RESEARCH

U.S. Fire Service Fatalities at Structure Fires: 1977–2018

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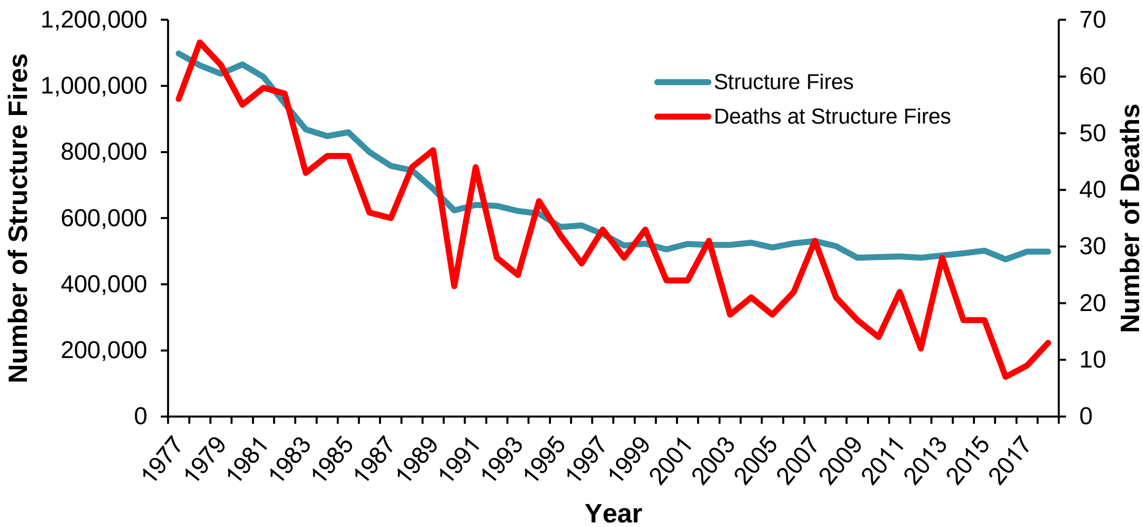
Since 1977, the number of U.S. firefighter deaths at structure fires annually has dropped by more than 80 percent, a finding that is often credited to improvements in protective clothing and equipment, fire ground procedures, and training.[1] Over the same period, the annual number of structure fires declined by 53 percent.[2] (Figure 1) To what degree then has the decrease in firefighter deaths been driven by the drop in the number of fires?

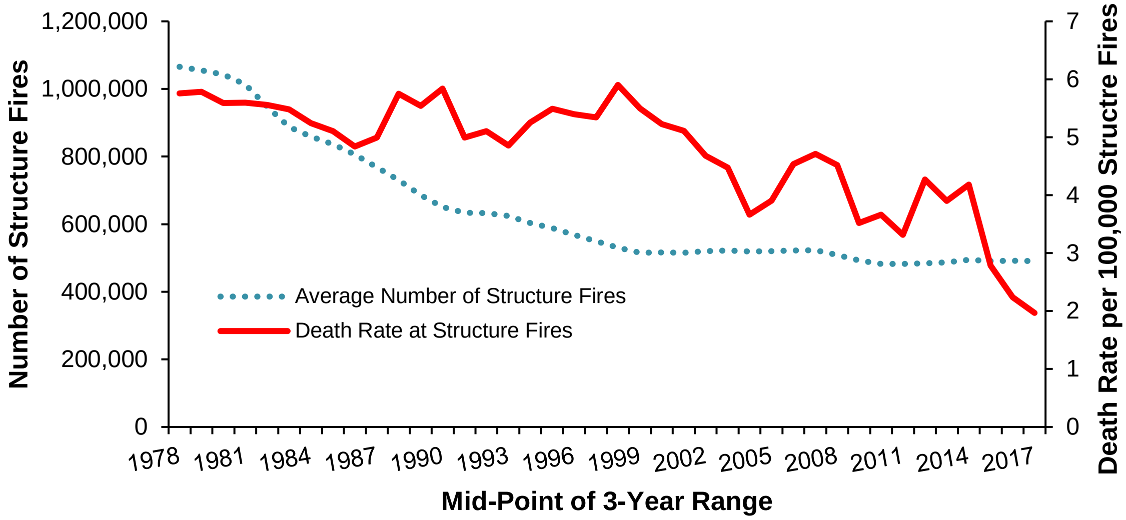
Figure 1. Structure Fires and Firefighter Deaths at Structure Fires 1977 - 2018



