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Building Theory to Impact Practice

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The *International Fire Service Journal of Leadership and Management (IFSJLM)* is composed of peer-reviewed and editor-invited articles focusing exclusively on fire leadership and management topics. **To our knowledge, it is the only academic journal with this focus in the world.** *IFSJLM* is published by Fire Protection Publications (FPP) at Oklahoma State University (OSU). FPP is part of the College of Engineering, Architecture, and Technology at OSU and is the leading publisher in the world of fire-related education and training materials.

IFSJLM would not be possible without the financial support of the College of Engineering, Architecture, and Technology and FPP. This support represents a commitment to the continued professionalization of the American fire service.

As a further indication of the support of FPP to the international fire community, all volumes of the *IFSJLM* are available for reading **free of cost** at the Journal's website. Please go to https://www.IFSJLM.org to read and/or download previous volumes of the *Journal*.

The Dr. Granito Award

Dr. John Granito Award for Excellence in Fire Leadership and Management Research

The Dr. John Granito Award for Excellence in Fire Leadership and Management Research is presented at the *International Fire Service Journal of Leadership and Management (IFSJLM)* Research Symposium held annually in July at the International Fire Service Training Association (IFSTA) Validation Conference. The award honors Dr. John Granito.

Until his retirement, John was one of the premier fire and public safety consultants in the United States. Just a few of his many Fire, Rescue, and Emergency Services research projects include: Oklahoma State University-Fire Protection Publications Line of Duty Death Reduction project (3 years); Centaur National Study (3 years); Research Triangle Institute/National Fire Protection Association/International City/County Management Association project (4 years); Fire Department Analysis Project (FireDAP) of the Urban Fire Forum (13 years); *Combination Department Leadership* project, University of Maryland, Maryland Fire & Rescue Institute (4 years); and the Worcester Polytechnic/International Association of Fire Fighters/International Association of Fire Chiefs/National Institute for Occupational Safety and Health *Fire Ground Performance Study*. John has participated in more than 400 fire department studies.

John also has strong ties to academia. He served in a number of academic positions for almost 30 years, including 16 years at the State University of New York at Binghamton. He is Professor Emeritus and Retired Vice President for Public Service and External Affairs at SUNY Binghamton, which is consistently ranked in the top public universities by *U.S. News and World Report*.

John has published numerous articles, chapters, and technical papers, served as co-editor of the 2002 book published by the International City/County Management Association entitled, *Managing Fire and Rescue Services*, and is a Section Editor of the NFPA® 2008 *Fire Protection Handbook®*.

Dr. Granito was the first recipient of the award that honors him and his service to the fire service and to academia. Each year the recipient of the Dr. Granito Award presents the Keynote Address at the annual *IFSJLM* Research Symposium. The Keynote Address is subsequently published as the lead article in the following year's volume of the *International Fire Service Journal of Leadership and Management*.

Recipients of the Dr. John Granito Award for Excellence in Fire Leadership and Management Research

Research Symposium 2008	**Dr. John Granito**	Professor and Vice-President Emeritus, State University of New York Binghamton and Fire & Emergency Services Consultant
Research Symposium 2009	**Dr. Denis Onieal**	Deputy U.S. Fire Administrator
Research Symposium 2010	**Dr. Lori Moore-Merrell**	President and CEO, International Public Safety Data Institute
Research Symposium 2011	**Dr. Edward T. Dickinson**	Professor and Director of EMS Field Operations, Department of Emergency Medicine, Perelman School of Medicine, University of Pennsylvania
Research Symposium 2012	**Dr. Daniel Madrzykowski**	Research Director, Fire Safety Research Institute, Underwriters Laboratories, Inc., Columbia, MD
Research Symposium 2013	**Dr. Anne Eyre**	Independent Consultant, Trauma Training, Coventry, United Kingdom
Research Symposium 2014	**Chief Dennis Compton**	Former Fire Chief, International Fire Service Training Association, Fire Protection Publications, Oklahoma State University
Research Symposium 2015	**Dr. Denise Smith**	Tisch Family Distinguished Professor, Department of Health and Human Physiological Sciences, Director of First Responder Health and Safety Laboratory, Skidmore College (NY) and Research Scientist, University of Illinois, Fire Service Institute, Champaign, IL
Research Symposium 2016	**Dr. Sara A. Jahnke**	Director and Senior Scientist, Center for Fire, Rescue & EMS Health Research, NDRI-USA, Inc., Leawood, KS
Research Symposium 2017	**Chief Ronald J. Siarnicki**	Executive Director, National Fallen Firefighters Foundation
Research Symposium 2018	**Dr. Jefferey L. Burgess**	Associate Dean for Research and Professor, Mel and Enid Zuckerman College of Public Health, University of Arizona
Research Symposium 2019	**Dr. Gavin Horn**	Research Engineer, Fire Safety Research Institute, Underwriters Laboratories, Inc., Columbia, MD
Research Symposium 2020	***No Recipient***	*Symposium Was Cancelled Due to Pandemic*
Research Symposium 2021	***No Recipient***	*Symposium Was Cancelled Due to Pandemic*

Message from Dr. Robert E. England

Founding Editor, *International Fire Service Journal of Leadership and Management* (*IFSJLM*), Fire Protection Publications, Oklahoma State University

Welcome to the *International Fire Service Journal of Leadership and Management* (*IFSJLM*) 2.0. Volume 15 is much different from previous volumes in style and presentation. Ben Brock at Fire Protection Publications has designed and provided the layout for the *IFSJLM* since the first issue in 2007. This year, Ben has redesigned the journal, adding several updates to what he created 15 years ago. The *IFSJLM* is now in full color, and we have moved from a two-column to one-column text format. Thanks, Ben, for your dedicated service and design expertise. We are excited to share the *IFSJLM* 2.0 with our readers.

Dr. Lori Moore-Merrell, International Public Safety Data Institute, Chantilly, VA, USA
Dr. Steve Kerber, Fire Safety Research Institute, Underwriters Laboratories, Columbia, MD, USA
Dr. Gavin P. Horn, Fire Safety Research Institute, Underwriters Laboratories, Columbia, MD, USA, and University of Illinois, Fire Service Institute, Urbana-Champaign, IL, USA
Dr. Denise L. Smith, University of Illinois, Fire Service Institute, Urbana-Champaign, IL, USA, and Skidmore College, Saratoga Springs, NY, USA

Effects of Crew Size on Firefighter Health and Safety

Abstract

Firefighters' safety during fire responses depends on sound policies and procedures that ensure they can do their jobs efficiently and effectively. Decisions on *vehicle crew size* and *total effective response force deployment* should be based on the best available evidence. It is imperative that fire department leaders and political decision makers understand how the fire department resource deployment impacts community safety related to civilian injury and death, firefighter injury and death, and property loss. This state-of-the-art review provides a comprehensive examination of (a) results from multidisciplinary (e.g., engineering, medicine, fire technology, and social sciences) research efforts, (b) published data, (c) industry standards, and (d) expert opinion. The review examines the effect of emergency response vehicle crew size and total effective response force deployment on firefighters' health and safety risks, recognizing that firefighter health and safety is necessary to ensure that firefighters can effectively perform their jobs and protect their community. We conclude, based on available evidence, that the crew sizes and the effective response force sizes recommended in NFPA 1710*, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments,* should be considered the ***minimum*** to provide for firefighters' health and safety. Whenever possible, additional resources should be provided to address firefighter physiological stress, limit fire growth, and mitigate occupational exposure in today's rapidly evolving fireground.

Keywords: firefighter, crew size, health and safety, effective response force

Introduction

Fire chiefs are often faced with policies created by municipal officials who are challenged to balance community service expectations with finite budgetary resources. Unfortunately, many officials who are acutely aware of budgetary challenges often lack the solid technical foundation they need to properly evaluate the impact of staffing and deployment decisions on the safety of the public and firefighters. This often results in planning fire department resources to meet budget needs, rather than budgeting to ensure the proper resource allocation and deployment to meet critical service and safety needs.

Effectively managing a fire department requires proper emergency resource allocation to known risk environments in local communities. It is imperative that fire department leaders, as well as political decision makers, consider how fire department resource deployment in their local community affects community outcomes in three important areas: (1) civilian injury and death, (2) firefighter injury and death, and (3) property loss. This article focuses on fire department response to structure fires and the resulting impact on firefighter safety, injury, and death.

Fire continues to be a devastating event in communities across the country, with structure fires accounting for most civilian casualties. National Fire Protection Association (NFPA) estimates indicate that structure fires account for only 38% (499,000) of fires nationwide, and 72% (357,000) of structure fires in homes. Structure fires account for a disproportionate share of losses: 77% (2,630) of fire deaths, 83% (12,160) of fire injuries, and $10.7 billion of direct dollar losses (Evarts, 2018).

Community leaders recognize that fire protection is an essential service, and more than 32,000 fire departments operate with a mandate to protect lives and property of residents and visitors in their community. Although the overarching goal of the fire service is to prevent fires by ensuring proactive protections like fire alarms, smoke alarms, and automatic sprinklers are in place, the sad reality is that structure fires still occur. Therefore, there is an obligation to assess personnel resources deployed to these events, the environment in which they work, and the physical effects on responding firefighters.

Fire departments must establish policies on response crew size and total effective response force (ERF) deployment, incident arrival, and assembly in order to ensure operational effectiveness and fulfill their responsibility to protect their communities. In addition, fire departments have an obligation to consider the health and safety of the firefighters they deploy to face hazardous working conditions. These conditions are becoming more hazardous due to changes in building construction and modern furnishings.

NFPA 1500™, *Standard on Fire Department Occupational Safety, Health, and Wellness Program*, addresses response resources in the context of firefighter health and safety, but it stops short of definitively linking the effects of different crew sizes on responding vehicles to the health and safety of firefighters. The industry standard — NFPA 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments* — details the resources needed to adequately respond to different types of hazards and has implications for firefighter health and safety. NFPA 1720, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments,* is a companion document for volunteer fire departments, but it is not based on performance objectives as is NFPA 1710.

Regardless of fire department organization and the NFPA standard(s) followed, protecting firefighter health and safety is an obligation of the fire chiefs and elected officials who oversee fire departments. This obligation is critical to protecting the community, as it ensures that firefighters can perform their essential public safety work. To make staffing decisions, leaders must understand how the size of responding crews and the timeliness of ERF assembly affect firefighter health and safety.

This review synthesizes research from multiple disciplines in order to:

- Detail the health and safety risks that firefighters face as they perform firefighting work
- Describe the work activities that firefighters must perform
- Characterize the work environment in which firefighters perform their duties
- Discuss the effect of response crew size and the timing of ERF assembly on firefighter health and safety
- Provide recommendations for policy makers to ensure effective and safe deployment of resources

Firefighter Health and Safety Risks

Firefighting is widely acknowledged as a dangerous occupation. Between 2009 and 2018, NFPA reported that 701 firefighters died in the line of duty, including 599 municipal firefighters from career and volunteer departments (Fahy & Molis, 2019, and reports from previous years). **Table 1** presents the number of fatalities for municipal firefighters by cause and nature for the 10-year period between 2009 and 2018 as reported by the NFPA. In 323 (53.9%) of the 599 duty-related municipal firefighter deaths in the past ten years, overexertion/stress/medical was listed as the cause of death. Sudden cardiac death was the nature of fatality most commonly reported by the NFPA. Stroke, a condition related to blood vessels in the brain, was identified as the nature of the fatality in another 29 firefighters, meaning that cardiovascular disease was responsible for more than half of line-of-duty deaths reported by the NFPA in the past 10 years. Internal trauma and crushing, asphyxiation and smoke inhalation, and burns were responsible for another 252 firefighter fatalities.

In addition to the fatalities addressed above, **Table 2** shows over 665,000 injuries were reported during this 10-year period, and it is widely acknowledged that injuries are underreported (see Campbell & Molis, 2019, and previous reports in the series). The majority of injuries were due to strains, sprains, and muscular injury. Some of these injuries include serious back or joint injuries that can require long treatment periods and expensive backfilling of positions. Over 7,000 firefighters suffered non-fatal cardiac events and strokes during the 10-year period. Burns, smoke inhalation, or the combination of the two resulted in injuries to 48,550 firefighters.

Table 1
Career and Volunteer Municipal Firefighter Fatalities Over a 10-Year Period (2009-2018)

Cause of the Fatality as Reported by the NFPA	Number of Fatalities	Percent of Total Fatalities
Overexertion/stress/medical	323	53.9%
Struck by object	61	10.2%
Motor vehicle crashes	47	7.9%
Lost inside/caught or trapped	41	6.8%
Fell	35	5.8%
Struck by vehicle	27	4.5%
Structural collapse	25	4.2%
Rapid fire progress	23	3.8%
Other[a]	17	2.8%
Nature of the Fatality as Reported by the NFPA	**Number of Fatalities**	**Percent of Total Fatalities**
Sudden cardiac death	287	47.9%
Internal trauma & crushing	179	29.9%
Asphyxia including smoke inhalation	51	8.5%
Stroke	29	4.8%
Burns	22	3.7%
Other[b]	31	5.2%
TOTAL	**599**	**100%**

Source: Campbell & Molis, 2019, and previous reports in the series.

Note. This table does not include data from non-municipal firefighters, which may include employees of forestry agencies, industrial fire brigades, the military, the federal government, prison crews, and impressed civilians as described at https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/Firefighter-fatalities-in-the-United-States/Firefighter-deaths. This list does not include firefighters at the World Trade Center, September 11, 2001.

[a] Other includes assault/murder, exposed to electricity, exposure, and caught underwater.
[b] Other includes gun shot, unspecified medical, drowning, electrocuted, suicide, drug overdose, asthma, and pneumonia.

Table 2
Firefighter Injuries over a 10-Year Period (2009-2018)

Nature of the Injury as Reported by the NFPA	Number of Injuries	Percent of Total Injuries
Burns (fire or chemical)	20,720	3.2%
Smoke or gas inhalation	20,445	2.9%
Burns and smoke inhalation	7,385	1.0%
Other respiratory distress	9,280	1.4%
Strain, sprain, muscular pain	365,860	55.3%
Wound, cut, bleeding, bruise	100,345	15.2%
Thermal stress (frostbite, heat exhaustion)	25,765	3.8%
Dislocation, fracture	17,380	2.7%
Cardiovascular disease (heart attack/stroke)	7,955	1.2%
Other	90,835	13.6%
TOTAL	**665,970**	**100.0%**

Source: Campbell & Molis, 2019, and previous reports in the series.

