U.S. FIRE SERVICE FATALITIES IN STRUCTURE FIRES, 1977-2009

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Since 1977, the number of U.S. firefighter deaths annually at structure fires has dropped almost two-thirds, a finding that often has been credited to improvements in protective clothing and equipment, fire ground procedures, and training, but little attention has been paid to the drop in the number of structure fires themselves.[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?

A comparison of the decline in the number of structure fires and the decrease in the number of firefighter deaths at structure fires shows that the trends track fairly closely, indicating that the drop in deaths may have been, to a great degree, a result of the reduction in the number of fires. 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 as likely to die today at structure fires as they were 25 or 30 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. (Because the 2009 fire experience data is not yet available, an estimate was calculated based on the number of structure fires in the previous three years.)

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 again to 5.8 in 1991. After falling to 4.8 deaths per 100,000 structure fires in 1994, it increased to 5.7 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. Since the mid-2000s, the number of structure fires has remained relatively unchanged, while the death rate has increased.

Given the improvements in personal protective clothing and equipment, training and operating procedures over the past two decades, what is the cause of these deaths, and are there any specific areas where deaths are increasing? 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. 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 1.1 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 0.4 deaths per 100,000 structure fires, after reaching a peak of 1.7 in the mid-1980s. (Figure 3)

The one area that had shown marked increases over the period is the rate of deaths due to traumatic injuries while operating inside structures. (Figure 4) In the late 1970s, traumatic deaths inside structures occurred at a rate of 1.8 deaths per 100,000 structure fires and by the late 1990s had risen to approximately 3 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 in recent years to more than 3 deaths per 100,000 structure fires. Part of the sharp increase in death rates over the past three years can be explained by a single, nine-fatality fire in 2007, but the dashed line in Figure 4 shows that the trend would still be increasing even without that fire.

Almost all of these non-sudden-cardiac-death fatalities inside at structure fires were the result of smoke inhalation or asphyxiation (63.5 percent), burns (19.5 percent) and crushing or internal trauma (15.3 percent). The rate at which these deaths have occurred per 100,000 structure fires is shown in Figure 5. All three categories were trending upward through the late 1990s, then fell. In this decade, however, asphyxiation and smoke inhalation deaths have climbed back to previous levels (or exceeded previous levels, with the 2007 nine-fatality included). Burn fatalities returned to the rate seen in the late 1990s. Only crushing and other internal traumatic injuries have decreased again, back to the lowest rates over the past 30 years.

The major causes of these traumatic injuries inside 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 cause of injury, together there was a clear upward trend over the full 33-year period. (Figure 6)

In order to reduce the number of deaths of firefighters operating inside at structure fires, it is crucially important to understand how they are happening and why they are not decreasing. 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 is providing a valuable database. Reports on many of the most recent fatalities can be found on their website: www.cdc.gov/niosh/firehome.html. However, we can give some general findings from the past decade (2000 through 2009).

In that 10-year period, 138 firefighters died while operating inside at structure fires. The deaths were the result of asphyxiation (78 deaths), burns (25 deaths), sudden cardiac death (20 deaths), and crushing injuries or internal trauma (15 deaths). Just over half the deaths occurred at one- and two-family dwellings (71 deaths). There were 24 deaths at retail establishments, 19 in apartment buildings, five in restaurants, four in storage facilities, two in a church, two in a woodmill and one in a nightclub. The remaining 10 deaths were in vacant dwellings (seven deaths), an office building under demolition (two deaths), and a dwelling under renovation (one death).

For the 78 firefighters since 2000 who died of asphyxiation (including smoke inhalation) while operating inside at structure fires, the major causes of injury were caught in structural collapses (27 deaths, of which 18 were in roof collapses, six in floor collapses, two in ceiling collapses and one in a wall collapse), caught by the progress of the fire, backdraft or flashover (24 deaths); and becoming lost inside the structure and running out of air (18 deaths). Five others fell through holes burned in floors, two were exposed to smoke while operating in the structure, one was struck by a falling awning, and one became trapped in product in a grain silo. All but three of the 78 victims were wearing self-contained breathing apparatus. Two of those three were operating at fires in their own homes, and were wearing no personal protective equipment. The third was a fire chief who entered a grain silo to assist fallen firefighters and was asphyxiated himself. Of those who were using SCBA, 14 did not have their facepieces in place. This could be because they removed the facepiece or it was knocked off when the victim fell or was struck. Eight of the 78 asphyxiation 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.

