and lightning. The fire premium was $12.6 billion. Thus, the total fire insurance premium for 2014 is estimated as 0.21×($86.3 billion + $38.9 billion + $13.6 billion) + $12.6 billion = $41.8 billion. To calculate the net fire insurance expenditure, again the same methodology is followed from the 2014 report, that is: Net fire insurance expenditure for 2014 = premiums - direct property loss estimate - 50% of indirect property loss estimate = $41.8 billion - $9.8 billion - $1.9 billion = $30.9 billion. Direct loss of $9.8 billion is from NFPAâĂŹs report: Fire Loss in the United States (NFPA, 2016a). The total direct property loss is $11.6 billion, however, from this, outdoor fires (wildland/grass/shrub) and vehicle/highway fires are excluded. One challenge in calculating the net fire insurance costs for years prior to 2014 is the availability of NAIC data on the premium values for those years. There is no publicly available report or source that provides this information.

We acknowledge that there could be year-to-year variations, however, we use estimates of 21% and 50% for premiums and indirect loss claims, respectively, as used in NFPA (2014b). That report says that the 21% estimate was generated in the 1990's based on a conversation with a staff person at the Insurance Services Office (ISO), and that this number has been verified for the 1998-2002 period as well. Furthermore, as the losses used in the NFPA formula above are those reported by fire departments (arguably well before the insurance claim is written), these reported losses may not be the same as the actual losses recovered by the property owners through insurance. The accuracy of the net fire insurance calculation could be improved significantly if the actual un-recovered losses could be estimated. However, this is an area that could be flagged for future research, as accurate estimation of the actual un-recovered losses would be possible only with more data from the insurance industry that is currently unavailable.

For this report, the ISO and the Insurance Information Institute (III) shared some inputs from the insurance industry's perspective. The ISO estimate for the total fire losses for a particular year is the sum of their estimates for three lines of business: Commercial Fire, Commercial Multiple Peril (CMP), and Homeowners. ISO's Fast Track data, A. M. Best's data, as well as FAIR plan loss data[7] are used for calculating "blow-up factors" and subsequently the fire losses, as shown in the equation below.

$$\begin{aligned}
\text{Fire losses for each line of business} &= (\text{Fast Track incurred losses}) \times (\text{blow-up factor}) \\
&\times (\text{\% of losses reported as fire}) \\
\text{Blow-up factor} &= (\text{Ratio of A.M. Best to Fast Track}) \\
&\times (\text{FAIR Plan loading factor}) \\
&\times (\text{factor to account for uninsured losses})
\end{aligned} \tag{1}$$

The percent of fire losses reported for a particular line of business is the ratio of losses reported under the fire subline for that line divided by corresponding total losses. ISO and III provided the values of the above parameters for 2012, 2013, and 2014, which were 19.9%, 21.0%, and 25.2% (average = 22.0%) for CMP and 25.0%, 29.9%, and 21.1% (average = 25.3%) for Homeowners, respectively. Obviously, the fire losses are 100% of the total losses for Commercial Fire every year. A reasonable assumption is made that the portion of premiums for a line of business that provide insurance for the losses under the fire subline is equal to the respective percentage estimate of fire losses. If the total premiums for the three lines of businesses are available, then the fire portion of premiums can be calculated using the aforementioned methodology. These values can be used in the NFPA formula for net fire insurance, provided the insurance industry's own estimate of the direct and indirect property losses are due to fire. However, due to the following reasons, the recent ISO/III data is not used for the final calculations: (i) ISO's data on percentage estimates on the 'fire-share' of losses for farm-owners insurance as well as indirect property losses due to fire are not available. (ii) Although the percentage values for 2012, 2013, and 2014 are available, there appears to be large year-to-year variations in these. Consequently, it will be difficult to estimate the values for other years (1980-2011) from these, using regression or other techniques. Nevertheless, it is possible to calculate the net fire insurance expenditure component more

[7] For more information, visit: http://www.verisk.com/insurance/products/iso-actuarial-service.html; http://www.ambest.com/sales/statementus/; and http://www.iii.org/article/what-if-i-cant-get-coverage.

accurately by replacing the 21% constant value used in Equation 2.3 with yearly percentage values that can potentially be obtained from the insurance industry.

Sample calculation for net fire insurance:

$$
\begin{aligned}
\text{Total fire-related premiums for 2014} &= \$37.7 \text{ billion} \\
\text{Direct property loss in 2014} &= \$13.8 \text{ billion} \\
\text{Indirect property loss in 2014} &= \$2.0 \text{ billion} \\
\text{Net fire insurance} &= \$(37.7 - 13.8 - 0.5 \times 2.0) \text{ billion} \\
&= \$23.6 \text{ billion}
\end{aligned}
$$

3 Loss Components of the Total Cost of Fire

3.1 Direct Loss

Direct loss from fires includes human losses and property losses. It is necessary to define the value of statistical life to evaluate the damage from human loss in fire incidents. Property damage, on the other hand, is a sum from the collection of reported data from fire departments. This is thus, already standardized. However, while estimating the direct losses may appear straightforward, it involves many challenges that are described in Section 4.1.

Direct Property Loss
The direct property loss is obtained from the NFPA's yearly report on Fire Loss in the United States NFPA (2016a). That report separates direct property losses into: public assembly; educational; institutional; residential; stores and offices; industry, utility, and defense; storage in structures; and special structures. As the Fire Loss report already presents details on the breakdown of direct property loss, they are not described here.

Sample calculation for direct property loss:
Property loss = $13.2 billion (NFPA, 2016a).

Human Losses
We use the NFPA's statistics on firefighter and civilian deaths and injuries (NFPA, 2016a,c, 2017b) to calculate the total human losses due to fires. To estimate the cost of deaths, we use the value of statistical life (VSL), and to estimate the cost of injuries, we introduce a new term, namely "the Value of a Statistical Injury (VSI)." We acknowledge that the cost of deaths do not consider the effects of long-term injuries or illnesses.

The VSL has been widely studied in welfare economics, and one of its primary application areas has been transportation risk analysis. Andersson and Treich (2011) explain that the concept of VSL is to quantify the monetary value of increased safety, and in particular, the value of reducing the risk of mortality. Also sometimes referred to as the "value of life," VSL is "the monetary value of a mortality risk reduction that would prevent one statistical death." The (U.S. Department of Transportation, 2017) defines VSL as "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," and calculates VSL using the Willingness to Pay (WTP) approach. This report will use DoT's VSL of $9.6 million for 2016 as the baseline value, and use the following formula suggested by DoT to calculate VSL for the previous years: $VSL_T = VSL_0 * (P_T/P_0) * (I_T/I_0)^\epsilon$, where 0 = Original Base Year; T =

Updated Base Year; P_T = Price Index in Year T; I_T = Real Incomes in Year T; and ϵ = Income Elasticity of VSL (U.S. Department of Transportation, 2017).

The new concept of VSI that we propose is similar to that of VSL. DoT uses the term "value of preventing injuries," and calculates this by the following method: "Each type of accidental injury is rated (in terms of severity and duration) on a scale of quality-adjusted life years (QALYs), in comparison with the alternative of perfect health. These scores are grouped according to the Maximum Abbreviated Injury Scale (MAIS), yielding coefficients that can be applied to VSL to assign each injury class a value corresponding to a fraction of a fatality" (U.S. Department of Transportation, 2017). The six MAIS levels are: 'minor,' 'moderate,' 'serious,' 'severe,' 'critical,' and 'unsurvivable.' The corresponding fraction values of VSL are: 0.003, 0.047, 0.105, 0.266, 0.593, and 1.000. Assuming that 'moderate' is the median injury level, the VSI would be 0.047×\$9.4 million = \$448,000, which is much higher than the CPSC estimate of \$166,000 per civilian injury which is used currently. NFPA (2014a) statistics of non-fatal home fire injuries during 2007-2011 reveal that 61% of those were 'minor,' 26% were 'moderate,' 7% were 'severe', and 6% were 'life-threatening.' This implies that the median fire injury type is 'minor,' however, this could result in significant underestimation of total injury costs, as more severe injury types would get underrepresented. Hence, we consider the 'moderate' MAIS level as a better choice for the median injury type. NFPA (2012) provides detailed cost calculations for civilian injuries, using CPSC's injury cost model (CPSC, 2000). Firefighter injuries are divided into different categories based on the type of duty during which the injury happened. NFPA (2016c) documents five types: responding to or returning from an incident, fireground, non-fire emergency, training, and others. NFPA (2014b) groups these into three major categories: fireground injuries that happen between the moment of arrival at the scene and departure time, for e.g., during setup, extinguishing, or overhaul) non-fireground injuries (that happen during on-duty activities other than fireground and excluding non-fire emergencies, for e.g., inspection, maintenance, training, or while responding to or returning from an incident), and injuries at non-fire emergencies (that happen while responding to calls related to EMS, rescue, HazMat, and natural disasters).