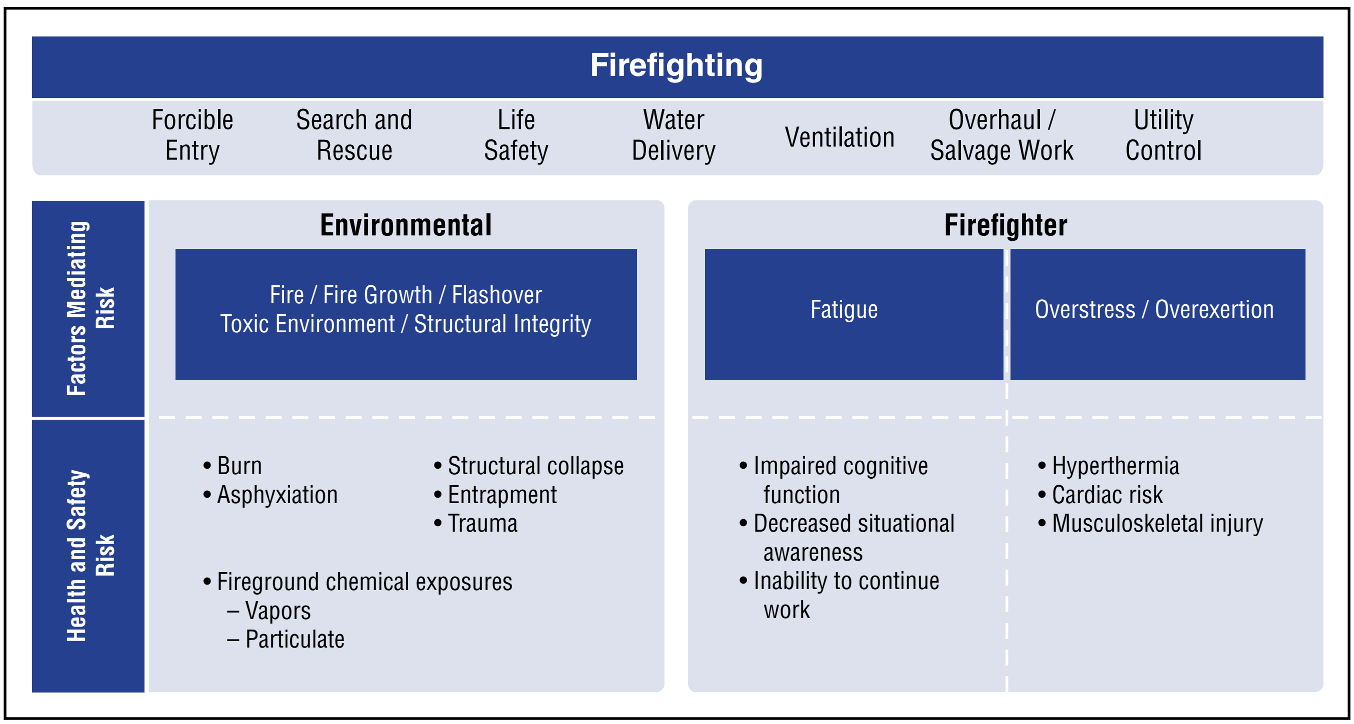
Calculating the number of injuries and fatalities may be easier than understanding what causes them. There are many hazards that lead to injury and fatalities, including fire, smoke, building components that fail and collapse, and pathophysiological responses to the stress of firefighting. A firefighter may be injured or killed by one acute event or a combination of events. One event may lead to another more serious injury, such as trauma from a fall leading to burns or asphyxiation when the firefighter becomes trapped under debris. Fire departments must understand the risks that firefighters face and plan their responses to ensure they can meet the operational needs of firefighting and mitigate risk appropriately. By considering these factors, policy makers can take meaningful steps to mitigate risk.

In addition to the acute risks that firefighters face, chronic exposure to products of combustion can have long-term impacts on firefighters' health. The National Institute for Occupational Safety and Health (NIOSH) has found cancer incidence and mortality rates in firefighters to be significantly higher than the national average. Mesothelioma and cancers of the esophagus, intestine, kidney, and oral cavity are particularly prevalent in firefighters. Research also shows an exposure-response relationship for lung cancer and leukemia (Daniels et al., 2014, 2015; Pinkerton et al., 2020). The International Association of Fire Fighters (n.d.) reports that occupational cancers accounted for 66% of the line-of-duty deaths among their membership of active and retired firefighters between 2002 and 2019. It is important to note that cancer-related deaths are not included in the NFPA statistics reported earlier.

Figure 1 depicts the health and safety risks that a firefighter faces in the context of the firefighting work performed, the environment in which it is performed, and the physical, physiological, and psychological strain it places on the firefighter. The following subsections address some of the major health and safety risks that firefighters face and discuss the complex interactions between different types of risk that increase the potential for injury and death in the line of duty.

Figure 1

Relationship Between Firefighter Health and Safety Risks, and Firefighting Work, and the Firefighting Environment



Burns and Asphyxiation

Perhaps the two most readily recognized risks that firefighters face are burns and asphyxiation due to the hot, smoke-filled environment in which they work. These conditions can occur separately or in combination. Burns and asphyxiation occur most often when fire conditions change rapidly, overcoming a firefighter. They also occur when a firefighter becomes lost or trapped due to the collapse of building structures or the excessive fatigue that makes escape impossible or that impairs cognitive function. Burn injuries vary in severity, depending on the type, depth, and extent of the burning. Severe burns can be fatal.

Structural Collapse/Trauma/Entrapment

Traumatic injuries are a broad category of sudden onset physical injuries that require immediate medical attention and can lead to death. Any part of the body can be injured by trauma, and traumatic injuries can vary greatly in severity. Traumatic injuries include crushing injuries, head injuries, and back injuries. While the traumatic fatalities are devastating, traumatic injuries can lead to multiple surgeries and require months or years of rehabilitation.

There are numerous ways that a firefighter can be injured or killed by traumatic events on the fireground. Building components can collapse and fall on a firefighter, or firefighters can fall through floor or roof systems that have been structurally compromised. Firefighters can fall from ladders or elevated work locations that are necessary to complete fireground missions. Uncontrolled fire growth provides the greatest risk for structural collapse. Structural collapse can lead to trauma, entrapment, and/or burns and asphyxiation, further exemplifying the overlapping nature of the risks that firefighters face.

Chemical Exposure Risk

More than ever, firefighters are becoming aware of chemical exposure risks on the fireground. Fires involving common household furnishings in residential structures can produce hundreds of compounds, including those that exist primarily in the vapor phase (e.g., benzene, styrene, 1,3-butadiene, formaldehyde, vinyl chloride, dioxins) and those that exist primarily in the solid phase (Austin et al., 2001; Jankovic et al., 1991). Many of these compounds are known or probable human carcinogens.

Fireground exposures can be experienced through inhalation, ingestion, and dermal absorption. Inhalation is the most direct route of exposure for firefighters who do not wear respiratory protection inside or outside the structure. Products of combustion may also be absorbed through the skin. The longer a chemical is present on the skin, the more time is available for transdermal absorption.

Fatigue

Fatigue is a natural result of firefighting activity because firefighters perform heavy muscular work while wearing heavy, insulative, and protective clothing. However, the potentially dangerous results of excessive fatigue are seldom addressed. In addition to causing medical events related to overexertion, fatigue can decrease the physical work firefighters can perform. An impaired ability to perform the time-critical work of applying water to the fire can allow the fire to grow, placing both civilians and firefighters at greater risk. Fatigue can also decrease situational awareness because changes in cognitive function may jeopardize a firefighter's ability to make sound decisions.

Overexertion/Medical Events

There are numerous injuries and fatalities that are broadly attributed to overexertion. The most common medical issue encountered on the fireground is heat exhaustion. Firefighters who perform heavy muscular work while wearing personal protective equipment (PPE) have an increase in core body temperature that can lead to heat exhaustion. Most firefighters who suffer heat exhaustion will recover if they are provided with appropriate cooling, hydration, and rest. Heat stroke, the complete breakdown of the body's ability to thermoregulate, is a more serious and rarer condition than heat exhaustion.

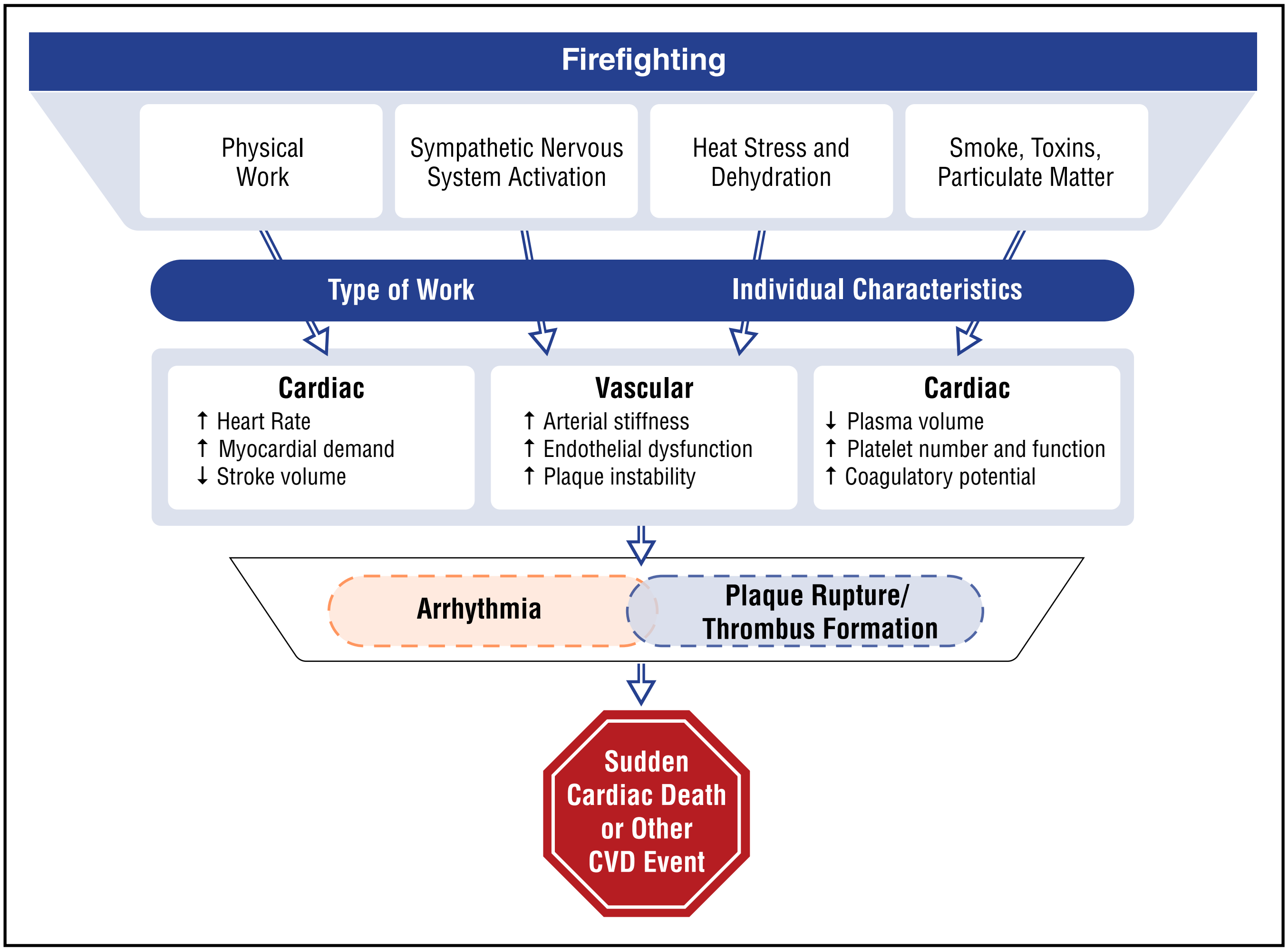
Musculoskeletal injuries are also more likely in a firefighter who is fatigued. Deteriorating biomechanics and/or impaired cognitive functions make recognizing hazards more difficult. These injuries, including sprains and strains, result in more than 50% of reported injuries.

Cardiovascular Events

Cardiovascular events are a major concern in the fire service. Research demonstrates that firefighting activity dramatically increases the risk of suffering a sudden cardiac event. In fact, a firefighter is 10 to 100 times more likely to suffer sudden cardiac death after firefighting than a firefighter engaged in non-emergency duties (Kales et al., 2007; Smith, Haller et al., 2019). More than 7,000 firefighters suffered non-fatal, duty-related cardiovascular events in the last 10 years (Campbell & Molis, 2019, and previous reports in the series).

As outlined in **Figure 2**, cardiovascular events may be triggered in vulnerable individuals by multiple stressors that are part of firefighting work, including physical exertion, activation of the sympathetic nervous system, heat stress and dehydration, and exposure to smoke and particulate matter. Research of the general population has shown that strenuous physical work, sympathetic stimulation, and particulate matter are all factors that increase the risk of sudden cardiac death (Mittleman, 2007; Willich et al., 1993). Firefighters are exposed to all these risk factors and often to a greater extent than the public.

Figure 2
Model Linking the Physical and Physiological Stress of Firefighting to Cardiovascular Responses and to Potential Triggering of a Cardiovascular Event



Source: Smith et al., 2013.

Firefighting Work

The health and safety risks that firefighters face are multifactorial and often overlap. These risks are directly related to the work firefighters perform and their work environment.

Firefighting crews must address four priorities at a fire scene:

1. Life safety of occupants and firefighters
2. Confinement and extinguishment of the fire
3. Property conservation
4. Reduction of adverse environmental impact

Firefighting personnel conduct interdependent and coordinated activities to meet these priority objectives. Specific tasks, such as advancing a hose line to the fire, ventilation, and search and rescue, can be conducted simultaneously or sequentially. Conducting these activities simultaneously is the most efficient manner. Performing tasks sequentially can limit coordination and delay tasks on the fireground, contributing to rapid fire growth and escalating risk.

Each arriving emergency vehicle (fire engine or truck) transports firefighters to the scene. The group of firefighters associated with a particular emergency vehicle is called a *fire crew* or *fire company*. According to NFPA 1710 (2020), the minimum crew size is four firefighters, including one designated as an officer. This requirement is important to understand as on scene tasks and risks are explained.

Because every fire can present a unique set of conditions, fire department leaders should match the mobile and personnel resources they deploy to the risks they are likely to encounter at the scene. The risks vary according to building size, structure type, and occupancy load. NFPA 1710 identifies four structure categories:

1. Single-family
2. Open-air strip malls
3. Garden-style apartment buildings
4. High-rise buildings greater than 75 feet (23 m)

The standard also indicates the minimum number of firefighters who must be available on scene for “low hazard” single-family dwelling responses (16), “medium hazard” strip malls or garden apartment responses (27), and “high hazard” high-rise fires (43). The resources deployed include firefighters, vehicles, and equipment. Another element that must be considered in the resource/risk match is each crew’s arrival, overall assembly, and intervention time(s). The arrival and intervention time of the responding vehicles and crews often depends on how many fire stations are in the community, where the stations are located, and whether the stations are sufficiently staffed with vehicles and crews to be effective during an emergency response. Fire department total response time calculations must include call intake and dispatch, turnout time for firefighters, and travel time for each responding fire crew to arrive on scene. For safe and effective firefighting operations, it is critical that ERFs arrive, assemble, and engage on the scene in a timely manner.