A comparison of the decline in the number of structure fires and the decrease in firefighter deaths at structure fires shows that the trends tracked fairly closely until about 2001, indicating that the drop in deaths may have been largely due to the reduction in the number of fires. Since then, however, the number of firefighter deaths at structure fires has continued a general downward trend, while the number of structure fires has leveled off. This leads to an important second question: how has the *rate* of deaths at structure fires trended over the same period? In other words, are firefighters less likely to die today at structure fires than they were 35 or 40 years ago?

In order to smooth out the year-to-year fluctuations in the number of deaths, Figure 2 displays a comparison of the number of structure fires and the *rate* of firefighter deaths at structure fires using a rolling three-year average. The mid-point of each three-year range is shown at the bottom of the graph.

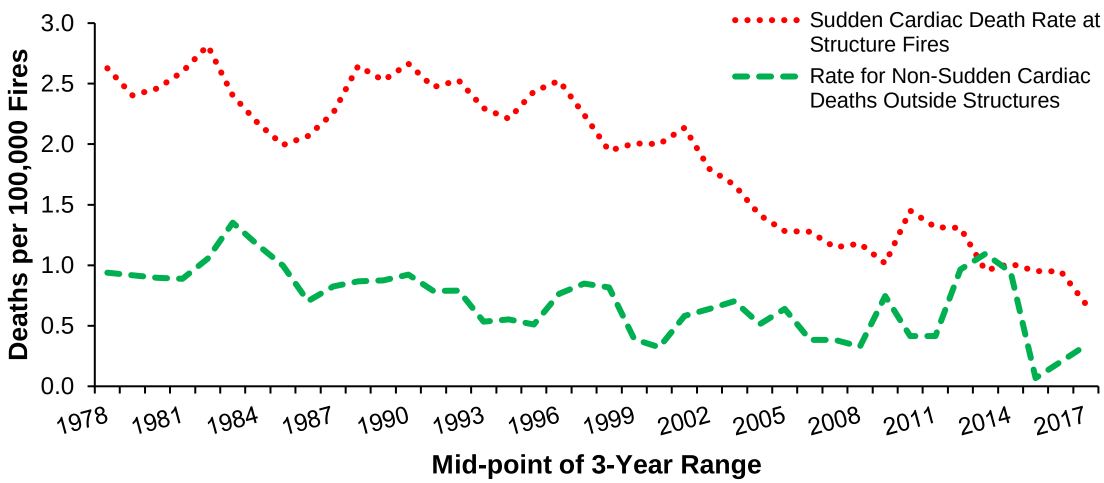
Figure 2. Structure Fires and Firefighter Death Rate at Structure Fires - Rolling 3-Year Averages 1977 - 2018



As Figure 2 shows, the rate of firefighter deaths at structure fires in the late 1990s was roughly the same as the rate in the late 1970s. In the late 1970s, the death rate was approximately 5.8 deaths per 100,000 structure fires. That rate dropped to approximately 4.8 deaths per 100,000 structure fires around 1987 but rose to 5.8 in 1991. After falling to 4.8 deaths per 100,000 structure fires in 1994, it increased to 5.9 deaths per 100,000 in the late 1990s. The death rate at structure fires then dropped steadily, to under 4.0 deaths per 100,000 structure fires by the mid-2000s, while the number of structure fires plateaued at approximately 520,000. The number of structure fires has remained relatively unchanged, while the death rate fluctuated before dropping sharply in recent years.