NFPA (2014b) documents a study conducted in 2013 to estimate differences in the cost of injuries to firefighters and civilians. That study used the CPSC figures for VSL and VSI, and found that "firefighter fireground injuries and non-fireground injuries had estimated costs of 30% and 10% of the CPSC average for civilian fire injuries." That study also said that the "average severity of a civilian injury reported to a fire department was considerably less than that reported to a hospital emergency room." Hence, NFPA (2014b) estimated the actual cost of a civilian injury as 60% of the CPSC figure. We use the same percentage multipliers (30%, 10%, and 60% for firefighter fireground, firefighter non-fireground, and civilian) alongside the DoT figures (instead of the CPSC figures).

NFPA's report (NFPA, 2016c) on fireground injury incidence patterns across age profiles during 2012-2014 shows that the firefighters aged 40-44 have experienced the most injuries (17%), followed by the 35-39 and 45-49 age groups (15% and 14%), respectively. That report also provides the distribution of the severity of firefighter fireground injuries by the age of victim (Table 5). The severity levels are "minor," "moderate," and "severe," for which no claims/cost estimates are given. Using the data given in that report as well as the MAIS coefficients for minor, moderate, and severe injuries (0.003, 0.047, and 0.266, respectively of the VSL value of \$9.4 million for 2014), the total cost of firefighter fireground injuries (yearly average for 2012-2014) is calculated as $Z \times \sum_{i=1}^{N} \sum_{j=1}^{M} (f_i \cdot t_{ij})$ = \$6.1 billion, for 2014. This is less than the previously calculated value of \$9.0 billion. Here $Z = 30,290$ is the yearly average number of firefighter fireground injuries for 2012-2014, f_i is the percentage of fireground injuries for age group i, t_{ij} is the percentage number of injuries for age group i and severity type j, $N = 11$ is the number of age groups, and $M = 3$ is the number of injury severity types.

A recent study (Griffin et al., 2016) analyzes the cost savings of the Tuscon (Arizona) Fire Department's Probationary Firefighter Fitness (PFF-Fit), which was aimed at decreasing injuries and compen-

Table 5: Firefighter fireground injuries and severity by age of victim, 2010-2014 annual averages. Source: NFPA (2016c).

Age of victim		15-19	20-24	25-29	30-34	34-39	40-44	45-49	50-54	55-59	60-64	≥ 65
Fireground injuries (%)		1	7	12	13	15	17	14	10	5	2	1
Injury type	Minor	79	77	72	70	67	65	65	65	65	65	76
	Moderate	20	22	26	29	31	33	33	32	31	29	18
	Severe	1	0	2	1	2	2	3	3	4	6	7

sation claims/costs. The program was piloted in 2012-2013 during the recruit academy and over the probationary year. The study shows that the mean claims cost per recruit was \$1,241 for the control classes (2007, 2008, and 2009), and that it dropped to \$208 for the intervention class of 2012. These values are, however, much less compared to the CPSC and DoT values used in the previous calculations. Two important points to note here about the (Griffin et al., 2016) study are: (i) The claims could be for direct medical expenditures only, and hence might not cover the inconvenience costs due to injury. (ii) Only the new firefighter recruits are considered; firefighters with more than a year's experience are not included in the study.

Some gaps in the fire prevention literature exist regarding the value of life and firefighter injuries. For example, a WTP approach has not been directly applied to a fire protection context. This approach allows for estimates of the value of human life to be calculated specifically for fire protection context. NIST (2005) reviews five relevant studies that seek to quantify the costs of injuries in different contexts and attempts to apply the methodologies to firefighters. This study shows the variation of estimates and how firefighter injury quantification has additional losses associated with it, including city expenditure for firefighter insurance, prevention efforts, investigations of injuries, legal fees, worker's compensation, additional overtime, paperwork, and data collection.

Sample calculation for human losses:

$$\begin{aligned}
\text{Total number of civilian deaths} &= 3,275 \\
\text{Total number of on-duty firefighter deaths} &= 64 \\
\text{Total deaths} &= 3,275 + 64 = 3,239 \\
\text{Total cost of deaths} &= 3,239 \times \$9.4 \text{ million} = \$30.4 \text{ billion} \\
\text{Number of civilian injuries} &= 15,775 \\
\text{Number of firefighter injuries} &= 63,350 \\
\text{Number of firefighter fireground injuries} &= 27,015
\end{aligned}$$

$$\begin{aligned}
\text{Number of firefighter injuries} & \\
\text{at non-fire emergencies} &= 14,595
\end{aligned}$$

$$\begin{aligned}
\text{Number of firefighter non-fireground injuries} & \\
\text{(excluding injuries at non-fire emergencies)} &= 63,350 - (27,015 + 14,595) = 21,740
\end{aligned}$$

$$\begin{aligned}
\text{Cost of civilian injuries} &= 15,775 \times 0.6 \times \$448,000 = \$4.3 \text{ billion} \\
\text{Cost of firefighter fireground injuries} &= 27,015 \times 0.3 \times \$448,000 = \$3.6 \text{ billion} \\
\text{Cost of firefighter non-fireground injuries} &= 21,740 \times 0.1 \times \$448,000 = \$1.1 \text{ billion}
\end{aligned}$$

$$
\begin{aligned}
\text{Total cost of injuries} &= \$4.3 \text{ billion} + \$3.6 \text{ billion} + \$1.1 \text{ billion} \\
&= \$9.0 \text{ billion}
\end{aligned}
$$

$$
\text{Total human loss (deaths and injuries)} = \$30.4 \text{ billion} + \$9.0 \text{ billion} = \$39.4 \text{ billion}
$$

3.2 Indirect Loss

Indirect loss, referred to as the “economic impact of fire" in this report, is arguably the most difficult cost component to estimate. For example, the difficulty in estimating the indirect property losses is evident from the previous discussion in Section 3.1 on the challenges in accurately estimating direct property losses. Previously, NFPA estimated that indirect losses are four times that of direct losses in business closures. It was also estimated that 2% of reported non-residential structure fires result in business closings (NFPA, 2014b). However, this methodology could be outdated for use today as fires of different severities can have varying impacts on different businesses. Larger fires, logically, have a much higher impact, in which case, Meade (1991)'s formula (NFPA, 2014b) could be used. Moreover, for non-closure cases, the NFPA uses their own estimates for constant multipliers (e.g., 65% for manufacturing and industrial properties), which may or may not be accurate for different types of businesses. It is also necessary to consider the potential indirect effects of a fire in a high-rise building in an urban area to near-by buildings. Even when the fire is not severe, the news/rumor of fire may lead to businesses in adjacent buildings closing down for a few hours or for a day, which leads to indirect losses. The magnitude of such losses depend on many factors such as population density, type of building, and adjacent businesses. By collecting such data from sources, including the U.S. Census, potential indirect losses can be estimated.

One method for calculating the economic impact of fire is using econometric input-output models. For example, economic forecasting tools developed by Regional Economic Models, Inc. (REMI) have been used for studies related to the economics of fire. The State of Wyoming (2005) used REMI's Policy Insight (Regional Economic Models, Inc., 2017) tool to study the economic impact of fire on Wyoming's economy from a business perspective. That study uses the idea that the various indirect effects of fire on a business firm (such as decline in output sales, relocation, or closure) would result in employment reduction. This reduction in employment, termed as “employment shock," is induced into the Policy Insight model, and the changes in the economy are calculated. For example, a reduction of 10 employees due to a fire in a small retail trade firm has the following effects on Wyoming's economy: the total employment decreases by 2, the output sales decrease by \$133,522, the Gross State Product drops by \$77,852, and the personal income decreases by \$42,657 (please note that the values are in 2005 dollars). That analysis considers a single fire to a specific type of business, namely a retail firm. However, attempting to perform a similar calculation for the whole of the U.S. requires that information be available on the number of fires that affected different types of businesses. An important drawback of the REMI model seems to be that it cannot be used for calculating the indirect losses from residential fires.