Local communities preplan emergency response deployments based on building sizes, structure types, and occupancy types. It is critical that fire suppression activities and search and rescue operations begin as quickly as possible. Because many cities lack resources to ensure an ERF is available from the same station, fire crews are often deployed from multiple fire stations. Fire departments assign geographic areas in close proximity to each fire station as first due areas. Each fire station in the U.S. has a predetermined first due area. If a fire or emergency incident occurs at an address inside that geographic area, the vehicles (companies) in that fire station are dispatched to respond and arrive first on the scene. The second and subsequent crews that are part of the ERF often respond from other stations outside the immediate area to work with the first-arriving crew. Communities unable to send an ERF on their own may rely on mutual or automatic aid. Mutual aid is an agreement between or among fire departments to help each other across jurisdictional boundaries and occurs only when local emergencies exceed local resources. Automatic aid is a more formal agreement to send the additional resources automatically.

At all fires, the first-arriving emergency response vehicle and crew must complete several tasks quickly. The officer from this crew establishes Incident Command, completes a scene size-up, and then determines the operational plan for the incident. The driver secures a water supply and engages and monitors the hydraulic pump on the engine to ensure water is available for fire attack. The remaining firefighters assigned to that initial crew position hose lines and prepare to intervene in fire suppression through a combination of exposure control, fire confinement, and fire extinguishment.

Figure 3 depicts how different crew sizes may be deployed at a representative point in time prior to structure entry. At a minimum, two firefighters are assigned to position a hoseline to apply water to the fire, and another member is charged with operating the pumping apparatus. As more members are available on the scene, a dedicated Incident Commander (IC) and an Intial Rapid Intervention Crew (IRIC) are established. A 3-person crew does not allow firefighters to enter the structure because there are not enough firefighters on the outside to facilitate a rescue should the fire dynamics change quickly and the entry crew become trapped. By comparison, a crew size of five provides enough firefighters to deploy the attack line for interior fire suppression and a back-up hoseline with an IRIC ready to engage should fire dynamics change for the worse. More firefighters in the initial crew means more required tasks can be done simultaneously and safely. Larger crews can also apply water to a fire from an interior position more quickly.

Figure 3

Deployment Scenarios at a Representative Point in Time prior to Structure Entry for Crew Sizes of (Top) Three, (Middle) Four, and (Bottom) Five Firefighters

Note. A 3-person crew does not allow firefighters to enter the structure while also supporting the "two in/two out" rule.

Additional vehicles/crews are dispatched at the same time as the first-arriving vehicle, but they may come from farther away and arrive minutes/seconds after the initial vehicle. As these additional crews arrive on scene, they provide firefighting resources to control the incident, stop risk escalation, and support a host of other activities. Because life safety is a priority, crews are often assigned to conduct search and rescue throughout the structure. Additional arriving crews may be tasked with laddering the building to support rescue, providing additional exterior means of egress, or assisting in ventilation to control smoke and increase survivability. Additional crews assigned to ventilate the structure may remove windows from the structure at the same level as the fire (horizontal ventilation) or create openings above the level of the fire through the roof, attic, or upper-story windows (vertical ventilation).

Firefighters assigned to overhaul use a variety of tools to locate hidden fires throughout the structure, particularly in wall and ceiling voids, and check to ensure the fire has been fully extinguished. Overhaul involves heavy physical work and may continue long after the initial fire has been extinguished. Salvage operations are conducted during fire suppression and/or overhaul to protect as much of the building and contents from smoke and water damage as possible.

Figure 4 provides an example of how an ERF of 16 firefighters and one IC may be deployed for a low-hazard, residential fire. (The figure shown wearing a white helmet is labeled the IC.) In this example, the fire department has responded with three engines and a ladder truck. Each vehicle is staffed with four firefighters (including one crew officer). The first engine to arrive on scene (labeled E1) is considered the fire attack engine and is the first to get water to the fire. The first engine officer assumes the role of IC until a higher-ranking officer (e.g., Battalion Chief, etc.) arrives, and command is officially transferred. Two of the firefighters on this crew take the attack line to the fire. The remaining crew member is the pump operator at

Figure 4
An Example Effective Response Force (ERF) of 16 Firefighters Deployed for a Low-Hazard Residential Fire with Firefighters Assigned to Engine 1 (E1), Engine 2 (E2), Engine 3 (E3), and Truck 1 (T1); Incident Commander (IC) Responds in a Command Vehicle

the engine who, along with the engine officer, remains outside the fire environment to be the IRIC. They are prepared to rescue the two firefighters entering the structure (as shown in the middle diagram in Figure 3).

In this scenario, the crew from the first ladder truck to arrive (T1) divides into two teams of two firefighters to conduct search and rescue throughout the structure, raise ladders to second-story windows to provide egress for trapped occupants and firefighters, and ventilate the structure as needed to assist with fire extinguishment and the release of toxic gases. The second engine to arrive (E2) establishes a sustained water supply to the first engine using a nearby fire hydrant and connects a backup attack line to get water to the fire. The crew members on the third engine (E3) become the designated RIC, which allows the E1 officer to move up to supervise and assist the members on the initial attack line (if Command has been transferred to another IC).

Depending on the structure type and fire growth, the initial full-alarm ERF may require more crews and can be upgraded if the IC calls for more resources. **Table 3** provides the crew size and ERF that NFPA 1710 (2020) recommends for different hazard levels. In addition to the work that firefighters perform, their work conditions greatly influence the health and safety risks they face.

Table 3
Crew Size and Effective Response Force Recommendations from NFPA 1710

Crew Size	Engine	Truck
Minimum on duty	4	4
High volume/geographic restrictions, isolation/urban area	5	5
Tactical hazards, dense urban area	6	6
Effective Response Force	Minimum	If Aerial Used
Low hazard	16	17
Medium hazard	27	28
High hazard	43	43

Source: NFPA, 2020

The Work Environment: Fire Dynamics

Fire growth is the primary factor that drives the need for sufficient available resources to intervene in a structure fire in a timely manner. Knowledge of fire dynamics and the associated potential for risk escalation can be used proactively to assist in planning firefighter staffing patterns and fire station locations.

Flashover is a significant transition in fire behavior. When flashover occurs, fire may quickly engulf the room. A compartment fire that has flashed over generates a tremendous amount of heat, smoke, and pressure with enough force to spread fire beyond the room of origin. This situation presents a serious threat to firefighters operating in the vicinity.

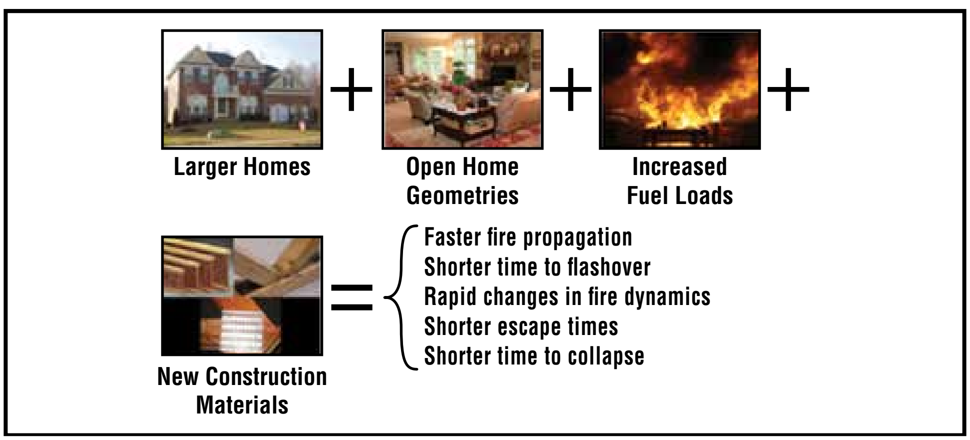
Flashover is a significant transition point of fire development for several reasons:

- The likelihood of survival and the chances of saving any occupants from the fire compartment drop dramatically.
- Flashover is associated with a rapid increase in the rate of combustion. The resulting increase in heat release rate and smoke production raises the health and safety risk for firefighters.
- More water is needed to absorb the increased energy being released and extinguish the burning material.
- More firefighters are required if fire spreads to different compartments and assemblies in the structure.

Larger hose streams or multiple handlines that require more firefighting personnel may become necessary to flow enough water fast enough to extinguish the fire. After flashover, the deteriorating conditions can compound the search and rescue task in the remainder of the structure, again requiring greater resources to mitigate the incident.

Recent changes in the built environment have necessitated changes in the way firefighters must respond to and work within structure fires. Societal priorities and personal preferences have also contributed to changes in the residential fire environment (Kerber, 2012). These residential structure changes include larger homes, open floor plans with spacious rooms, increased usage of synthetic furnishings and materials, and changing construction materials (see **Figure 5**). At the same time, residential fires continue to be the leading cause of fire fatalities in the U.S. (NFPA, 2014–2018).

Figure 5
Fire Dynamics Formula Representative of Early 21st Century Fireground Environments

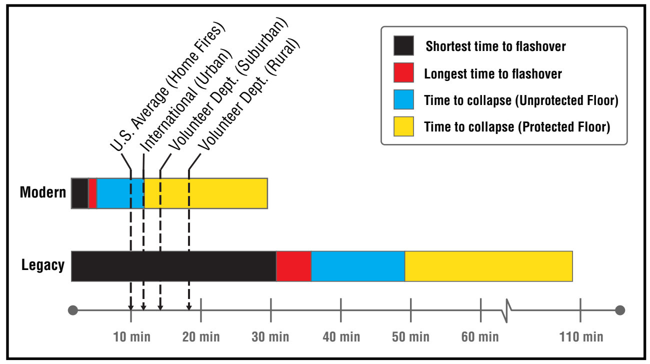


Source: Kerber, 2012.

Researchers at UL have conducted several experiments to compare the impact of changing fuel loads in residential houses. These experiments show that once living room fires have transitioned to flaming fires, flashover times of less than five minutes may be expected in today's fire environment. Flashover times were closer to 30 minutes in the mid-twentieth century. Other experiments demonstrate that the failure time of wall linings, windows, and interior doors has decreased over time, which also affects fire growth and firefighter tactics. Related research has shown that an engineered I-joist floor system, common in today's construction, can collapse in less than one-third the time it takes a dimensional lumber floor system to fail (Kerber, 2012; Kerber et al., 2012). This change in fire development and collapse risk impacts the necessary firefighter response times and operational timeframes once on scene. Responding crews must be able to assemble in a timely manner and quickly initiate application of water on the fire to stop continued risk escalation.

Understanding fire behavior, particularly flashover, is key to designing an emergency response system. Enough firefighters and equipment must be strategically located throughout the community to ensure the minimum acceptable response force can be assembled to engage in a fire before substantial risk escalation occurs. **Figure 6** shows how the timeline for major events has changed from legacy construction to the modern fire scenario and superimposes a timeline that represents, on average, how long it takes for fire departments to arrive on the scene. To save lives and limit property damage, firefighters must be properly trained and arrive at the right time with adequate resources to do the job.

Figure 6
The Relative Timeline of Hazard Progression Flashover to Structural Collapse and the Relationship to Average Fire Department Response Times (US Average, International, Volunteer Suburban, Volunteer Rural)



Source: Kerber, 2012.

Note. The legacy home timeline, which may be used by some jurisdictions for staffing and response policies, is misleading because it suggests there is more time to assemble an ERF than there actually is prior to significant risk escalation.

Regulations Addressing the Effect of Staffing/ Crew Size on Firefighter Health and Safety

The number of personnel assigned to each emergency response vehicle (crew size) and the number of firefighters deployed to the entire event (ERF) directly influence operational effectiveness. Operational effectiveness has a significant effect on firefighter health and safety risks because it influences firefighters' ability to control fire growth, the risks associated with fire growth, and the amount and pace of work that must be performed to limit additional risk.

There are valuable resources available to assist decision makers and fire service leaders in planning for adequate emergency resource deployment in their community to ensure that firefighter intervention occurs in a timely and coordinated manner. These resources are designed to address health and safety to varying degrees, but they all seek to limit risk escalation, civilian and firefighter injury and death, and property loss. These regulations and standards, and their recommendations relative to firefighter health and safety, are described below.

Department of Labor Occupational Safety and Health Administration "Two In/Two Out" Policy

The "two in/two out" policy is part of paragraph (g)(4) of the revised respiratory protection standard, 29 CFR 1910.134, of the Occupational Safety and Health Administration (OSHA). This paragraph applies to private sector workers engaged in interior structural firefighting and to federal employees covered under Section 19 of the Occupational Safety and Health Act. States that have chosen to operate OSHA-approved occupational safety and health plans are required to extend their jurisdiction to include employees of their state and local governments. OSHA requirements for the number of workers who must be present for operations in immediately dangerous to life and health (IDLH) atmospheres also apply to the number of persons who must be on scene before firefighting personnel can initiate an attack on a structural fire.

Conducting firefighting operations in an interior structural fire is considered working in an IDLH atmosphere and requires the use of respirators. At least two standby persons must be present before a minimum of two firefighters may enter the building to fight the fire. In order to comply with this standard, a minimum of four firefighters must arrive on the scene. This regulation allows an exception for rescue operations conducted in the event of an imminent life-threatening situation where immediate action may prevent the loss of life or serious injury.

NFPA 1500™, *Standard on Fire Department Occupational Safety, Health, and Wellness Program*

NFPA standards are industry standards developed through the consensus of experienced leaders, relevant experts, and where it exists, scientific empirical data. NFPA 1500™ sets the minimum safety guidelines for personnel involved in rescue, fire suppression, emergency medical services, hazardous materials operations, and special operations. NFPA 1500™ is designed to help prevent and reduce the severity of accidents, injuries, and exposures. Like NFPA 1710, NFPA 1500™ also sets requirements for the minimum number of personnel on an emergency scene.

Specifically, the standard addresses the following:

- the organization of a safety and health program
- the training requirements of personnel
- maintenance and operation requirements of vehicles and equipment
- protective clothing requirements
- emergency operations management
- medical and physical requirements of firefighters
- wellness programs

The NFPA 1500™ Annex A (2018) specifically notes that to reduce the risk of firefighter death or injury due to understaffing, emergency scene operations should be limited to those that can be safely conducted by the number of personnel on scene. Personnel can be assigned to and arrive at the scene of an incident in many ways, but it is strongly recommended that interior firefighting operations not be conducted without an adequate number of qualified firefighters operating in crews under the supervision of company officers. Annex A further recommends a minimum acceptable staffing level that matches the recommendations in NFPA 1710.