Of the 25 firefighters who died of burns inside at structure fires since 1990, 13 were caught or trapped by fire progress, backdraft or flashover, seven were caught in structural collapses, two fell through holes burned in floors, two became lost inside the structures and one was trapped by falling debris inside the structure.

Of the 15 firefighters who died as a result of crushing injuries or internal trauma, nine were killed in structural collapses, three jumped or fell from windows, one fell on a camera and ruptured his spleen, one was crushed in a manlift and one was struck by a door and power saw in an explosion.

Full details on construction are not available for many of the collapse incidents and incidents where firefighters fell through floor, but between 2000 and 2009, seven incidents were identified where lightweight wood trusses and/or pre-engineered I-beams were involved in the collapse. These seven incidents claimed nine lives. Eleven firefighters were killed in two fires where steel roof trusses collapsed.

The apparent increase in the rate of firefighter deaths while operating inside at structure fires raises 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 are ignoring 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 closer analysis and NIOSH's investigation program will provide some important answers. In the meantime, there is a lot that can be done to reduce these deaths.

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 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 25% 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 critique 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 changes 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 over half of the firefighter deaths while operating inside at structure fires in the past 10 years occurred at house fires, which would not be subject to pre-incident plans.

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 a very unforgiving learning environment.

REFERENCES

1. Fahy, R.F., LeBlanc, P.R. and Molis, J.L., " Firefighter Fatalities in the United States -- 2009," National Fire Protection Association, Quincy MA, July 2010.

2. Karter, M.J., " Fire Loss in the United States," National Fire Protection Association, Quincy MA, August 2009 (revised September 2009).

Figure 1
The drop in firefighter deaths at structure fires follows, and recently surpasses, the drop in structure fires

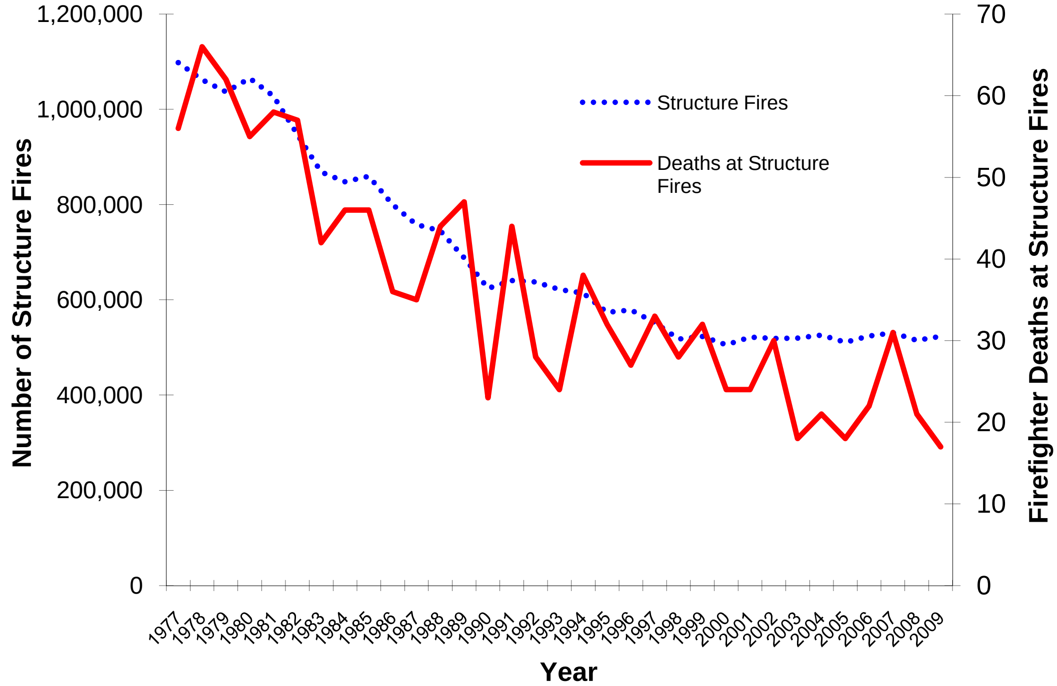

Figure 2
While the number of structure fires and deaths at structure fires has dropped, the rate of firefighter deaths at structure fires has not followed the same pattern