Given the improvements in personal protective clothing and equipment, training and operating procedures over the past few decades, what is the cause of these deaths, and what are the trends? A review of the data shows that the rate of sudden cardiac deaths at structure fires (inside and outside) has been dropping since the early 1980s, as has the rate of non-sudden-cardiac-death fatalities outside at structure fires, though less sharply. Sudden cardiac deaths at structure fires occurred at the rate of 2.6 deaths per 100,000 fires in the late 1970s and dropped to 0.7 deaths per 100,000 structure fires in the most recent three-year period. The rate of non-sudden-cardiac-death fatalities *outside* of structures dropped over the same time interval to a low of 0.3 deaths per 100,000 structure fires, after reaching a peak of 1.4 in the mid-1980s. (Figure 3) The sharp increase around 2013 was influenced by a single nine-fatality fire.

Figure 3. Rates of Sudden Cardiac Deaths (SCD) and Non-SCD Deaths Outside Structure Fires - Rolling 3-Year Averages 1977 - 2018



The one area showing increases over the period is the rate of deaths due to traumatic injuries while operating inside or on structures. (Figure 4) In the late 1970s, traumatic deaths inside or on structures occurred at a rate of 2.5 deaths per 100,000 structure fires, rising by the late 1990s to approximately 3.1 deaths per 100,000 structure fires. The rate then dropped over the next several years to 1.7 deaths per 100,000 structure fires but rose again to more than 3 deaths per 100,000 structure fires. Part of the sharp increase in death rates can be explained by a single, nine-fatality fire in 2007. Since then, the death rate while operating inside or on structures has fallen, reaching under 1.0 death per 100,000 structure fires in the latest three-year period.

Almost all of these non-sudden-cardiac-death fatalities inside or on structures were the result of smoke inhalation or asphyxiation (59.7 percent), crushing or internal trauma (19.2 percent) and burns (18.9 percent). The rate at which these deaths has occurred per 100,000 structure fires is shown in Figure 5. There has been considerable fluctuation from year to year for all three categories, but deaths due to asphyxiation and burns trended upward through the late 1990s, then fell, only to rise again before decreasing to their lowest levels in the most recent three-year period. There is no clear trend for deaths due to crushing and internal trauma. The most recent spike in deaths due to asphyxiation and smoke inhalation can be attributed to the nine-fatality incident in 2007. The dash line in Figure 5 shows the trend without that single fire.