These recommendations, based on experience derived from actual fires and in-depth fire simulations, are the result of critical and objective evaluations of fire crew effectiveness. Averill et al. (2010, 2013) also indicate significant reductions in performance and safety when crews have fewer members than the above recommendations. Five-member crews were found to provide a more coordinated approach for search and rescue and fire-suppression tasks than crews with fewer members.

NFPA 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*

NFPA 1710 sets minimum standards for firefighter crews, response times, and other factors involved in determining the organization and deployment of firefighting and emergency medical systems. NFPA standards apply to jurisdictions regardless of their geography, topography, fiscal capacity, service burdens, population density, or local variations.

NFPA 1710 (2020) states that fire engines (pumper) and fire trucks (ladder) companies shall be staffed with a minimum of four on-duty personnel. The standard also requires these companies be staffed with a minimum of five on-duty members in first-due response zones with a high number of incidents, geographical restriction, or geographical isolation. Although NFPA 1710 defines operating units as a fire crew with staffing requirements based on minimum levels necessary for safe, effective, and efficient emergency operations, this standard establishes the floor, not the ceiling, for staffing of each vehicle.

According to NFPA 1710, the number of on-duty firefighters shall be sufficient to perform the necessary firefighting operations given the expected firefighting conditions. Additionally, the fire department shall identify minimum vehicle crew size as necessary to ensure that a sufficient number of members are available to respond with each vehicle. The deployment section of the standard identifies the fireground tasks that must be completed for each structure category as described in Table 3.

Timely Response

In addition to having enough firefighters to respond, it is important that they respond in a timely manner. NFPA 1710 defines dispatch, turnout, and travel times to the emergency scene. These times are relevant to the discussion of firefighter safety as the intent is to arrive at the scene in a timely manner with enough trained personnel to reduce the potential for further risk escalation. The criteria listed in NFPA 1710 establish the following times based on the science of fire dynamics previously discussed and the experience and consensus of NFPA 1710 technical committee members:

- 80 seconds turnout time for fire and special operations,
- 240 seconds or less travel time for arrival of a first engine crew,
- 360 seconds or less travel time for arrival of the second crew (engine or truck) with a minimum of four personnel,
- 480 seconds or less travel time for arrival of the full ERF for structures other than high-rises, and
- 610 seconds or less travel time for arrival of the full ERF for high-rises.

On Scene Safety: Rapid Intervention Crews (RIC)

In NFPA 1710, the RIC is defined as a dedicated crew of at least one officer and three members, positioned outside the IDLH atmosphere, appropriately trained and equipped, and assigned for rapid deployment to rescue lost or trapped members. NFPA 1710 specifically states that, at a minimum, an IRIC may be assembled from the initial attack crew and, as the ERF arrives, a full and sustained RIC should be established with four personnel (NFPA 1710, 2020). If the first-arriving crew is short-staffed with less than the minimum four persons, this safety mechanism cannot be put in place. A crew of fewer than four firefighters cannot intervene in the emergency without increased risk to their own safety and well-being.

Research Addressing the Effect of Crew Size on Firefighter Safety

Recent research has helped to better understand the effects of crew size on key operational milestones, as well as the physical and physiological responses and chemical exposure risk of firefighters. A National Institute of Standards and Technology (NIST) study on staffing and deployment in a low-hazard residential fireground environment (Averill et al., 2010) quantified the effects of crew sizes, ERF assembly, and arrival times on firefighting operations. Important outcomes included factors that influence fire growth and exposure risk, and thus affect occupant survivability and firefighter health and safety. The project included multiple components, including the effect of crew size and computer modeling to predict fire growth and environmental toxicity.

NIST Residential Fireground Field Experiments

The residential fires component of this study evaluated how long it took different crew sizes (two to six firefighters) to complete a series of 22 essential fireground tasks in single-family dwellings. The study included acquisition of air samples to assess toxicity levels and computer modeling to understand how fire growth rate affected the survivability of citizens trapped within the structure.

Of all the essential tasks studied, "time to water on fire" had the most significant impact on successful operations. Importantly, there was a 6% difference in the "water on fire" time between the 3- and 4-person crews and an additional 6% difference between the 4- and 5-person crews. The 4-person crews completed laddering and ventilation (for life safety and rescue) 25% faster than the 3-person crews. In other findings, the 4- and 5-person crews started and completed a primary search 6% faster than the 3-person crews. The 4-person crews were nearly 25% faster than 3-person crews on overall scene time necessary to complete all tasks. These results clearly demonstrate the impact of crew size on the operational effectiveness of firefighters: the larger the crew, the greater its ability to limit fire growth and save lives.

The NIST study also found that survivability of potential trapped occupants was affected by crew size and time of arrival. Independent of fire size, there was a significant difference in the exposure to toxic compounds, expressed as fractional effective dose (FED), in occupants at the time of rescue depending on arrival of the ERF. The smaller or later the responding crews, the greater the risk to trapped occupants.

NIST High-Rise Fireground Field Experiments

NIST researchers and study partners also conducted a resource deployment study in a high hazard, high-rise fireground environment (Averill et al., 2013). When responding to fires in high-rise buildings, firefighting crews of five or six members—compared to three or four members—are significantly faster in putting out fires and completing search and rescue operations.

In the high-rise component of this study, an analysis of 14 "critical tasks"—those undertaken when potential risks to building occupants and firefighters are greatest—found that 3-person crews took almost 12 minutes longer than 4-person crews, 21 minutes longer than 5-person crews, and 23 minutes longer than 6-person crews to complete all tasks.

Computer modeling with data from live experimental burns was also conducted in the Averill et al. (2013) study. The results indicated that smaller crews would be required to engage and work for a longer period of time to suppress larger fires than would a larger crew, as shown by the additional time required to complete all necessary firefighting tasks. A 3-person crew, for example, may battle a medium-growth rate blaze that is almost 60% larger than the fire faced by a larger crew. The larger crew would start extinguishing a fire roughly three-and-one-half minutes earlier than the smaller crew.

The research team also evaluated whether dispatching more 3- or 4-member crews to a high-rise fire would be as effective as sending a smaller contingent of emergency response vehicles staffed by larger crews of firefighters. The research found that a smaller contingent of vehicles with crews of four or five firefighters outperforms a response of similar manpower delivered using more vehicles with crew sizes of three firefighters. For example, there was a 2-minute and 14-second (8.1 %) difference in the time to put the fire out between the 3- and 4-person crews. There was an additional 1-minute and 15-second (5.0 %) difference in this time between the 4- and 5-person crews. In other words, 5-person crews extinguished the fire 3 minutes and 29 seconds faster than 3-person crews. Finally, there was a 7-minute and 2-second (25.6 %) difference in the time to put the fire out between the 3- and 6-person crews.

When assessing task end times and incrementally increasing crew size by a single firefighter (i.e., 3 to 4, 4 to 5, and 5 to 6), time improvements were reported with expanded crew size. As firefighter crews navigated the later tasks in an event, like laddering a building, the time gains reached the 10- to 15-minute range. Time improved for search and rescue tasks (over 11 minutes) when crew size increased from four to five members. The improvements in the times to complete all tasks were substantial (9 to 12 minutes) when crew size increased from three to four or from four to five members.

Overall, the results of this study showed that the number of firefighters in each responding crew had a dramatic effect on the ability to protect lives and property. When responding to a medium growth rate fire on an upper floor of a high-rise structure, 3-person crews ascending to the fire floor confronted an environment where the fire had released 60% more heat energy than the fire encountered by the 6-person crews. As described earlier, larger fires expose firefighters and occupants to greater risks and are more challenging to extinguish. Thus, deployment of smaller crews on each vehicle increases the health and safety risks that firefighters face.

FSRI Study of Coordinated Attack in Acquired Structures

UL's Fire Safety Research Institute (FSRI) team conducted 40 full-scale, live-fire experiments in acquired structures slated for demolition. These structures included single-family homes (Regan et al., 2020), apartments within larger multi-family dwellings (Stakes et al., 2020), and units within a strip mall (Weinschenk & Zevotek, 2020). The study was designed to increase the understanding of suppression and ventilation tactics to improve firefighter safety and effectiveness. Importantly, occupant safety improves with increases in firefighting effectiveness.

While the focus of the study was not on staffing levels, key findings showed the importance of coordinating firefighting crews. Ventilation actions coordinated within 30 seconds of suppression limited additional fire growth in all experiments using this approach. In general, the effectiveness of post-suppression ventilation varied substantially between structures. However, the experiments in which toxic gas concentrations remained highest for the longest were those in which no timely ventilation actions were performed close to the occupant location. Ventilation post-suppression should be focused on the areas of greatest exposure hazard for potentially trapped occupants. The more staffing available, the more operations can be coordinated in order to suppress the fire, ventilate the areas where occupants may be located, search for them, and remove them from the hazard.

Research Addressing the Effect of Crew Size on Firefighter Health

As noted in the Firefighter Health & Safety Risk section, significant advances have been made in the understanding of the immediate hazards associated with structural firefighting. A number of scientific studies have been conducted to understand how firefighting affects the physical and physiological state of firefighters.

Risk for Acute Fatigue

Acute fatigue is a common occurrence during firefighting tasks (see Figure 1). Increased body temperature due to strenuous work and exposure to high temperatures has been shown to have detrimental physiological and psychological effects on firefighters, including a rapid onset of muscular fatigue. Fatigue can have significant impacts on firefighters' ability to safely navigate the fireground. For example, movement errors often lead to trips and falls. Research has confirmed that walking stability can be affected by strenuous firefighting activity and associated fatigue caused by heat and stress (Park et al., 2011). Fatigue from simulated firefighting activity has been shown to decrease clearance and increase contact errors during obstacle crossing, which increases trip and fall risk (Angelini et al., 2018). Kesler et al. (2016) observed significant effects of firefighting-induced fatigue on stair ascent and descent that could also increase the risk of falling.

When firefighters are called upon to work through a second cylinder of air, as often occurs during firefighting activities with limited manpower available, additional deficits in their ability to work and safely move about the fireground are expected. When firefighters were tasked with working through a second cylinder of air after a short break, significant declines (between -10% and -27%) in simulated firefighting work output were measured in the second bout when compared to the first bout of work (Kesler, Ensari, et al., 2018). Importantly, extended duration of simulated firefighting activity resulted in changes in gait performance (Kesler, Bradley, et al., 2018) and significant declines in firefighters' functional balance (Kesler, Deetjen, et al., 2018). The increased physiological strain induced by a second round of activity and cumulative fatigue may have contributed to reduced performance. Fatigue may also compromise cognitive function and impair situational awareness (Smith et al., 2001).

Cardiovascular Risk

Sudden cardiac events account for approximately 50% of firefighter line-of-duty deaths reported by the NFPA (Table 1), and these events are much more likely to occur after firefighting (Kales et al., 2007; Smith, Haller, et al., 2019). Data in Table 1 clearly indicates that fire suppression activities can trigger sudden cardiac events in individuals with underlying heart disease. The physical work, environmental stressors, and psychological stress associated with firefighting can all contribute to cardiac events in vulnerable firefighters (Soteriades et al., 2011; Smith et al., 2018). Research has proven that firefighting leads to significant cardiovascular strain, including increased cardiac work, decreased stroke volume, impaired diastolic function, vascular stiffness, changes in ECG, and a procoagulant state (Smith et al., 2001; Fahs et al., 2011; Fernhall et al., 2012; Smith et al., 2011; Burgess et al., 2012; Smith et al., 2014; Smith, Horn, Woods, et al., 2016; Smith, Horn, Fernhall, et al., 2019). Firefighting may also trigger an arrhythmia or plaque rupture which leads to sudden cardiac death or a non-fatal cardiac event (see Figure 2).

Cardiac strain related to crew size was assessed during the NIST residential fireground field experiments (Barr et al., 2014). Cardiac monitors were worn by study participants during the live-fire experiments. Heart rate data were compiled and analyzed according to job assignment and crew size. Average working heart-rate responses in firefighters on the engine declined as crew size increased from a 3-person to a 4-person to a 5-person crew. This study concluded that average working heart rates of firefighters were higher when smaller crews were deployed. The combination of longer work times and higher working heart rates when 2-person crews were deployed demonstrates that smaller crews experienced considerably more cardiovascular strain than larger crews deployed to fight a fire of the same size.

Occupational Exposure Risk

Occupational exposures of firefighters have received considerable attention because they are linked to occupational cancer. Occupational exposures to asphyxiants and particulate matter also increase the risk of sudden cardiac events. The number of firefighters responding to an incident can affect this exposure risk in multiple ways.

Water on Fire More Rapidly

Studies show that techniques to get water on the fire more rapidly may translate to reduced uptake of chemicals (Fent et al., 2020). While Fent and colleagues focused on fireground tactics (interior vs transitional attack), there may be limited options available for the location where the first application of water can take place based on the relative location of the fire and the personnel available. The more rapidly an effective firefighting force is assembled, the more rapidly interior suppression activities may begin. Rapid suppression may translate to a reduced uptake of fireground chemicals.

Overhaul Requirements

In recent years, the need for firefighters to wear SCBA to protect their airway throughout the firefight has become apparent. Inhalation of fire effluent is likely the most direct route for uptake of fireground contaminants. However, enforcing SCBA usage brings with it increased weight and restrictions for movement during overhaul operations that often require long periods of physical activity. Core temperatures measured from firefighters conducting overhaul with SCBA may exceed the temperature increases measured during fire suppression (Horn et al., 2018). Furthermore, firefighters who operate on a second cylinder of air after conducting initial fire suppression or ventilation activities often begin overhaul with an elevated core temperature.

With enough staffing available on the scene, the IC can send a fresh crew in for overhaul and feasibly enforce SCBA usage without further increasing the risk for heat injuries to the initial attack crews. This approach will also reduce the time required to implement hygiene practices for the initial crews with the highest level of exposure (Fent et al., 2017).

Hygiene Requirements

While PPE provides substantial protection against fireground chemical exposures, firefighters experience some level of contamination reaching their skin (Fent et al., 2017). In these cases, rapid implementation of hygiene practices is recommended. While skin-cleansing wipes can be used on the fireground, they have been found only partially successful at removing contamination (Fent et al., 2017). It is recommended that firefighters shower as rapidly as possible but, to do so, crews must be taken out of service for a period of time. Implementation of such a policy must be supported by enough personnel to maintain assembly of an effective firefighting crew while appropriate hygiene activities take place.

Rehabilitation (Rehab)

Rehab provides a critical fireground function by providing hydration, nutrition, rest, and potentially medical monitoring of the crews to help control heat stress and physiological strain (Burgess et al., 2012; NFPA, 2014-2018; Smith, Haller, et al., 2016). Fireground hygiene is commonly integrated into rehab to formalize rapid skin cleansing, reduce opportunities for ingesting fireground contaminants, and mitigate the spread of contamination to other skin sites. Rehab is a critical health and safety function made possible by appropriate staffing levels at the incident scene.