REMI's tools have also been used by Evans (2017) to measure the economic impact of the City of Phoenix Fire Department's successful intervention of fires. The study looks into eight fires that affected thirteen commercial organizations in the period of June 1 to August 31, 2012, which were extinguished successfully by the City of Phoenix Fire Department. The results show that the intervention efforts saved 2,322 jobs throughout the state of Arizona and \$196 million (2012 \$) out of Gross State Product, which could have been lost over the course of one year. Both The State of Wyoming (2005) and Evans (2017) use the REMI model to measure the economic impact of fire, however, from two different perspectives. The former tries to measure the losses due to fire occurrences, which is in line with the definition of the “economic impact of fire" used in this report, whereas the latter measures savings from successful fire interventions. Yet, it is recognized that both of these uses are important in understanding the fire problem in the U.S. The former approach can address the magnitude and severity of fires in the U.S., whereas the latter can be used to quantify the savings that the fire service brings to society. Another recent study by Delorme and Waterhouse (2017) shows that the Montréal City Fire Department's successful intervention of 110 fires (there were 274 successful interventions in total, out of which 110 are analyzed) in 2015 resulted in a savings of $1.89 billion Canadian dollars to the Quebec province. One drawback with using the same methodology for calculating the economic impact of fire in the U.S. is that these studies require extensive data collection with respect to each business that was affected by fire. Hence, unless a statistically strong sample of businesses affected by fire is obtained, it is almost impossible to use these econometric models for a nationwide study. Another drawback is that the economic impact of residential fires cannot be estimated using econometric models. It could be argued that the economic impact of a residential fire is likely to be much less when compared to a fire in a commercial facility. However, the following two points suggest that the aggregate indirect losses of all resident fires may be significant: (i) the number of residential fires were 79.2% of the total structure fires during the period 2010-2014 (NFPA, 2017); and (ii) CPSC (2009) reported that for 65,000 residential fires during 2004-2005, “the conditions after the fire required families to stay out of the residence for one night or more."

There are tools available from the public sector to calculate the economic impact of fire. For example, Regional Input-Output Modeling System (RIMS II) “a regional economic model, is a tool used by investors, planners, and elected officials to objectively assess the potential economic impacts of various projects" (Bureau of Economic Analysis, 2013).

We use the following NFPA (2014b) formula for calculating indirect losses:

$$
\begin{aligned}
\text{Indirect damage in fires} = \{&(\text{Business interruption} + \text{Temporary lodging} + \text{Intangible losses}) \\
&\text{estimated as the sum of three terms :} \\
&[65\% \text{ x (direct damage in reported fires in manufacturing} \\
&\text{or industrial structures)]} \\
+&[25\% \text{ x (direct damage in reported fires in public assembly,} \\
&\text{educational, institutional, store, or office structures)]} \\
+&[10\% \text{ x ((direct damage in reported fires in residential, storage,} \\
&\text{or special structures)]}\} \\
\\
+&\{(\text{Value of closed businesses) estimated as } [4 \text{ x } 2\% \text{ x (direct damage} \\
&\text{in reported fires in non-residential structures} \\
&\text{excluding storage and special structures)]}\}.
\end{aligned}
$$

The sample calculation presented below uses the NFPA formula mentioned above. All direct and indirect losses include reported losses and unreported losses. The unreported losses are estimated as 13.6% of reported losses, based on CPSC (2009).

Sample calculation of indirect loss:

$$\begin{aligned}
\text{Direct damage in manufacturing or industrial} &= \$0.71 \text{ billion} \\
\text{Indirect damage in manufacturing or industrial} &= 0.65 \times \$0.71 \text{ billion} = \$0.46 \text{ billion}
\end{aligned}$$

$$\begin{aligned}
\text{Direct damage in assembly, educational,} & \\
\text{institutional, store, or office} &= \$1.40 \text{ billion}
\end{aligned}$$

$$\begin{aligned}
\text{Indirect damage in assembly, educational,} & \\
\text{institutional, store, or office} &= 0.25 \times \$1.40 \text{ billion} = \$0.35 \text{ billion}
\end{aligned}$$

$$\begin{aligned}
\text{Direct damage in residential, storage,} & \\
\text{or special structures} &= \$9.07 \text{ billion}
\end{aligned}$$

$$\begin{aligned}
\text{Indirect damage in residential, storage,} & \\
\text{or special structures} &= 0.1 \times \$9.07 \text{ billion} = \$0.91 \text{ billion}
\end{aligned}$$

$$\begin{aligned}
\text{Direct damage in non-residential} & \\
\text{(excluding storage and special structure)} &= \$2.12 \text{ billion}
\end{aligned}$$

$$\begin{aligned}
\text{Indirect damage in non-residential} & \\
\text{(excluding storage and special structure)} &= 4 \times 0.02 \times \$2.12 \text{ billion} = \$0.17 \text{ billion}
\end{aligned}$$

$$\begin{aligned}
\text{Total indirect damage} &= \$(0.46 + 0.35 + 0.91 + 0.17) \text{ billion} \\
&= \$1.9 \text{ billion}
\end{aligned}$$

Table 6 provides the breakdown of the total cost of fire in the U.S. into components, in billions of U.S. dollars (1980-2014). Table 7 presents the total cost of fire by year (1980-2014), in actual and 2014 dollars and as percentage values in comparison with U.S. GDP.

Table 6: Breakdown of the total cost of fire in the United States into components, in billion US dollars, 1980-2014 (Part 1 of 8)

Components of Cost	1980		1981		1982		1983		1984	
	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$
Expenditure	39.4	113.5	43.2	112.4	47.5	115.9	50.5	120.1	55.3	126.7
Direct expenditure	20.5	59.0	21.9	57.0	23.6	57.5	25.0	59.5	26.4	60.4
Active fire protection expenditure	20.5	59.0	21.9	57.0	23.6	57.5	25.0	59.5	26.4	60.4
Local fire department expenditure	5.4	15.6	6.0	15.5	6.7	16.3	7.2	17.1	7.7	17.7
Value of donated time of volunteer firefighters	14.9	42.9	15.8	41.0	16.7	40.7	17.6	41.8	18.4	42.1
Donations to fire departments	0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.6
Indirect expenditure	18.9	54.5	21.3	55.5	23.9	58.4	25.5	60.7	28.9	66.3
Passive fire protection expenditure	15.7	45.2	18.3	47.6	20.2	49.4	21.6	51.4	24.3	55.7
Fire safety costs in building construction	3.9	11.2	4.7	12.1	5.0	12.2	5.4	12.7	6.8	15.5
Fire grade products	8.7	25.1	10.0	26.0	11.0	26.8	11.6	27.7	12.4	28.5
Fire maintenance	1.6	4.7	2.0	5.2	2.4	5.8	2.6	6.3	2.9	6.8
Fire retardants	1.2	3.5	1.4	3.6	1.5	3.7	1.6	3.8	1.7	4.0
Disaster planning	0.2	0.4	0.2	0.5	0.2	0.5	0.2	0.6	0.3	0.6
Preparing/maintaining standards	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.3
Insurance	3.2	9.3	3.0	7.8	3.7	9.0	3.9	9.3	4.6	10.6
Loss	36.5	105.0	40.6	105.5	39.6	96.5	40.4	96.1	38.5	88.1
Direct loss	35.1	101.2	39.2	101.9	38.2	93.2	39.0	92.7	37.1	84.9
Property loss	7.2	20.6	7.6	19.8	7.3	17.7	7.5	17.8	7.6	17.4
Human loss	28.0	80.6	31.6	82.2	30.9	75.4	31.5	74.9	29.5	67.5
Cost of statistical deaths	21.7	62.4	24.7	64.3	23.7	57.8	23.8	56.7	22.0	50.4
Cost of statistical injuries	6.3	18.1	6.9	17.9	7.2	17.6	7.6	18.2	7.5	17.1
Indirect loss	1.3	3.9	1.4	3.5	1.4	3.4	1.4	3.3	1.4	3.3
Total	75.9	218.6	83.8	217.9	87.1	212.4	90.8	216.2	93.8	214.8

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for (i) the definitions of different components of the total cost of fire; (ii) calculation methodology and changes from previous version of this report (2014); and (iii) data sources used for calculation.