Figure 4. Non-Sudden Cardiac Deaths
Rolling 3-Year Average
1977 - 2018

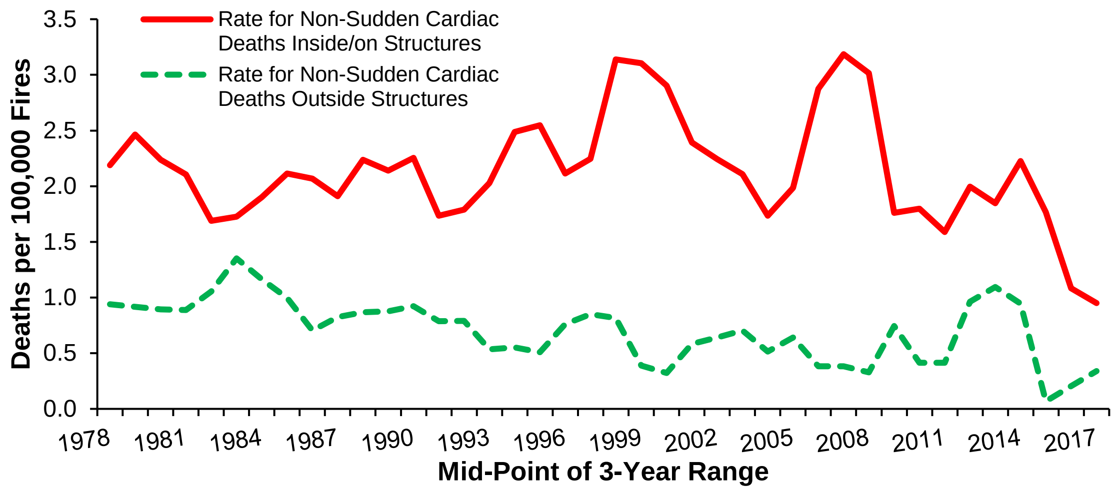
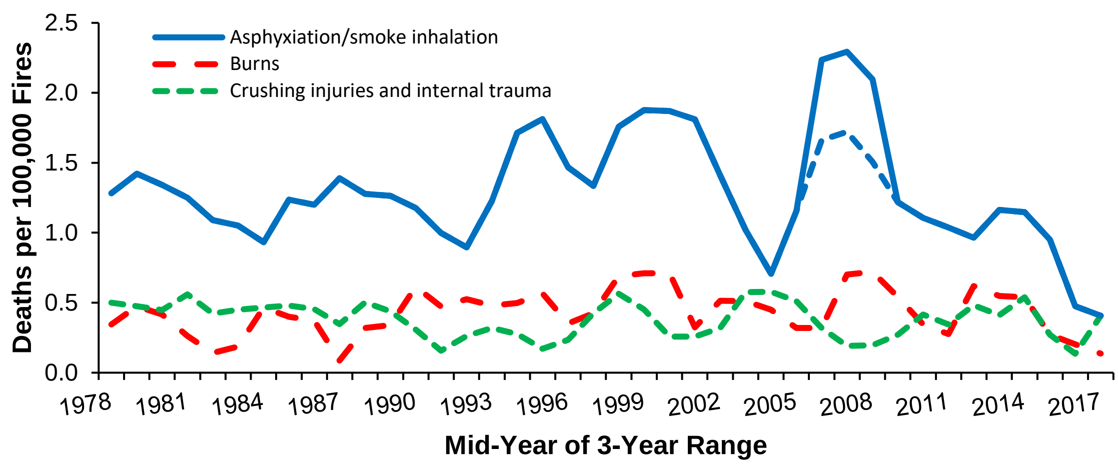
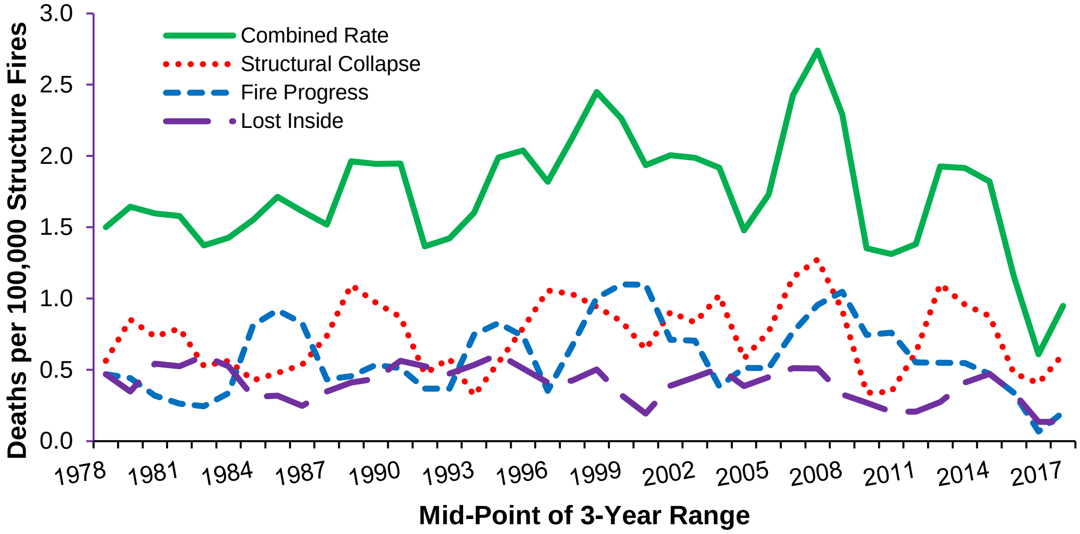