Recommendations

Based on a review of published research, industry standards, and expert opinion, we make the following recommendations:

1. All fire chiefs and individuals who are responsible for fire department budgets should use NFPA 1500™ and the performance objectives in NFPA 1710 to ensure adequate resources are deployed to protect communities and to minimize risks to firefighter health and safety.

2. Adequate resources, including properly trained firefighters and appropriate vehicles, should be deployed to arrive on scene in an appropriate timeframe to limit fire growth. Firefighters are facing an unprecedented level of risk in today's fires because of widespread use of synthetic building materials and furnishings, lightweight construction, larger buildings, and more open floor plans. In order to meet these challenges, enough firefighters must arrive on scene and initiate fire suppression activities as quickly as possible.
3. Firefighter health and safety is the responsibility of the entire fire department, but the ultimate accountability resides with the fire chief and city/county management. Adequate personnel are necessary to successfully perform firefighting operations without undue risk to citizens and/or firefighters.

Summary

Firefighters perform hazardous work that is critical for public safety, but most standards are not focused directly on the health and safety of firefighters. Instead, standards address crew size and ERF based on operational needs. This review considered firefighter injury and fatality statistics, the work that firefighters perform, the environment in which the work is performed, relevant standards, and multidisciplinary research about firefighter physical stress and fatigue, cardiovascular risk, and occupational exposure. It is essential that resources devoted to a structure fire enable firefighters to meet the risk they encounter and do so in a way that is consistent with their oath to protect people and property. It is also critical that resources be deployed in a way that considers firefighter health and safety.

Based on the available evidence, the ERF and crew sizes recommended in NFPA 1710 should be considered the ***minimum*** to provide for firefighter health and safety. Whenever possible, additional resources should be provided to address firefighter physiological stress, ensure that fire growth can be limited to the extent possible, and mitigate occupational exposure in today's rapidly evolving fireground.

Glossary of Terms

Crew – A team of two or more firefighters. (NFPA 1500™, 2021, 3.3.22).

Effective Response Force (ERF) – The minimum number of firefighters necessary to be assembled on the scene of an emergency to engage and stop the emergency while minimizing the probability of firefighter injury and death.

Flashover – A transition phase in the development of a compartment fire in which surfaces exposed to thermal radiation reach ignition temperature more or less simultaneously and fire spreads rapidly throughout the space, resulting in full room involvement or total involvement of the compartment or enclosed space. (NFPA 1700, 2021, 3.3.84).

Immediately Dangerous to Life and Health (IDLH) – Any condition that would pose an immediate or delayed threat to life, cause irreversible adverse health effects, or interfere with an individual's ability to escape unaided from a hazardous environment. (NFPA 1500™, 2021, 3.3.59).

Incident Commander (IC) – The individual responsible for all incident activities, including the development of strategies and tactics and the ordering and the release of resources. (NFPA 1500™, 2021, 3.3.62).

Initial Rapid Intervention Crew (IRIC) – Two members of the initial attack crew, positioned outside the IDLH, trained and equipped as specified in NFPA 1407, *Standard for Training Fire Service Rapid Intervention Crews*, who are assigned for rapid deployment (i.e., two in/two out) to rescue lost or trapped members (NFPA 1710, 2020, 3.3.53.1).

Rapid Intervention Crew (RIC) – A dedicated crew of at least one officer and three members, positioned outside the IDLH, trained and equipped as specified in NFPA 1407, who are assigned for rapid deployment to rescue lost or trapped members. (NFPA 1710, 2020, 3.3.53).

Declarations of Interest

Dr. Lori Moore-Merrell is deemed a subject matter expert in many of the topics covered in this manuscript. Dr. Moore-Merrell has no pending commitments to deliver testimony at the time of submission.

Dr. Denise Smith has served as a subject matter expert regarding the physiological strain of firefighting, cardiovascular risks associated with firefighting, and medical evaluation of firefighters.

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Knowledge Adsorption in the Public Sector: Heavy Smoke Showing in the Fire Service

Abstract

This study discusses the concept of knowledge adsorption, a condition by which valuable knowledge is readily available to an organization but is not absorbed into its internal knowledge stock. Through an application of Nonaka's SECI-*Ba* model, this article explains how structural (kinetic) and relational (energetic) factors can contribute to knowledge adsorption, adversely affecting knowledge transfer and reducing absorptive capacity in the public sector. This case study of the fire service sector in the Province of Quebec (Canada) is based on interviews with ten fire service personnel and content analysis of nine sources. Findings support the view that, for this provincial fire service sector, the capacity to absorb new knowledge involves a paradigm shift from a functionalist, siloed organizational view to an inter-cognitive view of public value creation. This shift involves individuals, organizations, and interactions within the sector. Results of the analysis provide fire service and public leaders with a framework to recognize and mitigate knowledge adsorption. It also provides data for an instructional "question grid" that can be used to develop a knowledge management strategy for various public services.

Keywords: knowledge management, absorptive capacity, knowledge adsorption, fire service, SECI-*Ba* model

Preface

The research reported in this article stems from previous work on knowledge management in Quebec's volunteer fire departments (Beauchamp, 2018). The 2018 study focused on exposing and explaining internal knowledge management processes. To our knowledge, this was the first research on knowledge management in volunteer fire departments. It built upon the knowledge management literature and serious leisure theory (which focuses on how people spend their free time) to advance a framework explaining how these fire departments managed their knowledge stock. This previous study found that *knowledge sharing among firefighters,* also called "buddy-learning," was the main process of knowledge management in the fire departments studied. The earlier research was based on a sampling strategy ($N = 310$, response rate of 42.5%) that allowed the researchers to gather a credible and sufficiently robust pool of data. Exploratory factor analysis provided evidence supporting the first empirically tested model of knowledge management in volunteer fire departments. Data analysis was completed by interviews with firefighters of different ranks ($N = 10$) and content analysis of municipal websites ($N = 20$).

A subsequent question about *absorptive capacity* (AC) of organizations emerged from this earlier research. The survey and data secured from interviews pointed to processes hindering knowledge sharing and transfer at the *organizational level* and *between and among organizations*. In fact, flaws in knowledge management collaborative governance underlined problems related to AC in the fire service and became the starting point for the research presented in this article.

Introduction to AC

Knowledge is recognized as a strategic organizational asset (Easterby-Smith & Lyles, 2011; Wiig, 2002). Cohen and Levinthal (1990) introduced the concept of organizational AC and defined it as the "ability to recognize the value of new information, assimilate it, and apply it to [organizational] ends" (p. 128). In this sense, high levels of AC can sustain strategic knowledge management (KM) to transfer valuable knowledge into an organization from external sources. However, knowledge absorption may prove difficult to achieve. Research has shown that the following factors can act as barriers to knowledge absorption: (a) organizational culture, norms, and values (Beauchamp, 2018; Cook & Yanow, 1993; Lucas & Klein, 2008; Wenger, 1998), (b) knowledge stickiness (Szulanski, 1996), (c) lack of translation capacity (Carlile, 2004; Rouse, 2004), and (d) organizational myopia (Catino, 2013). Obstacles to collaboration (Heikkila & Gerlak, 2005) and imbalances between and among participants (Sousa & Klyza, 2007) can also hinder an organization's ability to transfer and absorb new knowledge.

Research is needed to understand AC and KM processes in the public sector, particularly in the fire service (Beauchamp, 2018). Public sector organizations are not linked together by competitive market arrangements but by politico-administrative ties and the need to serve the common good (Harvey et al., 2010; Rashman et al., 2009). Developing a strategic knowledge stock in the public sector is not so much associated with competitive strategies like it is in the private sector, but rather with creating "public value" (Moore, 1995). As such, one could argue that knowledge conversion (Nonaka, 1994) should be well-developed in order to improve collective performance for the good of society (Walker et al., 2010, p. 1). In fact, some scholars contend that high levels of AC and KM efficiency in the public sector could enhance service and performance (Riege & Lindsay, 2006; Seba & Rowley, 2010).

Public organizations are often accused of guarding their knowledge by working in "silos," bureaucratic structures with rigid organizational boundaries (Lam, 2000; Wilson, 1989). These silos are detrimental to the collaborative efforts necessary to modernize public actions. Although public organizations, like fire departments, may be surrounded by valuable external knowledge from scientific and applied research, they may be unable to absorb this knowledge due to their boundaries' lack of porosity.

This study expands the literature on AC and KM by introducing and applying the concept of *knowledge adsorption*, in which valuable knowledge forms a layer at the organizations' boundaries without being absorbed into the internal knowledge stock. The impact of adsorption is an area of absorptive capacity research that has received less attention, especially when applied to public sector organizations. Based on a case study of fire service reform in the province of Quebec (Canada), the purpose of this article is to answer the following question: *How does knowledge adsorption affect knowledge conversion in a public service, specifically in the Quebec fire service?*

This article is structured into five sections. Section one presents the literature review. Section two discusses the research setting. Section three summarizes results emerging from the qualitative analyses. Section four provides the theoretical and practical contributions of the research. Finally, section five concludes the article by presenting the limitations of the research effort and offers suggestions for future research.

AC in the Public Sector: Literature Review

Since Cohen and Levinthal's seminal paper (1990), a growing body of literature has focused on identifying and understanding factors that affect absorptive capacity (AC) in private sector organizations. Many aspects of organizational life have an impact on AC, including organizational structures (Van den Bosch et al., 1999), routines and social integration mechanisms (Lewin et al., 2011; Zahra & George, 2002), organizational antecedents (Jansen et al., 2005), and feedback loops (Todorova & Durisin, 2007). AC is also conceived as a dynamic KM capability built on processes such as knowledge transfer, sharing, and creation; individual cognition; and shared mental models (Lane et al., 2006; Volberda et al., 2010). More recently, AC has been associated with challenges related to sharing of internal knowledge with other parties to realize value (Bravo et al., 2018; Denford & Ferriss, 2018; Meinlschmidt et al., 2016).

The study of AC in the public sector is a recent field of inquiry, although prior studies have indicated its relevance. According to Harvey et al. (2010), the high political salience of public organizations' performance and the associated cost of failure should direct attention to the importance of AC in the public sector. Murray et al. (2011) have also emphasized that the intensity and efforts required to create AC in the public sector should not be underestimated. To date, however, few studies have been conducted on which factors moderate AC in the public sector or how AC is contingent on distinctive features of public service.

Although scholars seem to agree that AC is dynamic in nature and involves synergies among modes of knowledge conversion, there is no agreement on what these modes should be. For example, Zahra and

George (2002) refer to acquisition, assimilation, transformation, and exploitation as modes of knowledge conversion. Lewin et al. (2011) refer to modes of combination, recombination, transformation, exploitation, and assimilation. On the other hand, there is agreement among scholars that AC is moderated by aspects of organizational culture such as: shared mental models, norms, and values; communication processes; and individual behavior towards knowledge (Jansen et al., 2005; Lewin et al., 2011; Todorova & Durisin, 2007; Zahra & George, 2002). This raises the question of how to take these moderating factors into account and through which knowledge conversion processes.

AC scholars have concentrated their work on absorption of knowledge, leaving aside problems associated with knowledge adsorption. Adsorption, not to be confused with absorption, is a surface phenomenon by which molecules of gases or liquids attach to the solid surfaces of the adsorbents. If the energetic or kinetic conditions allow the molecule to penetrate within the adsorbent phase, there is absorption.

Knowledge adsorption in organizations, particularly in the public sector, illustrates the effect of closed organizational boundaries on AC. Opportunities for learning or acquisition of external knowledge are available but, if they remain on the surface, there are no opportunities to realize their potential in the organizational environment. Problems of knowledge adsorption have been reported in the fire service (Beauchamp, 2018) and proven detrimental when efficient networking activities were necessary to resolve difficult problems (Provan & Kenis, 2008; Weber & Khademian, 2008).

AC depends on relational (energetic) and structural (kinetic) factors. Relational factors explain how organizational AC goes through people, their modes of exchange and management, as well as KM and learning. Structural factors include organizational movements, ranging from change-incentive events to structural or strategic changes that sustain or hinder behavioral changes. When there is dissymmetry between structural and relational factors (e.g. highly motivated individuals curious about new knowledge working in a highly hierarchized and rigid organization), the organization can suffer from knowledge adsorption.

To date, the literature on knowledge absorption capacity has focused on the structural and routine dimensions in private organizations, identifying moderating factors such as cultural or mental models. However, the processes of knowledge acquisition and integration need further study to better understand the opposite phenomenon: how adsorption *prevents* organizations from absorbing knowledge. More information about the structural-functional (kinetic) and relational (energetic) factors that promote or block the transfer of useful knowledge in public organizations would also contribute to this literature. Research on AC in the public sector may require a paradigm shift from AC research in the private sector because public services are rarely competitive. Public service involves different organizations that must function together as a knowledge network to perform complementary missions. In the context of the complex incidents the fire service must face, access to and absorption of knowledge from multiple sources is of utmost importance.

The next section contains a discussion of the conceptual framework for analyzing the structural (kinetic) and relational (energetic) factors that affect knowledge absorption-adsorption in the public sector.

A Conceptual Framework for Studying AC in the Public Sector: Nonaka's SECI-*Ba* model

In order to study how knowledge adsorption affects knowledge conversion in a public service organization, a conceptual framework is required. This framework must consider as enabling or constraining factors both the dynamic processes of knowledge conversion in the public service and an understanding of the structure, culture, and history of the government service. The framework used in this research is based on Nonaka's classic **S**ocialization – **E**xternalization – **C**ombination – **I**nternalization (SECI) model (1994). This model considers the cultural aspects of organizations, including shared mental models, values, and norms (von Krogh, 1998). It also places AC at the center of the knowledge conversion process. The conversion is achieved in a spiralling movement, which constantly fuels the AC and expands the current knowledge stock (Nonaka & von Krogh, 2009).

Knowledge conversion happens in different places or *bas*. A *ba* is a Japanese philosophical construct defined as a "shared context in motion, in which knowledge is shared, created, and utilized" (Nonaka & Toyama, 2003, p. 6). The concept of *ba* is relevant to the study of KM in the public sector because it implies the possibility of thinking and acting simultaneously in interrelated contexts and at different levels.