Table 6: Breakdown of the total cost of fire in the United States into components, in billion US dollars, 1980-2014 (Part 2 of 8)

Components of Cost	1985		1986		1987		1988		1989	
	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$
Expenditure	57.9	127.9	64.1	139.8	68.6	143.3	72.7	146.1	76.7	147.4
Direct expenditure	27.6	61.1	31.9	69.6	33.9	70.8	36.5	73.3	37.9	72.7
Active fire protection expenditure	27.6	61.1	31.9	69.6	33.9	70.8	36.5	73.3	37.9	72.7
Local fire department expenditure	8.0	17.7	9.1	19.8	9.9	20.8	11.1	22.4	11.3	21.6
Value of donated time of volunteer firefighters	19.4	42.8	22.6	49.2	23.6	49.4	25.0	50.3	26.3	50.4
Donations to fire departments	0.2	0.5	0.3	0.6	0.3	0.6	0.3	0.7	0.3	0.7
Indirect expenditure	30.3	66.9	32.2	70.2	34.7	72.5	36.2	72.7	38.9	74.6
Passive fire protection expenditure	26.8	59.2	28.2	61.6	30.1	62.8	33.0	66.3	36.0	69.1
Fire safety costs in building construction	8.0	17.8	8.3	18.2	8.8	18.5	9.6	19.4	11.3	21.7
Fire grade products	13.3	29.4	13.9	30.2	14.5	30.3	15.7	31.6	16.6	31.9
Fire maintenance	3.2	7.0	3.6	7.9	4.1	8.7	4.8	9.7	5.1	9.8
Fire retardants	1.8	4.1	1.9	4.2	2.0	4.2	2.2	4.4	2.3	4.4
Disaster planning	0.3	0.6	0.3	0.7	0.4	0.8	0.4	0.9	0.5	0.9
Preparing/maintaining standards	0.1	0.3	0.2	0.3	0.2	0.3	0.2	0.4	0.2	0.4
Insurance	3.5	7.7	4.0	8.6	4.6	9.7	3.2	6.4	2.9	5.5
Loss	44.1	97.5	42.2	92.0	44.6	93.2	49.5	99.4	47.1	90.4
Direct loss	42.7	94.3	40.7	88.8	43.1	90.1	48.0	96.4	45.6	87.5
Property loss	8.3	18.3	7.6	16.6	8.2	17.1	9.5	19.2	9.9	19.0
Human loss	34.4	75.9	33.1	72.2	34.9	73.0	38.4	77.2	35.7	68.5
Cost of statistical deaths	26.9	59.3	25.7	56.1	26.7	55.9	29.7	59.7	27.1	52.0
Cost of statistical injuries	7.5	16.6	7.4	16.1	8.2	17.2	8.7	17.5	8.6	16.6
Indirect loss	1.4	3.2	1.5	3.2	1.5	3.1	1.5	3.0	1.5	2.9
Total	102.0	225.4	106.3	231.8	113.2	236.5	122.1	245.5	123.9	237.8

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for (i) the definitions of different components of the total cost of fire; (ii) calculation methodology and changes from previous version of this report (2014); and (iii) data sources used for calculation.

Table 6: Breakdown of the total cost of fire in the United States into components, in billion US dollars, 1980-2014 (Part 3 of 8)

Components of Cost	1990		1991		1992		1993		1994	
	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$
Expenditure	84.3	154.3	82.4	144.1	88.2	149.9	95.3	157.3	102.9	165.7
Direct expenditure	40.1	73.3	41.9	73.4	43.8	74.4	45.9	75.8	47.4	76.3
Active fire protection expenditure	40.1	73.3	41.9	73.4	43.8	74.4	45.9	75.8	47.4	76.3
Local fire department expenditure	12.5	22.8	13.0	22.8	13.6	23.2	14.6	24.0	15.3	24.6
Value of donated time of volunteer firefighters	27.2	49.8	28.5	49.9	29.7	50.5	30.9	51.0	31.7	51.0
Donations to fire departments	0.4	0.7	0.4	0.7	0.4	0.7	0.4	0.7	0.5	0.7
Indirect expenditure	44.3	81.0	40.4	70.7	44.4	75.5	49.4	81.6	55.5	89.3
Passive fire protection expenditure	40.5	74.1	38.6	67.6	41.0	69.6	45.8	75.6	50.0	80.4
Fire safety costs in building construction	13.9	25.4	10.8	19.0	10.9	18.6	13.5	22.3	15.1	24.4
Fire grade products	17.5	32.0	18.0	31.5	19.5	33.1	20.8	34.3	22.4	36.1
Fire maintenance	5.9	10.9	6.5	11.4	7.0	11.9	7.7	12.7	8.3	13.3
Fire retardants	2.4	4.4	2.5	4.4	2.7	4.6	2.9	4.8	3.1	5.0
Disaster planning	0.5	1.0	0.6	1.1	0.6	1.1	0.7	1.2	0.8	1.2
Preparing/maintaining standards	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4
Insurance	3.8	6.9	1.8	3.1	3.4	5.8	3.6	5.9	5.5	8.9
Loss	46.7	85.4	46.3	81.0	47.0	80.0	48.4	79.8	46.2	74.3
Direct loss	45.1	82.6	44.7	78.3	45.5	77.3	46.8	77.2	44.5	71.7
Property loss	8.9	16.2	10.8	18.9	9.4	16.0	9.7	15.9	9.3	15.0
Human loss	36.3	66.4	33.9	59.4	36.0	61.2	37.1	61.3	35.2	56.7
Cost of statistical deaths	27.2	49.8	24.6	43.0	26.6	45.2	26.9	44.3	25.6	41.2
Cost of statistical injuries	9.0	16.5	9.4	16.4	9.5	16.1	10.3	16.9	9.6	15.5
Indirect loss	1.5	2.8	1.6	2.7	1.6	2.7	1.6	2.6	1.6	2.6
Total	131.0	239.7	128.6	225.1	135.2	229.8	143.7	237.1	149.1	240.0

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for (i) the definitions of different components of the total cost of fire; (ii) calculation methodology and changes from previous version of this report (2014); and (iii) data sources used for calculation.

Table 6: Breakdown of the total cost of fire in the United States into components, in billion US dollars, 1980-2014 (Part 4 of 8)

Components of Cost	1995		1996		1997		1998		1999	
	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$
Expenditure	109.1	170.2	113.9	173.1	121.8	180.3	129.0	188.3	134.4	192.2
Direct expenditure	50.0	77.9	52.2	79.4	53.0	78.4	54.9	80.1	57.1	81.6
Active fire protection expenditure	50.0	77.9	52.2	79.4	53.0	78.4	54.9	80.1	57.1	81.6
Local fire department expenditure	16.2	25.2	16.8	25.5	18.3	27.1	19.3	28.1	20.0	28.7
Value of donated time of volunteer firefighters	33.3	51.9	35.0	53.2	34.1	50.4	35.0	51.1	36.4	52.1
Donations to fire departments	0.5	0.8	0.5	0.8	0.6	0.8	0.6	0.9	0.6	0.9
Indirect expenditure	59.2	92.3	61.6	93.6	68.9	101.9	74.1	108.2	77.3	110.6
Passive fire protection expenditure	54.2	84.6	59.1	89.9	66.5	98.4	71.3	104.0	75.6	108.1
Fire safety costs in building construction	16.7	26.0	19.0	28.9	22.3	33.0	24.9	36.3	26.3	37.6
Fire grade products	24.1	37.5	25.7	39.1	28.2	41.8	29.4	42.9	31.2	44.7
Fire maintenance	9.0	14.1	9.6	14.6	10.8	16.0	11.5	16.8	12.2	17.5
Fire retardants	3.3	5.2	3.6	5.4	3.9	5.8	4.1	6.0	4.3	6.2
Disaster planning	0.8	1.3	0.9	1.3	1.0	1.5	1.1	1.6	1.1	1.6
Preparing/maintaining standards	0.3	0.4	0.3	0.4	0.3	0.5	0.3	0.5	0.3	0.5
Insurance	4.9	7.7	2.5	3.8	2.4	3.5	2.8	4.1	1.7	2.5
Loss	49.4	77.0	52.8	80.3	46.8	69.2	47.3	69.1	46.4	66.4
Direct loss	47.7	74.5	51.2	77.8	45.1	66.7	45.6	66.6	44.7	63.9
Property loss	10.1	15.8	10.7	16.2	9.7	14.3	9.8	14.3	11.4	16.2
Human loss	37.6	58.7	40.5	61.6	35.4	52.4	35.9	52.4	33.4	47.7
Cost of statistical deaths	28.2	44.0	31.5	47.8	26.4	39.0	26.6	38.8	24.2	34.6
Cost of statistical injuries	9.4	14.7	9.1	13.8	9.1	13.4	9.3	13.6	9.2	13.1
Indirect loss	1.6	2.6	1.7	2.5	1.7	2.5	1.7	2.5	1.7	2.5
Total	158.5	247.3	166.7	253.4	168.6	249.5	176.3	257.4	180.9	258.6

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for (i) the definitions of different components of the total cost of fire; (ii) calculation methodology and changes from previous version of this report (2014); and (iii) data sources used for calculation.