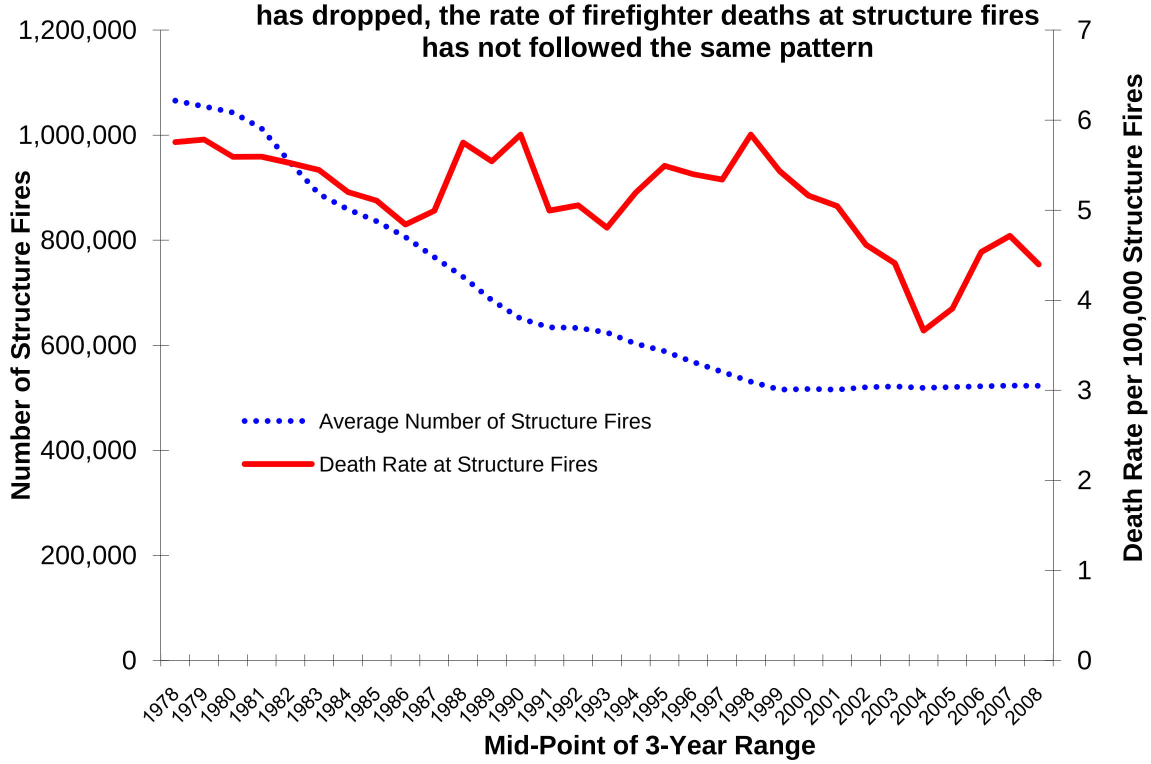

Figure 3
The rate of sudden cardiac deaths at structure fires and non-SCD deaths outside structure fires have been dropping, although the decrease for deaths outside has not been steady.