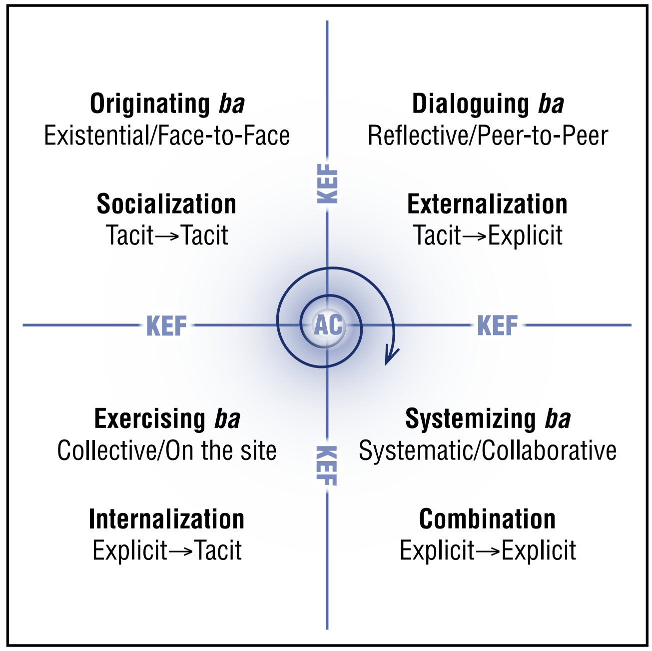
Figure 1 illustrates how each mode of knowledge conversion is associated with a *ba*. Structural and relational factors (kinetic and energetic factors or KEF) activate the spiralling movement of knowledge conversion, which contributes to AC in a feedback loop.

Ba also refers to the porosity of organizational boundaries. According to Nonaka and Toyama, *ba* is not limited to the frame of a single organization. It can be created across organizational boundaries: "*Ba* can be built as a joint venture with a supplier, an alliance with a competitor, or an interactive relationship with customers, universities, local communities, or the government" (2003, p. 8). Therefore, to understand the transition from one *ba* to another is to uncover

- the efficiency of KM strategies to manage KEF,
- the porosity to external knowledge sources, and
- the KM dynamics of a sector of activities.

Table 1 provides the framework used in this study to analyze the effects of AC's KEF on strategic KM in a sector of activity (i.e., a public service).

Figure 1
KEF and the SECI-Ba Model



Note: Adapted from Nonaka and Toyama (2003)

Research Setting and Methodology

This research was based on a case study of the Province of Quebec (Canada) fire service. In 2001, the provincial government passed a new Fire Safety Act (FSA) that signaled an extensive revision of the fire service requirements, policies, and practices. A new KM governance, defined as KM through governmental steering via legislation, rules, policies, and the establishment of new agences and/or institutions, was implemented during the revision process to improve and encourage professional development among firefighters.

This article presents an analysis of the outcome and its implications for KM in the fire service and other public sector agencies/organizations. The research used a mixed methods design (Creswell & Creswell, 2018) to provide a comprehensive analysis of the following data sources: semi-structured interviews of fire service personnel and content analysis of textual sources.

Semi-Structured Interviews

To ensure that a wide range of perspectives were represented, the first researcher conducted private, face-to-face interviews with firefighters of different ranks (firefighter, acting lieutenant, lieutenant, deputy-chief, and chief) and years of experience. Data saturation was reached after 10 respondents (Mason, 2002). The average length of the interviews was 1 hour and 20 minutes. A general inductive approach was used to structure the analysis of evidence from the interviews, and data treatment followed Thomas's method (2006).

Content Analysis

To anchor the study in its historical context, a content analysis (Robson, 2002) was performed on the following textual sources:

- legislative papers about the fire service;
- minutes pertaining to the fire service from (a) the Quebec National Assembly from 1992 to 2000 and (b) a fire service forum held in 2012;
- annual reports from the National Fire Academy (NFA) from 2001 to 2018;

Table 1
Absorption-Adsorption/Ba KEF Analytic Framework

Ba (Nonaka, 1994; Nonaka & Konno, 1998; Nonaka et al., 2000; Nonaka & Toyama, 2003; Nonaka et al., 2006; Nonaka & von Krogh, 2009; von Krogh et al., 2000)	**Current and potential absorption factors**	**Adsorption factors**
Originating *ba* - socialization Tacit→tacit + existential/face-to-face The originating *ba* is the socialization mode of knowledge conversion's locus and is characterized by face-to-face interactions between individuals. It is an existential place, a habitus, where individuals transcend the boundary between self and others by sharing experiences, feelings, emotions, and mental models. Care, love, trust, and commitment form the basis for knowledge conversion among individuals. The originating *ba* is influenced by modes of socialization, the activity's core values, organizational culture, traditions, norms, and routines.	**Which factors condition the individual's sense of belonging and moderate learning by socialization?** Kinetic/energetic factors	**Which factors restrict or block learning by socialization?** Kinetic/energetic factors
Dialoguing *ba* - externalization Tacit→explicit + reflective/peer-to-peer The dialoguing *ba* is the externalization mode of knowledge conversion's locus where knowledge is outsourced through collective and face-to-face interactions between actors. In this *ba*, mental models and skills are shared, converted into common terms, and articulated as concepts. The articulated knowledge is also brought back to each actor, and further articulation occurs through self-reflection. The dialoguing *ba* requires mechanisms supporting exchanges between units and networking capacity. This *ba* is influenced by the actors' modes of communication and capacity to reflect on and define the sector's activities (mental models, competencies).	**What are the sources of reflection on knowledge and channels of communication in the sector?** Kinetic/energetic factors	**Which factors prevent reflection or communication within the sector?** Kinetic/energetic factors
Systemizing *ba* - combination Explicit→explicit + collaboration The systemizing *ba* is the combination mode of knowledge conversion's locus as explicit knowledge is transmitted to many actors in explicit form. It is characterized by collective and virtual interactions allowing actors to exchange necessary information or answer each other's questions in order to collect and disseminate knowledge and information effectively and efficiently. The systemizing *ba* supports mechanisms to standardize the collective knowledge capital and is influenced by the degree through which a sector is structured so that actors interact in a complementary way.	**What are the sources and opportunities for collaboration that moderate learning within the sector?** Kinetic/energetic factors	**Which factors restrict or block learning by collaboration?** Kinetic/energetic factors
Exercising *ba* - internalization Explicit→tacit + collective The exercising *ba* is the internalization mode of knowledge conversion's locus as knowledge moves from explicit to tacit. It is characterized by individual and virtual interactions and synthesizes the transcendence and reflection through action to enhance organizational knowledge capital. This *ba* is conducive to innovation and paradigm changes and represents the space where new knowledge is integrated in the actor's knowledge capital. The exercising *ba* is influenced by the degree through which a sector of activity promotes learning or not.	**What are the sources or opportunities for innovation in the sector?** Kinetic/energetic factors	**Which factors inhibit innovation?** Kinetic/energetic factors

- one research report from the NFA;
- a memorandum submitted by the NFA at the 2012 fire service forum;
- a research report published in 2015 by the Association of Quebec Fire Safety Chiefs (ACSIQ);
- a White Paper on the state of the Quebec fire service published in 2018 by the ACSIQ;
- reports on the fire service from the Coroner, the Occupational Health and Safety Agency, and the Ombudsman; and
- (nine) websites of the NFA, ACSIQ, the Fire Instructors' Association, and the Fire Prevention Officers' Association.

For validity purposes (Yin, 2014), the research included recommended strategies, rival explanations of results from subject matter experts, and an audit trail (Creswell & Creswell, 2018; Robson, 2002).

Case Study: Analysis and Results

On November 26, 1992, fire chiefs from all over the Province of Quebec gathered at the National Assembly to protest the government's lack of support for the fire service. At the time, the Quebec fire service was plagued by an outdated knowledge stock, an increase in the number of fires and deaths caused by fire compared to other Provinces, and rising costs associated with insurance claims. The Quebec fire service had become entrenched in past traditions and practices and refused to engage in dialogue that could improve fire service policies and procedures. Fire chiefs hoped the new reforms would provide, among other things, a more comprehensive KM strategy to benefit the fire service's performance.

The 1992 Assembly of Fire Chiefs began a ten-year period of extensive legislative reform to modernize the Quebec fire service. In 2001, the provincial government passed a new FSA and mandated training for *all* firefighters. The Ministry of Public Security offered orientation sessions to guide the fire service and local authorities in implementing regional safety cover plans. The FSA also established the NFA to ensure firefighters and other municipal fire safety personnel in Quebec received qualifying professional training that was relevant and up-to-date. At the time, this program of fire service reform was considered one of the most progressive in Canada.

Before 2001, access to knowledge was problematic for firefighters in the Quebec province. Only career firefighters were required to complete the vocational studies program delivered by the Institute of Fire Protection (IFP), a dedicated fire school under the jurisdiction of the Quebec Ministry of Education. Most volunteer or part-time firefighters did not have access to this program, even though it was considered the training standard that would guide service delivery. Municipal funds available for training, access to training facilities in remote regions, and lack of qualified instructors were some of the pressing issues.

The reform's first five years (2001-2006) became synonymous with extensive changes that definitively and positively impacted fire service practices. Regional safety cover plans, which had to be certified by the Minister of Public Security, required municipalities to work together through dialogue and collaboration to reorganize their response to emergencies. The NFA also introduced service delivery standards. For example, 10 firefighters with equipment and apparatus were now required to be on scene in 10 minutes. Moreover, the NFA worked extensively to provide training programs for all firefighters, systemizing knowledge to meet the certification requirements mandated by the new regulation such as Firefighter I and II, Fire Officer I and II, and apparatus operators.

During its first years, the NFA had a positive impact on the standardization of the knowledge stock in the fire service. However, the organization was also faced with problems that hindered its leadership as the KM governing entity. Because the government continued to reduce the NFA's financial subsidies, it had to make cuts to staffing and investments. Consequently, the NFA had difficulties fulfilling many aspects of its mandate that directly impacted AC, such as fostering, facilitating, and planning exchanges of expertise and knowledge with persons or agencies outside of Quebec. As a result, the NFA could not continue to support the development of innovative fire service practices. The provincial training regulations for firefighters were based on population. Because the NFA could not offer the IFP training required for firefighters in large cities, its scope was limited to part-time and volunteer firefighters in smaller communities and rural areas. Although the NFA was created by the new legislation to act as the training governing body for the entire province, it did not have any impact on the fire service in urban centers like Montreal. For this reason, the NFA's credibility among career firefighters was never established.

In 2012, the Ministry of Public Security (MPS) organized a provincial forum to reflect on the first decade of the NFA reforms, an event that became a landmark in the fire service's dialoguing *ba*. Fire chiefs, fire service associations, and representatives from the municipal, education, and insurance sectors gathered in Quebec City. While participants agreed that the fire service had changed for the better, they also noted disparities in safety cover plans, lack of investment from municipal authorities, and pressing problems related to KM governance at the fire service level. These problems included training costs, access to training programs, and disparities in training offers.

In 2014, a major fire in a retirement home claimed the lives of 32 elders in a small rural town in eastern Quebec. A public investigation by the Coroner led to a devastating report on fire operations and public safety. Lack of knowledge, training, situational awareness, and operational capabilities were identified as contributing factors to the high death toll. Moreover, the Coroner criticized a legislative clause that exempted from training and certification processes any firefighter hired prior to 1998. The report also emphasized the government's delay in passing regulations mandating automatic fire suppression systems in retirement homes. The Coroner's report identified many problems that were still affecting the fire service and most were in the systemizing *ba*. The report also prompted government implementation of an extensive financial program to support small municipalities in training their firefighters.

In 2018, a White Paper published by the Quebec Provincial Fire Chiefs' Association provided an overview of previous reforms in the Quebec fire service. The chiefs recognized valuable changes in the level and quality of service offered to the population, the benefits of comprehensive fire prevention initiatives, and the advances in firefighter training. However, they were critical of a reform that faded over time. Since the safety cover plans did not prompt local authorities to invest sufficiently in fire protection, the chiefs feared that these plans would create a false sense of security in the population. The Ministry of Public Security's gradual disengagement from the promotion of these plans depreciated their value and relevance to local authorities. The fire chiefs considered the NFA's leadership problems a sign that KM governance had yet to be achieved. Finally, amidst new challenges prompted by disasters and civil security emergencies, the chiefs decided it was time to take a comprehensive, all-risks approach to rebuilding the fire service. In order to achieve this vision, they underscored the need for strong governance in the fire service much like they did in 1992.

The case study analysis presented above identified structural/functional (kinetic) and relational (energetic) factors that blocked (adsorption) or promoted (absorption) knowledge conversion among organizations in the Quebec fire service. Different information sources were available, such as academic and applied research, research and development projects, networking, collaboration, and international exchanges. But many KEFs still caused adsorption in the Quebec fire service, limiting AC and the development of an optimal knowledge stock. The following four tables provide a summary and discussion of absorption and adsorption factors that affected the originating *ba* (**Table 2, p. 34**), systemizing *ba* (**Table 3, p. 35**), dialoguing *ba* (**Table 4, p. 36**), and exercising *ba* (**Table 5, p. 37**) in the Quebec fire service.

Two key findings emerged from these summaries and discussions of the four *bas*: (1) a revised SECI/*Ba* model for the public service and (2) a KM practice question grid.

A Revised SECI/Ba Model

Nonaka's model (1994) assumes both the validity and relevance of the spiralling movement of knowledge conversion and the absorptive capacity of individuals and organizations. This model is also based on a specific linear sequence between *bas* (see Figure 1), a sequence that has rarely been challenged (Glisby & Holden, 2003; Gourlay, 2006). However, when considering this model in the study of KM in a public service organization (fire department in Quebec), results suggest the necessity of a new *ba* arrangement.

The public sector and the overwhelming majority of public sector organizations continue to operate even when plagued with problems and adversity. This finding suggests that all four *bas* are always active in knowledge conversion. Second, public organizations are dependent on legislation and regulations to systemize their operations. Therefore, the systemizing *ba* becomes fundamental for the public sector to operate and develop strong dialogue/collaboration and practices. Quebec fire chiefs pleaded for government funds to provide this type of legislation and collaboration.

Table 2
Originating Ba

Ba	Current and potential absorption factors	Adsorption factors
Originating *ba* - socialization Tacit→tacit + existential/ face-to-face	**Which factors condition the individual's sense of belonging and moderate learning by socialization?** **EF:** • Volunteer firefighting as a serious leisure expresses one's passion. • Firefighters come from different trades with knowledge and skills that benefit the group's knowledge stock. Firefighting requires basic and advanced qualifications but benefits from diverse skills. • Paramilitary culture/nature of firefighting fosters a sense of strength, courage, and faith in the home group. • Since its origins, the organizational culture maintains a sense of *esprit de corps* and competition between fire services. • Buddy-Learning as a mode of socialization and belonging to the group; firefighters learn from others and feel a responsibility to share what they know with their colleagues. Sharing knowledge is an act of caring. • Relationships characterized by passion, care, trust, teamwork, fraternity, creativity, help, commitment, and personal development. • Firefighters identify strongly with their profession: the lives of others and their own are at stake. They also identify with their fire station and their environment. • Fire station is the central place of socialization where the individual must share his/her knowledge to be accepted by the group. • Construction of local training sites promote complex learning and team-building activities. • Firefighters become involved in their community. • Firefighters are community members who make the choice to volunteer to fight fires while protecting people and property. Strong identification with the job becomes a motivation to socialize and learn continuously beyond the fire station.	**Which factors restrict or block learning by socialization?** **KF:** • Linguistic factors. • Isolation in remote regions. • Recruitment difficulties. • Lack of diversity and inclusion. • Positions of authority filled in-house. **EF:** • Buddy-Learning: knowledge shared between individuals represents the most value. • Experience-based knowledge is valued at the expense of new paradigms. • Paramilitary culture resistant to change. • Citizens' loss of interest in becoming volunteer firefighters. • Volunteer firefighters characterized as hands-on individuals not prone to theoretical studies. • Recruitment challenges.