Table 6: Breakdown of the total cost of fire in the United States into components, in billion US dollars, 1980-2014 (Part 5 of 8)

Components of Cost	2000		2001 (Including 9/11 WTC incident)		2001 (Excluding 9/11 WTC incident)		2002		2003	
	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$
Expenditure	148.1	204.3	157.5	211.0	153.7	207.7	158.3	208.9	166.8	216.8
Direct expenditure	59.7	82.4	62.1	83.2	62.1	84.9	64.4	85.0	66.3	86.2
Active fire protection expenditure	59.7	82.4	62.1	83.2	62.1	84.9	64.4	85.0	66.3	86.2
Local fire department expenditure	21.9	30.2	23.7	31.8	23.7	31.8	24.1	31.8	25.1	32.6
Value of donated time of volunteer firefighters	37.1	51.2	37.7	50.5	37.7	52.2	39.6	52.2	40.4	52.6
Donations to fire departments	0.7	0.9	0.7	0.9	0.7	0.9	0.7	1.0	0.8	1.0
Indirect expenditure	88.4	121.9	95.4	127.8	91.6	122.7	93.9	123.9	100.5	130.7
Passive fire protection expenditure	84.1	116.1	85.2	114.1	85.2	114.1	83.3	110.0	87.4	113.7
Fire safety costs in building construction	29.6	40.9	30.3	40.6	30.3	40.6	28.3	37.4	30.3	39.4
Fire grade products	34.2	47.2	33.1	44.3	33.1	44.3	32.7	43.2	33.7	43.8
Fire maintenance	13.8	19.1	15.4	20.7	15.4	20.7	15.9	21.0	16.8	21.9
Fire retardants	4.8	6.6	4.6	6.2	4.6	6.2	4.5	6.0	4.7	6.1
Disaster planning	1.3	1.8	1.4	1.9	1.4	1.9	1.5	1.9	1.6	2.0
Preparing/maintaining standards	0.4	0.5	0.4	0.5	0.4	0.5	0.4	0.5	0.4	0.5
Insurance	4.3	5.9	10.2	13.7	6.4	8.6	10.5	13.9	13.1	17.0
Loss	52.0	71.8	103.8	139.1	49.6	65.7	49.9	65.8	49.6	64.4
Direct loss	50.3	69.4	101.2	135.7	47.8	63.4	48.1	63.5	47.8	62.2
Property loss	12.7	17.6	45.4	60.8	12.0	16.1	11.7	15.4	14.0	18.2
Human loss	37.6	51.9	55.8	74.8	35.8	47.3	36.4	48.0	33.9	44.0
Cost of statistical deaths	28.3	39.0	46.6	62.4	27.0	35.6	27.4	36.2	25.1	32.7
Cost of statistical injuries	9.3	12.9	9.3	12.4	8.8	11.7	9.0	11.9	8.7	11.3
Indirect loss	1.7	2.4	2.6	3.4	1.8	2.4	1.8	2.3	1.7	2.2
Total	200.1	276.1	261.3	350.1	203.3	273.4	208.1	274.7	216.4	281.3

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for (i) the definitions of different components of the total cost of fire; (ii) calculation methodology and changes from previous version of this report (2014); and (iii) data sources used for calculation.

Table 6: Breakdown of the total cost of fire in the United States into components, in billion US dollars, 1980-2014 (Part 6 of 8)

Components of Cost	2004		2005		2006		2007		2008	
	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$
Expenditure	183.3	230.9	193.7	236.3	213.7	250.1	224.8	256.3	237.7	256.7
Direct expenditure	71.0	89.5	72.6	88.6	78.0	91.2	82.0	93.5	86.3	93.2
Active fire protection expenditure	71.0	89.5	72.6	88.6	78.0	91.2	82.0	93.5	86.3	93.2
Local fire department expenditure	26.9	33.9	29.6	36.1	32.6	38.2	35.1	40.0	38.2	41.2
Value of donated time of volunteer firefighters	43.3	54.5	42.1	51.4	44.4	51.9	45.8	52.3	47.0	50.7
Donations to fire departments	0.8	1.0	0.9	1.1	1.0	1.2	1.1	1.2	1.1	1.2
Indirect expenditure	112.3	141.4	121.1	147.7	135.7	158.8	142.8	162.8	151.4	163.5
Passive fire protection expenditure	97.5	122.9	106.9	130.4	119.5	139.9	127.1	144.8	138.6	149.7
Fire safety costs in building construction	35.3	44.5	38.4	46.8	43.7	51.1	44.9	51.2	49.3	53.3
Fire grade products	36.5	45.9	39.5	48.2	42.9	50.2	45.9	52.4	48.4	52.2
Fire maintenance	18.6	23.5	21.1	25.8	24.3	28.4	26.8	30.6	30.8	33.3
Fire retardants	5.1	6.4	5.5	6.7	6.0	7.0	6.4	7.3	6.7	7.3
Disaster planning	1.7	2.2	2.0	2.4	2.2	2.6	2.5	2.8	2.8	3.1
Preparing/maintaining standards	0.4	0.5	0.4	0.5	0.5	0.6	0.5	0.6	0.5	0.6
Insurance	14.7	18.5	14.2	17.3	16.2	18.9	15.7	17.9	12.8	13.8
Loss	51.5	64.9	54.0	65.8	55.0	64.3	55.7	63.5	61.2	66.1
Direct loss	50.0	63.0	52.4	63.9	53.1	62.2	53.6	61.1	58.5	63.2
Property loss	11.1	14.0	12.2	14.8	12.8	15.0	16.6	18.9	17.6	19.0
Human loss	38.9	49.0	40.2	49.0	40.3	47.1	37.0	42.2	40.9	44.2
Cost of statistical deaths	30.1	37.9	30.9	37.6	30.2	35.4	27.5	31.3	30.8	33.2
Cost of statistical injuries	8.8	11.1	9.4	11.4	10.1	11.8	9.6	10.9	10.1	10.9
Indirect loss	1.5	1.9	1.6	2.0	1.8	2.2	2.1	2.4	2.7	3.0
Total	234.8	295.8	247.6	302.1	268.7	314.4	280.5	319.8	298.9	322.8

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for (i) the definitions of different components of the total cost of fire; (ii) calculation methodology and changes from previous version of this report (2014); and (iii) data sources used for calculation.

Table 6: Breakdown of the total cost of fire in the United States into components, in billion US dollars, 1980-2014 (Part 7 of 8)

Components of Cost	2009		2010		2011		2012		2013	
	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$	actual$	2014$
Expenditure	237.7	256.7	218.2	242.2	220.9	240.8	229.6	241.1	251.2	261.3
Direct expenditure	86.3	93.2	86.7	96.2	88.3	96.2	88.2	92.7	87.8	91.3
Active fire protection expenditure	86.3	93.2	86.7	96.2	88.3	96.2	88.2	92.7	87.8	91.3
Local fire department expenditure	38.2	41.2	38.2	42.4	40.1	43.7	40.2	42.2	40.3	41.9
Value of donated time of volunteer firefighters	47.0	50.7	47.3	52.5	47.0	51.2	46.9	49.2	46.3	48.1
Donations to fire departments	1.1	1.2	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.3
Indirect expenditure	151.4	163.5	131.5	146.0	132.6	144.5	141.3	148.4	163.4	170.0
Passive fire protection expenditure	138.6	149.7	116.3	129.1	115.0	125.4	122.8	128.9	143.1	148.8
Fire safety costs in building construction	49.3	53.3	39.6	44.0	30.5	33.2	31.0	32.6	48.0	49.9
Fire grade products	48.4	52.2	38.2	42.4	43.0	46.9	48.1	50.5	50.6	52.6
Fire maintenance	30.8	33.3	30.0	33.3	32.1	35.0	33.4	35.0	33.8	35.1
Fire retardants	6.7	7.3	5.3	5.9	6.0	6.5	6.7	7.0	7.0	7.3
Disaster planning	2.8	3.1	2.8	3.1	3.0	3.2	3.1	3.2	3.1	3.2
Preparing/maintaining standards	0.5	0.6	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Insurance	12.8	13.8	15.2	16.9	17.6	19.2	18.5	19.5	20.4	21.2
Loss	61.2	66.1	54.5	60.5	51.2	55.8	53.3	56.0	53.4	55.5
Direct loss	58.5	63.2	52.4	58.2	49.4	53.8	51.4	54.0	51.5	53.6
Property loss	17.6	19.0	14.2	15.8	13.2	14.4	13.3	14.0	14.1	14.6
Human loss	40.9	44.2	38.2	42.4	36.2	39.5	38.2	40.1	37.4	38.9
Cost of statistical deaths	30.8	33.2	29.0	32.2	26.7	29.1	28.6	30.0	27.7	28.8
Cost of statistical injuries	10.1	10.9	9.2	10.3	9.6	10.4	9.6	10.0	9.7	10.1
Indirect loss	2.7	3.0	2.1	2.3	1.8	2.0	1.8	1.9	1.9	1.9
Total	298.9	322.8	272.7	302.7	272.1	296.6	282.9	297.0	304.6	316.8