Figure 5. Death Rates for Non-Cardiac Deaths Inside and On Structures - Rolling 3-Year Average
1977 - 2018



The major causes of these traumatic injuries inside and on structures were firefighters becoming lost inside, structural collapse and fire progression (including backdraft, flashover and explosion). Although individually there were no consistent trends when looking at causes of injury, together there was a clear upward trend until about 10 years ago, and the total number of deaths in these three categories has since fallen. (Figure 6)

Figure 6. Death Rates for the Three Major Causes of Fatal Injuries Inside and On Structures - Rolling 3-Year Averages 1977 - 2018



In order to reduce the number of deaths of firefighters operating inside at structure fires, it is important to understand how they are happening. A detailed look at each incident is beyond the scope of this analysis, but the National Institute for Occupational Safety and Health (NIOSH) has a program of on-site data collection and investigation of on-duty firefighter fatalities that provides a valuable database. Reports on many structure fire fatalities can be found on their website: www.cdc.gov/niosh/firehome.html. However, we can give some general findings from the most recent decade (2009 through 2018).

In that 10-year period, 101 firefighters died at fires while operating inside and on structures. The deaths were the result of smoke inhalation or running out of air (34 deaths), sudden cardiac death (21 deaths), crushing or internal trauma (18 deaths), burns (17 deaths), mechanical or compression asphyxia (10 deaths) and gunshot (1 death). Close to half the deaths occurred at fires in one- and two-family dwellings (43 deaths). There were 18 deaths in apartment buildings, nine in restaurants or a tavern, six in storage facilities, six at retail establishments or offices, two in a social hall, two in manufacturing properties, one in a church, one in a theater and one on a movie set. The remaining 12 deaths were in vacant buildings (four in vacant factories, three in vacant dwellings and two vacant storage facilities), an apartment building under renovation (two deaths), and a home under construction (one death).

For the 34 firefighters who died of smoke inhalation or ran out of air, the major causes of injury were caught in structural collapses (10 deaths, of which five were in roof collapses and five were in floor collapses), becoming lost inside the structure and running out of air (10 deaths), and caught by the progress of the fire, backdraft or flashover (nine deaths). Four firefighters died in falls (three through holes burned in floors and one through a hole burned through the roof) and one firefighter became trapped in product in a grain silo. All but three of the 34 victims were known to be wearing self-contained breathing apparatus. One of the three was the shift safety officer who fell through the floor of an exposed structure as operations were wrapping up at the fire. Another was a fire chief who entered a grain silo to assist fallen firefighters and was asphyxiated himself. No details were reported for the third firefighter.

Of the 18 firefighters who died as a result of crushing or internal trauma, eight were killed in structural collapses; six fell or jumped – one from the roof of a building, one through a skylight, one from a ladder, one out a window, one down an elevator shaft, and one through a hole burned in the floor; three were thrown from silos when explosions occurred; and one was struck when the catastrophic failure of a nearby propane tank occurred.

Of the 17 firefighters who died of burns at structure fires since 2009, 11 were caught or trapped by fire progress, backdraft or flashover, four were caught in structural collapses, and two became lost inside the structures.

As mentioned above, 10 of the deaths were the result of compression or mechanical asphyxia, which can occur when a victim is trapped under debris or in a hole and is unable to breathe. Nine of these deaths occurred as a result of structural collapse and one firefighter fell down an elevator shaft.

Firefighter deaths while operating inside at structure fires raise some important questions: Are firefighters putting themselves at greater risk while operating at fires inside structures? Do firefighters think modern protective equipment provides a higher level of protection but do not realize the limitations of that equipment or ignore those limitations? Have some aspects of modern building construction or changes in the burning properties of today's contents and furnishings changed the way fires develop? Were adequate resources available on-scene to deal with the various demands presented? This area of the firefighter fatality problem requires close analysis and NIOSH's investigation program can provide some important answers and recommendations.