Table 2 also showed that the originating *ba*, knowledge conversion through socialization, was characterized by a parochial/local vision of the fire service turned inward. Relational factors include the desire of individuals to share knowledge among themselves, and to support learning and AC at the individual and group levels. However, some relational factors — organizational myopia and reluctance to make paradigm changes — cause adsorption.

Changes to the Province of Quebec fire service were intended to move past this originating *ba* by systemizing (i.e., knowledge conversion through collaboration) the fire service through structural factors:

Table 3
Systemizing Ba

Ba	**Current and potential absorption factors**	**Adsorption factors**
Systemizing *ba* - combination Explicit→explicit + collaboration	**What are the sources and opportunities for collaboration that moderate learning within the public sector?** **KF:** • Fire safety cover plan determining fire protection objective, including the development and maintenance of staff knowledge. • Safety cover plans certificate of compliance issued by the Minister of Public Security. • NFA's mission to ensure that firefighters and other municipal fire safety personnel in Quebec receive pertinent, high-quality, and coherent qualifying professional training. • Governmental orientations supporting an integrated municipal vision of risk management. • NFA's professional qualification processes accredited by international fire service agencies (IFSAC and ProBoard). • Standardization of practices through production and translation of training documents and regional courses. • NFA's implementation of regional training managers. • Statutory training obligations for all firefighters. • Merging of regional fire services.	**Which factors restrict or block learning by collaboration?** **KF:** • Lack of coordination between government organizations. • Lack of resources to carry out the safety cover plan exercise. • Act, art. 38 (NFA): Not in force. Any training received to meet the conditions set by the government must be validated by the NFA. • Act, art. 55 (NFA): Restriction of the NFA's capacity to offer training programs provided by the Ministry of Education, thereby reducing the scope of its influence. • Problem of coordination and standardization of practices related to the disparity and multiplicity of the provincial training offered. • Lack of risk management overview associated with poor sectoral knowledge systematization. • Training prerequisites beyond the mandatory regulation. • Difficulty hiring fire chiefs trained in organizational management. **EF:** • Ministry of Public Security's gradual disengagement since 2001. • NFA's incapacity to assume KM sectoral leadership. • Resistance to ministerial change/directions. • Negative attitude of some fire chiefs and elected representatives towards the reform and risks. • Municipal officials' varying degree of acceptance of risk coverage plans' obligations. • Municipal officials' fear of losing sovereignty. • Difficult acceptance of a new paradigm of volunteer firefighters' professionalization. • Municipal officials' fear of rising costs. • Fire chiefs' difficulty incorporating new regulatory requirements and the fact that many individuals volunteer their time as firefighters. • Fire service sector's slow adhesion to the NFA's professional qualification processes: sector's lack of knowledge about professional qualification and accreditation processes. • Fear of rising costs and too high standards associated with professional qualification processes. • IFP's sovereign attitude towards NFA. • Career firefighters do not identify with the NFA.

Table 4
Dialoguing Ba

Ba	Current and potential absorption factors	Adsorption factors
Dialoguing *ba* - externalization Tacit→explicit + reflective/ peer-to-peer	**What are the sources of reflection on knowledge and channels of communication in the sector?** **KF :** • ACSIQ's annual conference, regional meetings, and seminars. • Annual study sessions held jointly by fire instructor and fire prevention officer associations. • NFA's courses, seminars, and instructor certification sessions. • Training provided by regional poles. • Regional merging of fire services. • Inter-municipal assistance during fires or disasters. • Training workshops delivered by various firms. **EF:** • Fire chiefs' manifestation of 1992, triggering fire service reform. • ACSIQ's public position in 2018. • MPS's Forum of 2012. • Incident operations post-mortem debriefings. • Local and regional charity events. • Increased contact between fire services and external partners during emergency operations other than fire. • Social networks and dedicated fire service pages/websites.	**Which factors prevent reflection or communication within the sector?** **KF :** • Organizational structure focused on a localized vision of service delivery. • Multiplication and disparity of training offers. **EF :** • Municipalities' parochialism towards the need for regional collaboration. • Steeple wars between fire chiefs causing resistance to networking and exchange (except during mutual aid for rescue). • Chiefs value knowledge-sharing among brigade members but are reluctant to create opportunities for knowledge-sharing with other brigades. • Vision of several municipal elected officials reducing the position of Fire Chief to a municipal fire technician whose duties are internally oriented (reflected in several job postings). • Fire chiefs express criticism about MPS's lack of integrative leadership.

legislation, regulations, defining key stakeholders' responsibilities, and the creation of the NFA. However, the FSA included provisions, such as articles 38 and 55, restricting its scope of action. Meanwhile, many relational factors associated with the fire service's cultural and leadership issues created knowledge adsorption, causing the spiralling movement of knowledge conversion to stall at the systemizing *ba*. Therefore, it comes as no surprise that collaboration and practice exhibited so many KEFs that caused knowledge adsorption: parochialism, steeple wars, the Ministry of Public Security's fading leadership, lack of collaboration by some municipal authorities, and poor or absent networking. All of these factors impaired reform in the Quebec fire service.

Based on results from this study, **Figure 2 (p. 38)** depicts a revised SECI/*Ba* model in which all four *bas* have a simultaneous and direct effect on the spiralling movement of knowledge conversion.

In this new *ba* model, the concept of knowledge adsorption proves beneficial, bringing the attention on KEFs related to AC. It then becomes possible to identify which factors have a negative effect on AC in the fire service and identify the most problematic *ba* or *bas*.

Results showed that new KM governance, as the systemizing *ba*, initially moved the fire service toward value-added knowledge. However, problems related to KEFs in that *ba* explained why the dialoguing and exercising *bas* did not reach their full potential. Knowledge activism (Von Krogh et al., 2000) and strategic KM were impaired by the lack of networking competencies (Meier & O'Toole, 2010), illustrated in part by leadership issues, steeple wars, and parochialism.

Table 5
Exercising Ba

Ba	Current and potential absorption factors	Adsorption factors
Exercising *ba* - internalization Explicit→tacit + collective	**What are the sources or opportunities for change in the sector?** **KF :** • NFA to offer advanced training activities and conduct training-oriented fire safety research. • NFA to conclude an agreement with researchers, experts, fire safety services, and educational or research institutions. • NFA to conduct or commission research or studies in areas related to the work of municipal fire safety personnel and that may have an impact on their training. • NFA to publish and disseminate research results. • NFA to foster, facilitate, and plan exchanges of expertise with persons or bodies outside Quebec and, in particular, encourage participation by Quebec specialists in international exchange missions on fire safety training. • Guidance from the Minister on an integrated municipal vision for risk management. • Investigations' results following specific incidents. • Scientific and applied research on the fire service. • Technological advances in equipment. • Expansion of the profession from fire safety to emergency response (first responders and emergency rescue). **EF:** • Some fire chiefs want to create a culture of openness/diversity that embraces new technologies. • More complex rescue operations require inter-organizational collaboration and collective development of knowledge.	**Which factors inhibit change?** **KF:** • NFA's reduced capacity to assume the sector's KM governance. • NFA's lack of commissioned research or studies related to the fire service and of international missions on fire safety training. • Sector's culture is bureaucratic, mechanistic, and resistant to change. • Lack of French-language research on fire safety. • Lack of mechanisms for translating and disseminating current fire safety research. • Knowledge management is limited to meeting regulatory requirements and maintaining competency through training. • Training exemption for firefighters hired before 1998 decried by the Coroner. • Focus on potential costs rather than on the efficiency/effectiveness from innovation. **EF:** • Weak sectoral KM governance. • ACSIQ places responsibility for sector's issues with the MPS. • ACSIQ questions NFA's leadership in coordinating multiple offers in the areas of training, learning, and research. • Lack of KM at the sector level to ensure continuous improvement and innovation, despite the evolution and greater complexity of public safety. • Lack of sectoral leadership in research, particularly by the NFA. • Low qualification level of many fire chiefs: no professionalization path for fire service executives and few senior officer designations. • Wait-and-see attitude: procedures not corrected until after tragic or serious events occur.

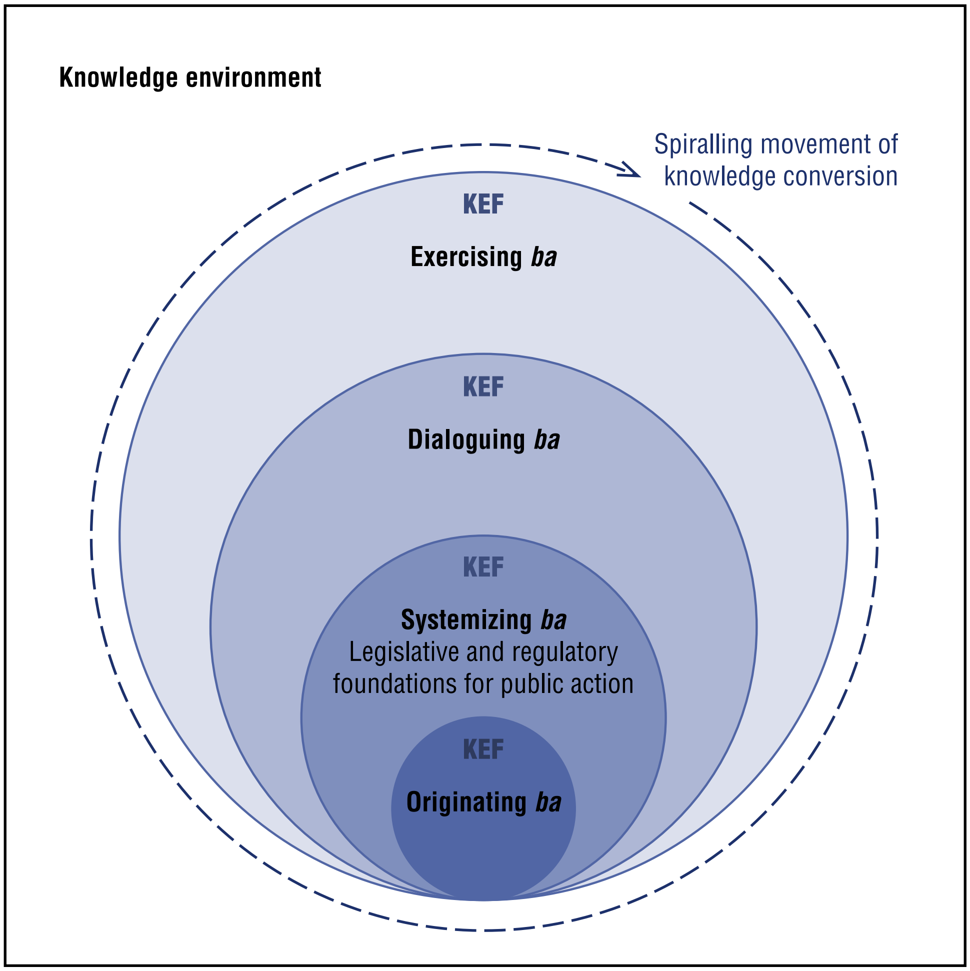
In particular, the NFA's leadership problems exemplified the distance between the promulgation of regulations and actual fireground practices (Rouse, 2004). Although a growing body of research provides information on best practices that can improve firefighter health and safety, the provincial fire service does not put this knowledge into practice. This problem plagues the fire service and emergency services management at large (Rouse, 2004). As a knowledge activist, the NFA could act as the network administrative organization (Provan & Kenis, 2008) or gatekeeper (Cohen & Levinthal, 1990) to help the fire service mitigate knowledge adsorption. Because no real strategies are in place to support the development of KM governance (Schwella,

2014) in the fire service, the NFA's leadership issues raise questions about horizontal collaboration (Kettl, 2000) and collaborative governance (Emerson & Gerlak, 2014).

A Public Service KM Practice Question Grid

Analysis of Tables 2-5 also enabled the researchers to create a general question grid for key stakeholders to assess the practice of KM for any public service. In the case of the research presented in this article, the grid was based on fire safety and emergency response by firefighters (see **Table 6**). By answering the question grid and documenting KEFs, one can form the basis of a KM strategy for public service organizations.

Figure 2
Bas Sequence for Public Sector Knowledge Conversion



Discussion

This article makes theoretical and practical contributions. On a theoretical level, this research enriches the AC literature by introducing the concept of adsorption. The concept of adsorption makes it possible to identify and explain factors blocking transfer and absorption of new knowledge into organizations. This article also contributes to a better understanding of AC in the fire service, which is significantly understudied (Beauchamp, 2017).

Although the SECI-*Ba* model has become a classic in the KM literature, it rarely appears in applied research, particularly at the inter-organizational level in the public sector. The systemizing *ba* is important to the public sector because of its legislative and regulatory components. The case studied and the results emerging from our research suggest the SECI process is simultaneous rather than linear, the different interacting *bas* creating an overall *ba*. Knowledge conversion is therefore not sequential because the *bas* are intertwined and work in a consubstantial way.

Our analysis showed how knowledge adsorption and problems of knowledge transfer are detrimental to fire service organizations. The case study revealed how the fire service still relied on traditional and standardized knowledge acquired through training, even if "normal" training was not enough to solve the challenges firefighters face in modern emergencies (Okoli et al., 2014).

The Quebec provincial fire service's organizational boundaries had low porosity to valuable knowledge from external sources, thus indicating a low level of AC. To our knowledge, this area of research has never been explored before. As such, this paper has contributed towards a better understanding of knowledge adsorption, AC, and KM processes in the fire service as an area of public service.

On a practical level, the research provides better knowledge of the fire service and highlights the relevance and importance of KM as a lever for the development and evolution of a public sector service. AC is said to facilitate inter-organizational knowledge transfer (Van Wijk et al., 2008) since the porosity of organizational boundaries has a significant impact on knowledge transfer and overall organizational performance

Table 6
Public Service KM Practice Question Grid

Originating *ba:* What are the profession's core characteristics? What are the kinetic and energetic factors in this *ba*? Which *ba*(s) should be activated to meet the need for knowledge?
KEF **KEF**
Systemizing *ba:* Is there a need to revise current legislation? Is there appropriate governance? What are the kinetic and energetic factors in this *ba*? Are stakeholders collaborating as they should within the sector?
KEF **KEF**
Dialoguing *ba:* Is there a need to activate/encourage knowledge governance in the sector? What are the kinetic and energetic factors in this *ba*? Which stakeholders should be involved in knowledge governance? What are the appropriate mechanisms to foster dialogue/networking between stakeholders?
KEF **KEF**
Exercising *ba:* How can new knowledge be converted into practice? What are the kinetic and energetic factors in this *ba*? How can the public sector innovate or make continuous improvements for the betterment of public service? Which stakeholders can lead and implement change? How can value-added knowledge be translated into public value?
Feedback loop to originating *ba* ↻

(Argote et al., 2003). Our results underscore that the fire service is still characterized by bureaucratic silos and constituent organizations that have difficulties opening their boundaries. This indicates knowledge adsorption: valuable knowledge accumulates at the boundaries without being absorbed into the fire service causing a decrease in realized AC (Jansen et al., 2005).