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for (i) the definitions of different components of the total cost of fire; (ii) calculation methodology and changes from previous version of this report (2014); and (iii) data sources used for calculation.

Table 6: Breakdown of the total cost of fire in the United States into components, in billion US dollars, 1980-2014 (Part 8 of 8)

Components of Cost	2014	
	actual$	2014$
Expenditure	273.1	273.1
Direct expenditure	90.1	90.1
Active fire protection expenditure	90.1	90.1
Local fire department expenditure	41.9	41.9
Value of donated time of volunteer firefighters	46.9	46.9
Donations to fire departments	1.3	1.3
Indirect expenditure	183.0	183.0
Passive fire protection expenditure	159.4	159.4
Fire safety costs in building construction	57.4	57.4
Fire grade products	54.0	54.0
Fire maintenance	36.5	36.5
Fire retardants	7.5	7.5
Disaster planning	3.4	3.4
Preparing/maintaining standards	0.6	0.6
Insurance	23.6	23.6
Loss	55.4	55.4
Direct loss	53.5	53.5
Property loss	13.2	13.2
Human loss	40.4	40.4
Cost of statistical deaths	31.4	31.4
Cost of statistical injuries	9.0	9.0
Indirect loss	1.9	1.9
Total	328.5	328.5

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for (i) the definitions of different components of the total cost of fire; (ii) calculation methodology and changes from previous version of this report (2014); and (iii) data sources used for calculation.

Table 7: Total cost of fire, by year, 1980-2014

Year	Total Cost of Fire		U.S. GDP		Total Cost of Fire as a Percentage of GDP
	actual $	2014 $	actual $	2014 $	
1980	75.9	218.5	993.9	2,862.5	7.6%
1981	83.8	217.9	1,235.0	3,211.0	6.8%
1982	87.1	212.4	1,370.9	3,345.0	6.4%
1983	90.8	216.2	1,528.6	3,638.1	5.9%
1984	93.8	214.8	1,764.5	4,040.7	5.3%
1985	102.0	225.4	1,966.8	4,346.7	5.2%
1986	106.3	231.8	2,105.6	4,590.2	5.1%
1987	113.2	236.5	2,330.2	4,870.2	4.9%
1988	122.1	245.5	2,613.2	5,252.6	4.7%
1989	123.9	237.8	2,946.7	5,657.7	4.2%
1990	131.0	239.7	3,267.5	5,979.6	4.0%
1991	128.6	225.1	3,528.0	6,174.0	3.6%
1992	135.2	229.8	3,846.6	6,539.3	3.5%
1993	143.7	237.1	4,168.9	6,878.7	3.4%
1994	149.1	240.0	4,539.6	7,308.8	3.3%
1995	158.5	247.3	4,912.9	7,664.1	3.2%
1996	166.7	253.4	5,329.1	8,100.2	3.1%
1997	168.6	249.5	5,816.6	8,608.5	2.9%
1998	176.3	257.4	6,225.5	9,089.2	2.8%
1999	180.9	258.6	6,755.7	9,660.6	2.7%
2000	200.1	276.1	7,452.7	10,284.8	2.7%
2001 (9/11 included)	261.3	350.1	7,926.7	10,621.8	3.3%
2001 (9/11 excluded)	203.3	273.4	7,926.7	10,621.8	2.6%
2002	208.1	274.7	8,316.3	10,977.5	2.5%
2003	216.4	281.3	8,854.4	11,510.7	2.4%
2004	234.8	295.8	9,742.0	12,274.9	2.4%
2005	247.6	302.1	10,732.6	13,093.7	2.3%
2006	268.7	314.4	11,842.6	13,855.9	2.3%
2007	280.5	319.8	12,699.7	14,477.6	2.2%
2008	298.9	322.8	13,628.3	14,718.6	2.2%
2009	272.7	302.7	12,989.9	14,418.7	2.1%
2010	272.1	296.6	13,728.8	14,964.4	2.0%
2011	282.9	297.0	14,779.0	15,517.9	1.9%
2012	304.6	316.8	15,533.9	16,155.3	2.0%
2013	310.2	316.4	16,364.2	16,691.5	1.9%
2014	328.5	328.5	17393.1	17,393.1	1.9%

Notes: All values are in billion U.S. dollars. "Actual$" gives the actual cost in the corresponding year, and "2014$" gives the cost adjusted to inflation, in 2014 dollar equivalents. Refer to the report: *The Total Cost of Fire in the United States* (2017), for calculation methodology, changes from previous version of this report (2014), data sources used for calculation, and other details.

4 Discussion, Conclusion, and Future Work

4.1 Discussion

While this report makes significant contributions to measure the economic impact of fire, there is a considerable number of assumptions that need to be acknowledged. In addition, this section presents a projection of the total cost of fire and its components using regression analysis.

The first point of discussion is the cost of water for fire protection. Fire hydrants and the associated infrastructure form an inevitable component of active fire protection. These are built and maintained by water utilities, and the associated costs are recovered from the public through water bills in most places and through property taxes in others. The former system is based on the consideration that fire protection is a public good which is associated with the amount of water the people use, and the latter system is implemented in places where it costs the utility companies more to provide this public good than to solely deliver water for typical demand (Tiger, 2012). The American Water Works Association's (AWWA) manual AWWA (2012) mentions that “the total quantity of water used for fire fighting is minimal in comparison to other uses and is ignored in some studies. In other studies, a nominal amount of base use (between 0.5 and 1.0 percent) is assigned to fire protection because flow from fire hydrants is rarely metered." However, the cost of water is likely to increase in time, and hence it is reasonable to include the cost of water for firefighting. The AWWA (2012) manual also states that “The cost associated with public fire protection is typically charged to a municipal government where it is recovered through the ad valorem property tax system and perhaps other tax sources (e.g., sales taxes)." There are certain disadvantages for this method; for example, tax-exempt property owners do not pay ad valorem property taxes, and this issue becomes important in communities that have a significant value share (nearly 30%) of tax-exempt property. However, this method remains popular because this "may reflect local policy preferences for this method, may be required by state law, or could be the preferred method stipulated by a state regulatory commission" (AWWA, 2012). In addition to ‘public fire protection service’ (hydrants etc. located on public right-of-way), water utilities also provide ‘private fire protection services’ (hydrants, standpipes, sprinkler connections) to individual customers. The infrastructure costs for the latter are accounted for in Fire Safety Costs in Building Construction in Section 2.2, while the associated water costs are not. Neither for the former nor for the latter are the total nationwide costs of water utilities available. Analytics data from the private sector suggests that the total revenue of 294 water utilities across the U.S. was nearly $24 billion in 2012 Baum (2015). The cost of water for public fire protection service would be $0.18 billion, if estimated as 0.75% of the water utilities' net revenue. This number, although only a fraction of the total cost of fire calculated in this report, is significant enough to be acknowledged. The importance of the cost of water is expected to grow in the future years, along with challenges such as sustainability and firefighting in drought.