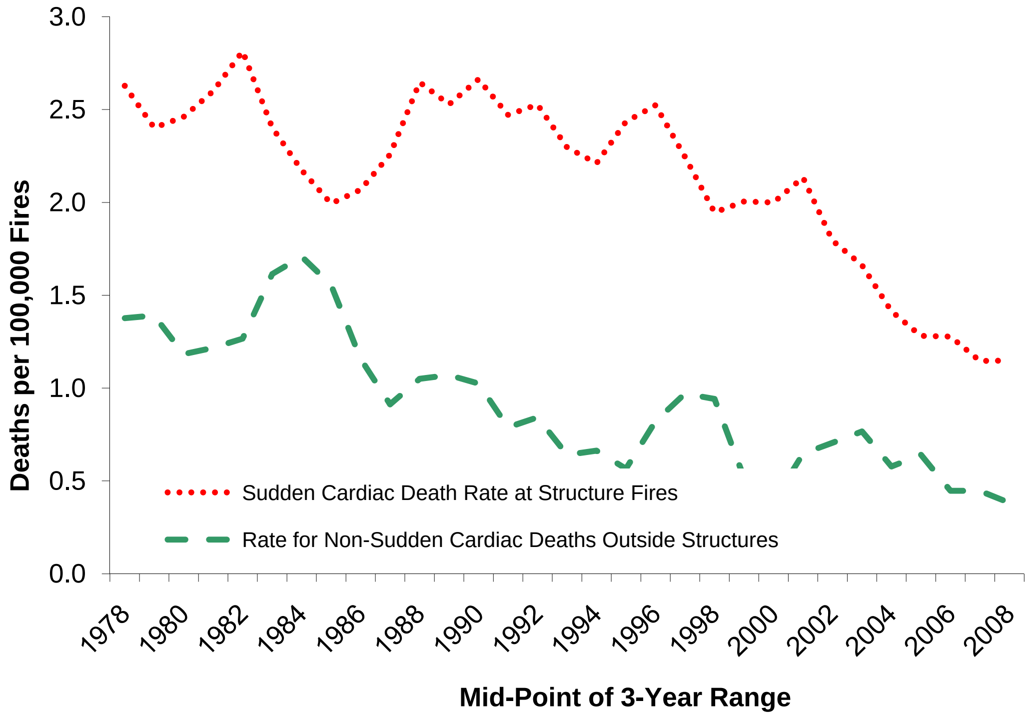

Figure 4
While the rate of non-cardiac deaths outside structure fires has been dropping, the rate for non-cardiac deaths inside remains high