Incident command systems and personnel accountability programs must be in place to ensure that incident managers know where their firefighters are. Firefighters must stay with their crews while operating inside structures. If firefighters encounter difficulties, Rapid Intervention Crews can be crucial in saving lives, but will only work when the locations of firefighters are well tracked and reported correctly.

During fire suppression operations, firefighters must remain highly aware of their surroundings – conditions can change rapidly and firefighters who have moved too far into a building may find their escape route cut off or too long to traverse. Firefighters must recognize the danger signs – fires burning in basements and attics indicating the potential for structural collapse, hot smoke and rolling flames at the ceiling indicating a potential flashover, and heavy, dirty smoke pushing through cracks in walls and at eaves indicating a potential backdraft, etc. – and respect them.

PASS devices must be turned on whenever firefighters enter a structure.   Firefighters must be aware of their air supply and usage and exit the building before their End of Service Time Indicator (EOSTI) or low air alarm sounds. Low air alarms must be heeded when they sound, and firefighters operating in large or complex structures must be aware that the time they need to evacuate the building might exceed the time available when they are warned that only 35% of their air supply remains. Firefighters must also know when self-contained breathing apparatus can be safely removed.

All these safety recommendations are covered in NFPA's series of standards for the fire service. But one additional point may not have been stressed sufficiently. The various safety recommendations work together as a system, and to a large degree, they rely on each other for their success. Compliance with half of the recommendations, for example, may not produce half of the safety benefit, because so much of the benefit depends on the interaction of the safety provisions. More than ever, it is clear that fire department management and safety officers need to guide their departments to *full* compliance with all safety requirements.

Anecdotally, there is a growing concern in the fire service related to whether firefighters and fire officers receive the degree of training and experience necessary to properly assess the risks on the fire ground. If the number of structure fires is decreasing, how in fact do firefighters and fire officers gain the experience to understand fire progression, fire behavior, and what happens to the structural integrity of a building under fire conditions?

Training is an integral component to allow firefighters and fire officers alike the opportunity to learn the intricate and un-exact science of firefighting. Computer and other types of simulations, where trainees are "put in the hot seat" of making decisions using incident command and fighting fires in different types of building construction, can help. The components of the command system, and its risk management decision-making process, can all be learned in the classroom simulation environment. A careful post-incident review of fire ground procedures following each fire, including an analysis of what went right and what went wrong, is a great opportunity not only for the people involved but for those firefighters and officers who were not at the incident to learn and improve their understanding of fire behavior.

Pre-incident planning is a key element in training, as well. A pre-incident plan can help responders identify critical features of a structure and its contents and help to anticipate potential scenarios and develop tactical options. The 2010 edition of NFPA 1620, *Pre-Incident Planning*, was a complete revision of the previous edition, and changed the document from a recommended practice to a standard, with minimum requirements for developing pre-incident plans for emergency responders. It is important to note, however, that almost half of the firefighter deaths while operating inside and on structures at fires in the past 10 years occurred at dwelling fires, which would not be subject to pre-incident plans. While dwellings are not addressed by NFPA 1620, the same pre-planning principles can be applied to examining the characteristics of different types of dwellings within a company's first due district. This will illustrate performance and tactical benchmarks during a firefighting operation.

NFPA has standards for training, professional qualifications, and incident management. It is incumbent upon today's fire service leaders to provide the certification and recurrent training as well as the proper promotional assessment processes to ensure company and chief officers understand the environment their firefighters are exposed to and the proper operational procedures to deal with that environment so the safety of everyone on the fireground is improved. The fireground is an unforgiving learning environment.

References

1. Fahy, R.F. and Molis, J.L., *Firefighter Fatalities in the United States – 2018,* National Fire Protection Association, Quincy MA, July 2019.

2. Evarts, B., *Fire Loss in the United States during 2018*, National Fire Protection Association, Quincy MA, September 2019.