Second, although this report uses NFPA's national estimates directly, calculating those estimates is challenging. The incompleteness and heterogeneity in the two major sources of local data, namely (i) the NFPA's annual Survey of Fire Departments for U.S. Fire Experience and (ii) NFIRS, need to be removed. As fire losses vary among communities primarily because of their population sizes, NFPA divides the fire departments into ten strata based on the population size of community protected by that department(NFPA, 2016a). For each fire statistic (e.g., property loss, fatalities), sample loss rates are calculated for each stratum, which are multiplied with population weighting factors to provide the overall national estimate. Furthermore, the USFA's methodology to calculate national estimates is to scale up raw NFIRS data, which is not based on a statistically selected sample of incidents or fire departments using estimates from NFPA's annual survey (USFA, 2017b). Hall. Jr. and Harwood (1989) documented the joint efforts by NFPA and USFA in preparing guidelines to be used in calculation rules to produce estimates of national fire statistics, which have been followed for more than two decades

(USFA, 2017b). At the raw data level, there may be inconsistencies in fire incident data reporting. There are clear guidelines, such as those from USFA's NFIRSGram (USFA, 2017c) that helps fire department personnel to calculate fire losses for accurately documenting fire incidents (in NFIRS database). USFA's NFIRSGram recommends using the International Code Council's Building Valuation Data (BVD) formula to help fire departments in estimating the dollar loss from fires. BVD provides average construction cost per square foot, which can be used to estimate of the cost fire damage. However, not all fire departments in the U.S. use the same format. The assessments of square footage loss of property and more importantly that of the contents loss due to a fire could have inherent subjective factors. However various state- and local-level efforts have been aimed at minimizing these inconsistencies. A good example is the Property Loss Estimation Tool (PLET), a free spreadsheet-based tool developed by the Kansas State Fire Marshal's Office (SFMO), then updated by the Massachusetts SFMO and the Atlanta Fire Rescue. PLET has been endorsed by a few states (e.g., New Hampshire Department of Safety, 2017), and some others have independent guidelines (e.g., Oregon Office of State Fire Marshal, 2017). A more uniform adoption of PLET or similar standard tools, preferably in the form of an application that can be run on mobile phones and tablets, by states and fire departments across the country would improve the accuracy of local fire loss estimation and in turn, that of the national estimates.

While this report presents a comprehensive analysis of the total cost of fire in the United States for the years 1980 to 2014, a caveat is that some of the methods used for calculation of certain components may have wide bands of uncertainty. Based on the information available, Sections 2 and 3 mention the accuracy of data sources used for calculations. In any case, the fact that fire has a huge impact on the U.S. economy is indisputable. While it is traditionally assumed that costs have a negative impact, there have been recent studies (Evans, 2017; Delorme and Waterhouse, 2017) that highlight the benefits from incurring this cost. These studies quantify the savings that the fire service provides to the economy, thereby showing the positive impact of fire protection costs. The cost studies and the savings studies are interrelated, and both contribute to aiding in decision making in fire protection.

Building codes could be one of the key determinants of the total cost of fire, contributing to both expenditure as well as losses. In the United States, there is no uniform building code for all the states to follow. Codes vary between states, and while some states enforce mandatory building codes, other states leave the discretion to local governments (Simmons et al., 2017). The Insurance Institute for Business and Home Safety (IBHS) assigns scores to 18 states "most vulnerable to catastrophic hurricanes along the Atlantic Coast and Gulf of Mexico," by evaluating and comparing "the quality of regulations and processes governing residential dwelling construction" in those states. Such a rating may be required for more informed policymaking on fire protection.

Finally, NFIRS is a potential source to get most of the data that is needed for estimating the total cost of fire. However, currently, participation of fire departments in the NFIRS data entry process is not uniform across the U.S. Hence, extrapolation of NFIRS data to find national estimates of the total cost of fire is difficult at this point.

Uncertainty: The report lists all the data sources that were used to calculate the components of the total cost of fire in Table 3, as well as in the individual sections where the calculations are described. While some estimates could be highly accurate (e.g., local fire department expenditure), some others may have wide bands of uncertainty (e.g., indirect losses). Hence, the uncertainty level gets magnified from individual data sources through the cost components to the total cost of fire. The difficulty in quantifying the uncertainties in the data provided by individual sources forms the biggest challenge in quantifying the uncertainty of the total cost of fire. Only very few of the data sources (e.g., the U.S. Census Bureau) provide uncertainty/error in their data. As a result, the traditional method of estimating 95% confidence intervals to quantify uncertainty is not applicable. In order to assign due importance to uncertainty, we introduce the "uncertainty score," provided in Table 3, which is a relative index of uncertainty between the various cost components. That score is subjectively estimated as a combination of three factors: data availability, calculation convenience, and availability of uncertainty estimates of individual data sources. A score of 1 indicates lowest uncertainty and a score of 5 represents the highest uncertainty. All components have scores greater than or equal to 2, which implies that there is scope for improvement for all components, with respect to one or more of the three factors mentioned previously. The local fire department expenditure is one of the components with the lowest score (least uncertainty), and most of the required data is obtained directly from the U.S. Census Bureau's estimates of state and local governments' finance data (U.S. Census Bureau, 2017c). It can be argued that these estimates are quite accurate and are the best available. The calculation convenience is also high, as there is no calculation required in this case, since the values for every year are directly available. However, due to the difficulty in estimating the percentage share of non-fire-related expenditures, which needs to be subtracted from the total fire department expenses to calculate the fire-related expenses, we assign a score of 2 to the local fire department expenditure component. On the contrary, indirect losses are hard to estimate due to non-availability of data, calculation challenges, and difficulty in obtaining accurate information on uncertainty levels. Hence, that component is assigned with a score of 5 (similar to other components such as donations to fire departments, fire maintenance, disaster planning, fire grade products, fire retardants, and preparing/maintaining standards). The uncertainty scores have been provided to indicate the confidence level on the estimates of the cost components. As seen in Table 3, six out of the fourteen components of cost have the highest uncertainty score of 5. While this acknowledges that the total cost of fire as calculated in this report has a high band of uncertainty, we perceive this as an avenue for future research. A higher uncertainty score for a particular component of cost represents not only a higher variability but also a more critical necessity of future work in improving estimates for that component. In general, the uncertainty scores will help future works in identifying where more data is needed and in understanding how that could improve the total cost estimates.

Regression Analysis: The individual components of the total cost of fire have been described in detail in Sections 2 and 3. This section presents the results of regression analysis on each component, in particular the 95% confidence intervals (Figure 9). The 'dots' in each figure represent the real values of the corresponding cost component, for all years in the period 1980 to 2014. Each figure also shows a nonlinear-fitted regression line which shows the trend of that particular cost component during the period 1980 to 2014. The shaded regions over the lines show the 95% confidence intervals. Overall, expanding the regression fitting and the confidence intervals to future years would be helpful for predicting the future cost of fire (expenditures and losses).

4.2 Conclusion

This document presents the latest report on the total cost of fire in the U.S. The literature relevant to calculating the total cost of fire is presented alongside the gaps in these prior studies. The shortcomings of previous methodology used are also presented beside the new methodologies that are followed in this paper. Additionally, the assumptions used in these new methodologies and the respective pros and cons are addressed. One key contribution of this report is the development of a uniform protocol (discussed in Sections 1), which includes the novel taxonomy and unique definitions for the various components of the total cost of fire. The discussion presented on defining and measuring the Value of Statistical Life (VSL) specifically for the fire protection context is also part of the uniform protocol.