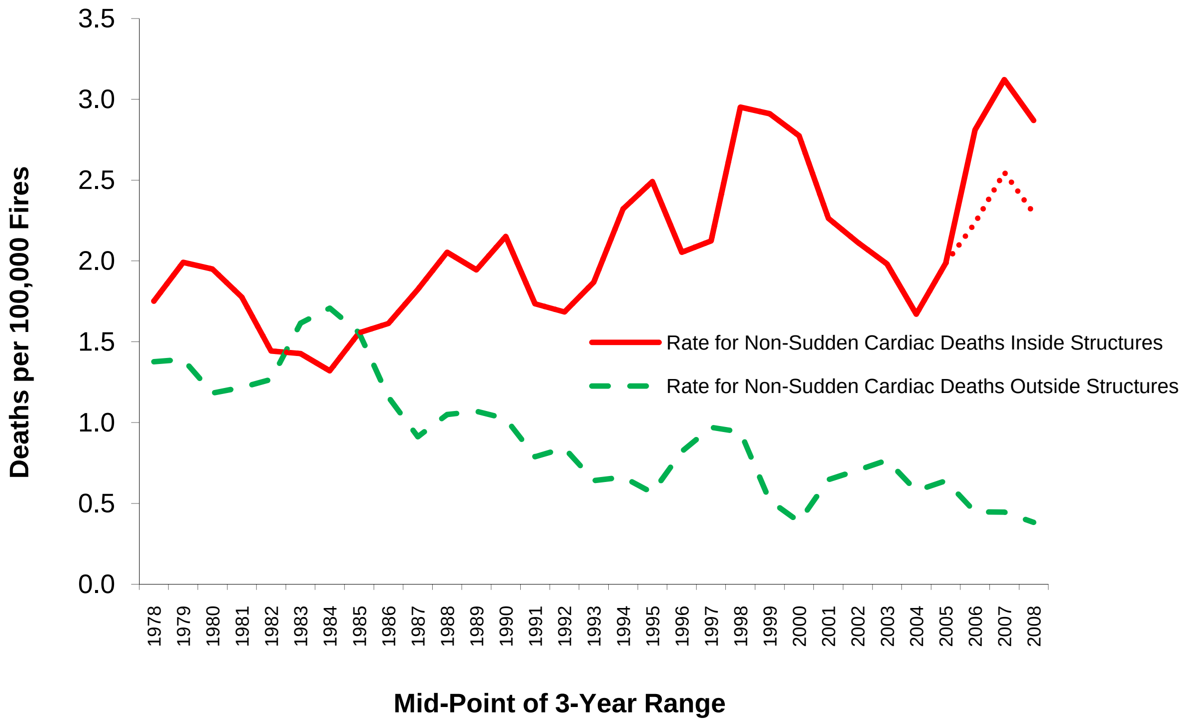

Figure 5
Almost all of the non-cardiac deaths inside structure fires were due to smoke inhalation, burns or crushing injuries, and the death rates due to these causes have not been falling.

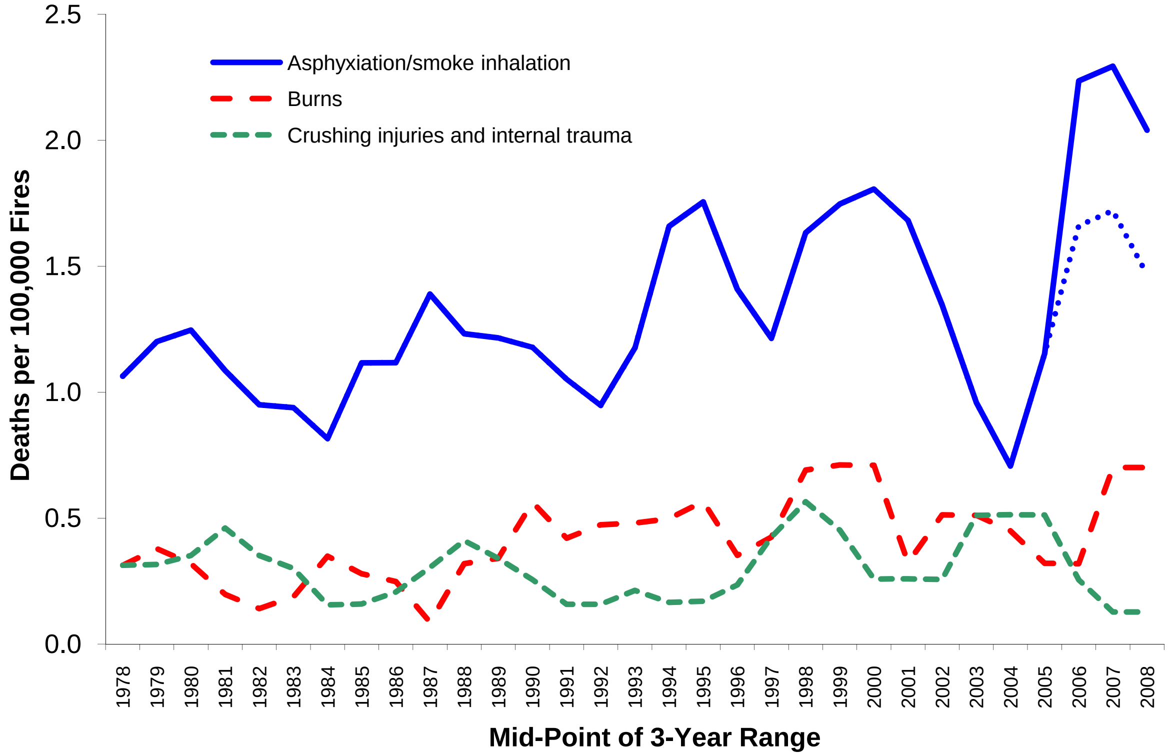

Figure 6
Death Rates for the Three Major Causes of Fatal Injuries
1977 - 2009