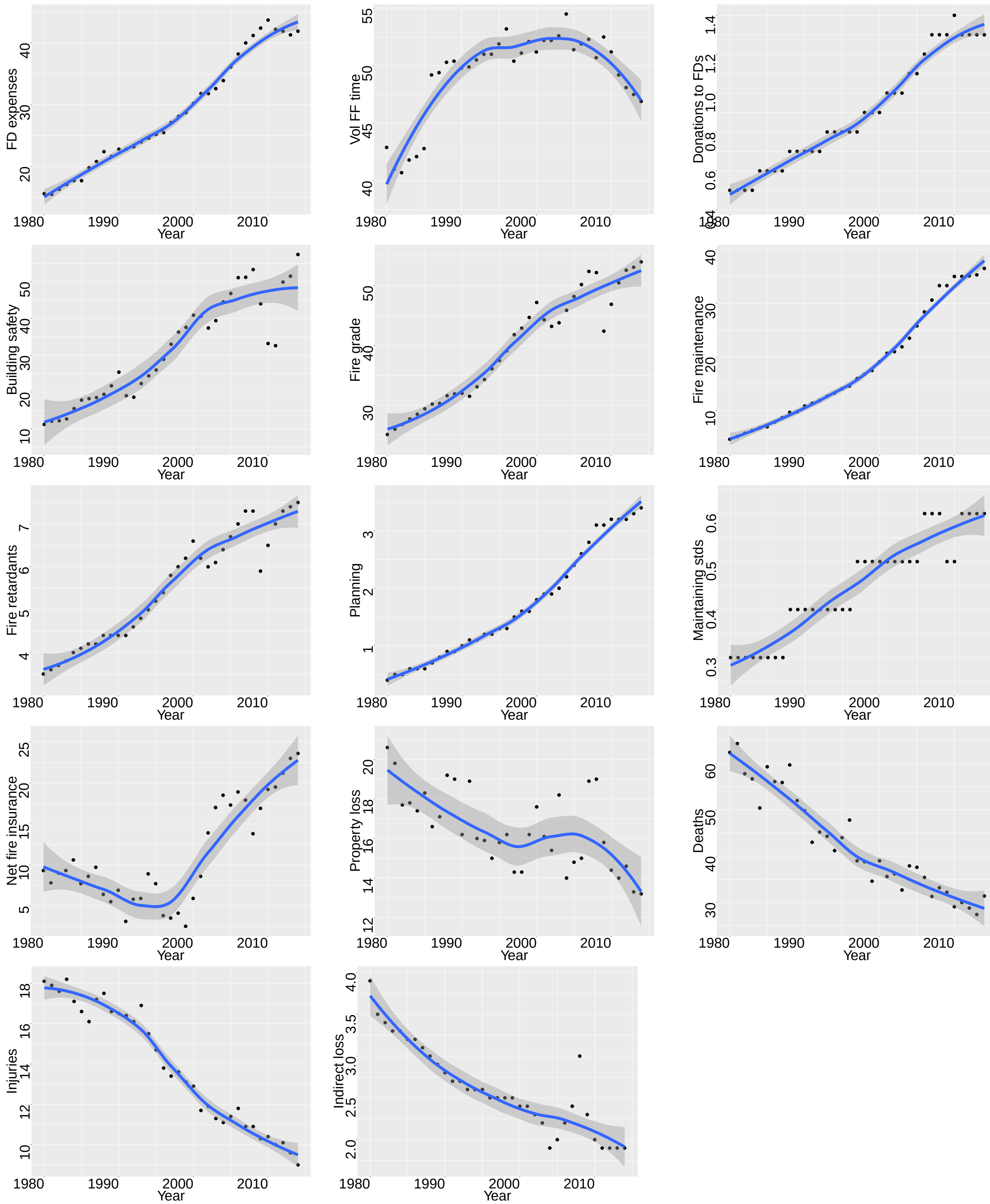

Figure 9: Regression analysis of components of the total cost of fire. The blue lines show the trend line and the gray band shows the 95% confidence interval.

4.3 Future Work

During the process of this project, we identified several future research directions related to many components of the total cost of fire. The higher a cost component's uncertainty score (given in Table 3), the more critical is the need for future work in collecting data and/or improving the accuracy of estimating that component. As discussed in Section 4.1, more study is required to improve the estimates of cost components, most critically for those with the highest uncertainty score given in Table 3. Specific to a few cost components, this report presents many areas which need in-depth study and analysis, which will be useful for future works related to the economic impact of fire and firefighting. This section consolidates such areas and presents research questions that may be pursued.

Volunteer firefighters are key to firefighting operations throughout the sub-urban and rural areas of the country. Various methodologies, some of which are mentioned in Section 2.1 of this report, may be used to calculate the value of time donated by volunteer firefighters. This value varies significantly between different methodologies, and the absence of a standard definition makes the task of selecting the most appropriate method challenging. Besides a consensus on a standard definition, more data collection and research on the amount of time donated by volunteer firefighters will be useful for more accurate calculations. Another important research direction is to calculate the value of hours donated by a volunteer firefighter, which is more specific than the value of a volunteer hour calculated by Independent Sector (2017). Such a calculation may take the additional factors into consideration, including the cost of injuries to volunteer firefighters in terms of the wages lost while away from their primary jobs.

There are certain aspects related to fires that are not considered in this report, wildfires being the most important. The techniques for prevention and suppression of wildfires are highly different from those of structural fires considered in this report. Moreover, wildland firefighting is funded by federal/state governments. Future studies may integrate the economic as well as the environmental costs of wildfires into the total cost of fire. Because forests and related natural resources are valued for the provision of many kinds of market-based and non-market goods and services, it is important to assign costs to wildland fire damages.

Future studies could prepare surveys and collect responses (from engineers, architects, building and property owners, construction contractors, and manufacturers of active and passive fire protection equipment) to estimate new, updated multipliers for calculating fire protection part of building construction expenditure. In addition to the costs of new building construction, costs of built-in fire protection could be considered, as a share of the capital investment. The surveys will also help to estimate the recurring maintenance costs of existing fire protection installations.

Another cost that is not accounted for in this report is the expenditure of various public services (other than fire departments) that attend to fires. For example, a fire in a high-rise building in the middle of a city will be attended to by a significant amount of police forces, medical services, and hazard relief and mitigation teams. This can incur additional costs which are not normally accounted for by these public services. This cost may be addressed in future research.

For estimating indirect property losses, one potential future research direction is to find potential relations between direct and indirect losses, using regression techniques. This may use the approach followed by Ramachandran (2002), in establishing "power" relationship between direct and indirect losses. That is, $IL = c(DL)^b$; where IL and DL are indirect and direct losses respectively. This report, in contrast, uses constant multipliers developed by NFPA (e.g., 65% for manufacturing and industrial properties) (NFPA, 2014b), which may or may not be accurate for different types of businesses. Ramachandran (2002) develops separate sets of parameters for each context in the UK (e.g., local, national, mercantile, manufacturing, non-manufacturing, warehouses). Future research may use case studies, sampled from different types of recent historical fires (e.g., high/medium/small losses, residential/non-residential, public/private, manufacturing/warehouse/business center), to test various regression models and subsequently select statistically significant models for each type of fire. Commonly used regression functions (e.g., linear, exponential, power form) may be explored to assess the relationship between direct and indirect losses. As discussed in Section 4.1, regression analysis could be performed on the total cost of fire as well as the individual components, in order to predict the future costs, expenditures, and losses. This would help in improved policymaking with considerations to future scenarios. NFPA (2016b) provides summary statistics of large-loss fires and the resulting economic damage. More elaborate case studies on such individual fire incidents, especially focusing on the indirect losses caused, are necessary future research directions to improve the estimation of the indirect losses and the economic impact of fire. Another essential consideration for future work is generating and publishing more data (with particular attention to the components with high uncertainty scores in Table 3.

From a macro perspective, future work may explore the deviance between expenditures and losses, which have been increasing over the years (as seen in Figure 5). This is underlined by the fact that expenditures constitute 1.9% of the U.S. GDP. It could be argued that a fair comparison of expenditures with losses happens when the latter is discounted, because the decreasing losses may be attributed, at least partly, to increasing successful fire interventions. However, the savings from fire service interventions are either unavailable or highly difficult to be calculated, thus making it difficult to estimate a discounting coefficient for the losses that factors in the savings. Calculating the savings that the fire service provide to the economy and considering those savings values in the comparison between expenditures and losses are two potential ideas for future research. This would enable fire departments to quantify and communicate their actual value to the public and to the policymakers, in the context of cost-cutting and resource scarcity. Another related advanced research direction is to calculate the effectiveness of expenditure in fire protection, which may differ between various regions in the U.S., due to inter-regional differences in the likelihood/vulnerability and consequences of fire. The various types of expenditure (such as personnel, building safety, and equipment) also may have different effectiveness levels. Policymakers could use this information to draft policies that allocate budget/resources based on effectiveness levels in addition to the conventional equity considerations.

Finally, the definitions for some of the components need to be revisited and rephrased to fit to the current fire protection context. In particular, the definitions of expenditures on fire grade products, fire maintenance, fire retardants, disaster planning, and preparing/maintaining standards, which together constitute 48.5% ($159.4 billion) of the total cost of fire ($328.5 billion), have been formed based on Meade (1991). These definitions and calculation methodology may need significant revisions to incorporate the current fire protection technology and practices. The fire safety cost in building construction, which is the largest individual component ($57.4 billion = 17.5% of the total cost), is also defined and calculated based on studies that may need significant updates (Apostolow et al., 1978; Meade, 1991). There would be clearly a need of future work for updating these definitions and estimates.

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