In sum, this research proposed a two-step approach to the analysis of AC in a public sector organization: (a) a diagnostic analysis based on factors promoting or constraining KM through socialization, collaboration, dialogue, and practice and (b) the development of a question grid to formulate a public service KM strategy. The case study reported here surely has peculiar dimensions associated with the Quebec fire service's socio-political context, which may be different from other jurisdictions and may have influenced how the fire service has developed. However, findings illustrated the phenomenon of knowledge adsorption in public organizations.

This research provided a new method for analyzing a public service in its capacity to develop through KM governance, understood here as a KM steering process. The systemizing *ba* may support functional governance through legislative means and by establishing the roles and responsibilities of the key players in the public service area. However, as the NFA's hindered capacity has shown, legal provisions may not be sufficient to ensure efficient KM governance in the public service.

Conclusion

Research reported in this paper sought to answer the question: *How does knowledge adsorption affect knowledge conversion in a public service, specifically the fire service in Quebec province?* The public sector is often composed of multiple organizations complementary in their mission but working in isolation from each other. Results showed that knowledge adsorption is a consequence of a functionalist organizational view. In order to mitigate knowledge adsorption, a paradigm shift appears necessary to implement an inter-cognitive view of public value creation involving individuals, organizations, and their interactions within the public service.

Research remains to be done on KM in public services such as law enforcement, parks and recreation, public health, and social services. Further research could focus on public sector response to complex issues such as disaster mitigation, global warming, or sustainable development. These challenging issues require multiple organizations to work cohesively and to transfer and absorb knowledge from multiple sources.

Glossary of Terms

Explicit Knowledge: Knowledge that is readily accessible, codified, and stored (e.g., knowledge accessed through sources such as training manuals, standard operating procedures, and instruction manuals).

Tacit Knowledge: Knowledge that is personal, not codified or documented, gained by experience and expressed by skills and abilities (e.g., knowledge accessed through sources such as discussions, demonstrations, mentoring, and job shadowing).

Knowledge Management (KM): A branch of the study of management science dedicated to organizational mechanisms of knowledge creation, sharing, transfer, and storage in the organizational context. KM is multidisciplinary and seeks to support organizational objectives by making the best use of knowledge.

Absorption [of Knowledge]: The process of integrating new knowledge into the organizational knowledge stock (e.g., training to implement a new successful fire ventilation tactic stemming from applied research).

Absorptive Capacity (AC) [of organizations]: The capacity of an organization to incorporate new knowledge into its existing knowledge stock.

Adsorption [of Knowledge]: (As a metaphor from the chemical phenomenon of adsorption known to hazmat teams.) A phenomenon that describes how and why new readily available knowledge is kept (deliberately or not) at a distance from the organizational knowledge stock and therefore not absorbed by the organization. For example, a fire department is aware that a new successful fire ventilation tactic has been developed by a neighboring fire department, but this new knowledge is not absorbed due to rivalries between the two fire departments.

Energetic Factors (EF): These factors are relational and influence people. For example, volunteer firefighters from different trades with new knowledge and skills share what they know to benefit the knowledge stock of the organization and its members.

Kinetic Factors (KF): These factors are functional and include organizational structures, norms, legislation, and socioeconomic realities (e.g., recruitment difficulties in volunteer fire departments related to labor market changes and values associated with balance between work and personal time).

***Ba*:** A Japanese concept referring to a space, either physical or virtual, where knowledge circulates between and among individuals (e.g. training site, classroom, online conferences, and the fire station's kitchen table) (Nonaka & Konno, 1998). There are four types of *ba*:

Originating *ba*: In the *originating ba*, individuals interact and share personal knowledge, emotions, and perceptions through **socialization**. Trust and care play a key role in this sharing of knowledge. In the fire service, this is illustrated by experienced firefighters sharing fire stories with newcomers.

Dialoguing *ba*: In the *dialoguing ba*, tacit knowledge is externalized to explicit knowledge through **dialogue** and metaphors. In the fire service, this is typical of a crew training with an instructor.

Systematizing *ba*: The *systemizing ba* is collaborative in nature and refers to a space where knowledge is combined from various sources though **collaboration.** In the fire service, debriefing meetings or meetings held among individuals at a fire scene after the fire has been extinguished support the aggregation of knowledge from various sources.

Exercising *ba*: The *exercising ba* seeks the systematization of **practices** by converting acquired knowledge into tacit knowledge. In the fire service, conducting live fire training exercises until it is believed that firefighters cannot "get it wrong on the fireground" is an example of exercising *ba*.

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The 3Es (Education, Engineering, and Enforcement) of Fire Prevention Services in the Age of Local Government Retrenchment

Abstract

This project examines the effects of the Great Recession on cutback strategies for fire prevention services in local fire departments. Utilizing a convenience sample of fire prevention providers from the Vision 20/20 Fire Prevention Cuts Survey, we developed an ordinal scale of 3E provision using the services of plan review, new construction inspection, existing building inspection, public education, and fire/arson investigation. We found the anticipated concentration of these services within the local fire department as we moved from small/volunteer communities to metropolitan/career contexts. We also found that the departments in larger communities were the most likely to report cuts to fire prevention, implying that larger populations may bear greater fire risk during periods of financial retrenchment. To some extent, cuts to fire prevention can be offset if fee-service activities like plan review are located within the local fire department. Likewise, large career departments are significantly more likely to engage in compensatory actions to offset the implications of budget and personnel cuts.

Keywords: fire service, fire prevention services, cutback management, Great Recession

For fire service leaders, the challenge of justifying and maintaining expenditures for fire prevention occurs within the larger context of external budget pressures on federal, state, and local governments. Given the vertical nature of funding streams, budgetary choices are subject to the reverberating effects of global economic events. In slightly more than a decade, we have experienced two depression-scale events: the 2008 global financial crisis and the 2020 COVID-19 pandemic shutdown. These volatile economic cycles remind us that, for many departments, a return to significant cutback strategies may be near.

Anecdotal evidence suggests that fire prevention programs are among the first items to be cut when fire departments face financial hardship. This project examines the 3E*s* of fire prevention — Education, Engineering, and Enforcement — used to manage cutbacks during the 2008 global financial crisis and its protracted recovery. We used the original responses given by fire officials to investigate the different structures through which 3E services are provided and the strategies used to implement constraint-driven budget cuts. While our findings are rooted in the Great Recession (2007-2009), they clearly apply to future economic cycles that will constrain available resources in the years to come.

Preventative 3E Services

Traditionally, the fire service has taken a reactive approach to its core mission and focused on fire suppression. However, the *America Burning* initiative ushered in a historical reduction in fire incidents and losses (National Commission on Fire Prevention and Control, 1973). Most of these declines were tied to improvements in engineering and an increased emphasis on public education. The reduction in fire incidents and losses also allowed fire departments to expand their mission and address other community risks. Subsequent pressures, both internal and external, raised community health and safety expectations currently placed upon fire departments (Donahue, 2004).

The 3Es originated with President Truman's 1947 Conference on Fire Prevention. Participants outlined a comprehensive approach to fire prevention that stressed voluntary action through public education as well as systems of passive and active protection through engineering and code requirements. In addition, a new emphasis was placed on code enforcement to increase compliance with emerging engineering requirements. Typical fire risk scenarios are conceptualized as causal chains (Weller et al., 2017) that are linked to multiple contributing factors (Corcoran et al., 2011; Jennings, 2013). Viewing fire risk from the perspective of these causal chains permits broad-based preventive interventions that utilize each of the 3Es.

Three primary approaches — education, engineering, and enforcement — reflect public health concepts of primary, secondary, and tertiary prevention. They also allow incidents to be viewed in pre-event, event, and post-event phases (Haddon, 1970; Runyan, 1998). Public fire safety education (hereafter "public education") focuses on changing people's behavior. Engineering focuses on fire protection features in the built environment. Enforcement focuses on fire and building code enforcement and fire/arson investigation.

There is no requirement for instituting all of the 3Es within the local fire department (Crawford, 2012). The administration of 3E provision is a fundamental policy of the local government and affected by changing budgetary constraints. Typically, public education is the responsibility of the local fire department. In some communities, engineering and enforcement may be assigned to other bureaucratic agencies (e.g., a building commission), and fire investigations may be conducted outside of the local jurisdiction.

Regardless of the preventative benefits provided by the 3Es, public trust in the fire service places a premium on response capacity. Consistent, prompt, and capable response leads communities to view the fire department as the responder of first and last resort, regardless of the perceived emergency (Freeman, 2002; Page, 2002). These responses have expanded to include emergency medical services, hazardous materials response, technical rescue (high-angle, collapse, water), and general service calls such as flooded basements and downed trees on houses. Contemporary fire departments are all-hazards response agencies, and they provide a panoply of emergency response services that keep them in the public eye (Page, 2002; Smoke, 2004; National Fire Data Center, 2009). Fire departments' community response demand tripled between 1980 and 2013 — from approximately 11 million to 32 million incidents per year (National Fire Protection Association, n.d.). The emphasis on expanded capability and the increase in service demand make the prospect of cutting emergency response budgets a daunting challenge for fire service leaders.

Institutional Theory and Cutback Management

In his influential article, "The Science of Muddling Through," Lindblom (1959) observed that the complex nature of social problems generally results in incremental decision-making within public organizations. According to Lindblom, policy innovation is often limited to changes at the margins that emphasize the value of past knowledge and understate the potential costs of future mistakes. This incrementalism stabilizes policy over time, but it also reinforces existing behaviors and stymies the emergence of newer, more effective approaches (Bednar & Page, 2018). Because incremental decision-making rarely considers unfamiliar options, it often presents inadequate solutions to particularly difficult collective action problems (Robinson & Meier, 2006).

Fire service policies based on the expectations of our local communities could be described as *path dependent*. In essence, path dependency is a multiphase process in which present and future behaviors are increasingly locked into past behaviors (Robinson & Meier, 2006; Sydow et al., 2009; Wilson, 2013). Path dependency develops due to the costs associated with: (a) learning new behaviors versus current ingrained ones; (b) challenging established complex social institutions; (c) emerging social and financial expenditures; and (d) institutionalizing self-amplified small changes over time (Kay, 2005; Robinson & Meier, 2006; Wilson, 2013).

Public expectations may prompt fire department leadership to favor emergency response over more vigorous prevention services. Path dependence is evident in public budgeting: the services that local governments provide, the relative priority of those services, who will benefit from them, and who will pay for them (Rubin, 2010). Local politicians such as mayors and city council members oversee the intense competition for limited resources among local government agencies. These political actors, systems of rules, and past outcomes all contribute to the allocative decision-making process.

The cutback environment is highly political, creating winners and losers among program constituents. Lobbying from vested stakeholders often determines the end result. However, in a reflection on Hardin's "The Tragedy of the Commons" (1968), a high degree of uncertainty can exist for electoral outcomes. Individuals typically base their votes on personal cost-benefit calculations rather than the consequences for the community. This means that reelection-seeking officials may not have knowledge of the resulting effects of budget cuts and will delegate the difficult task of making cuts to department administrators. These administrators must, in turn, weigh the impact that implementing these cuts may have on their own careers (Kwon et al., 2010).

Leaders normally take one of two path-dependent approaches to making budget cuts. They implement across-the-board budget cuts or ration cuts to specifically targeted agencies/services (Levine, 1978; Raudla et al., 2015). Across-the-board strategies cut equal amounts (or proportions) from all budget line items. Because sacrifice is shared, staff and services may be reduced but continue to perform. Targeted strategies impose selective budget cuts that may sacrifice specific services.

Unlike the private sector, the public sector faces long-term consequences for the adverse outcomes of cutback management. The resulting consequences may appear small at first but end up being quite significant should a highly salient event take place (e.g., a deadly fire). Cutbacks to public entities like fire departments have substantive consequences that are hard to anticipate. For this reason, we chose to study path-dependent aspects of budget cutback strategies that fire departments have implemented during severe economic conditions.

Vision 20/20 Fire Prevention Cuts Survey

To learn more about these cutback strategies, we utilized data from the *Vision 20/20 Fire Prevention Cuts (FPC) Project* [1] — a survey of fire service leaders administered during the spring of 2012. This project began in 2010 when, for months, fire marshals, fire code enforcement officials, and other fire prevention service providers conducted discussions via an electronic (information exchange) bulletin board. Discussion participants were concerned about the budget cuts to their departments' fire prevention programs caused by the Great Recession. In March 2011, a working group was created to develop a survey questionnaire that would help identify the post-recession status of fire prevention nationwide. The group consisted of eight individuals from across the United States with extensive career fire prevention experience at the national and local level. The Vision 20/20 project is supported through the U.S. Department of Homeland Security, the Assistance to Fire Fighters Fire Prevention and Safety Grant program, and the Institution of Fire Engineers U.S. Branch. No direct funding was provided for the survey, although it contributed to Vision 2020's Strategy 1 of greater advocacy for fire prevention.[2]

The FPC survey represents a nonprobability convenience sampling strategy. As such, the survey is not representative of the whole population of fire prevention providers or fire departments in general. Results are not generalizable to the population of fire departments (Johnson & Reynolds, 2012), but these data represent an initial step toward better understanding the balance between fire response and 3E services when budgets are tight.

The sampling method for the survey was based strictly on ready access to contact information. At the time of the survey, there were approximately 30,170 fire departments in the United States (United States Fire Administration, 2010). However, no comprehensive index of departments and contact information existed from which to gather information on the greater population for a random sample study. The working group decided the most feasible approach to sampling was to contact potential respondents through the existing Prevention Advocacy Resources and Data Exchange (PARADE) and National Fire and Life Safety Educators (NFLSE) electronic bulletin boards.

It should be noted that participants join these bulletin boards on an individual basis, not through their organization or department. At the time of the survey, PARADE had 937 registered members, and NFLSE had 451 registered members. Because both boards screened their participants, we were reasonably assured that the respondents were associated with fire prevention services.

Introductory and reminder emails were sent to all 1,388 registered participants. Of these, 1,321 survey starts were returned for an exceedingly high 95.2% response rate. The respondents represented a host of different organizations within the private and public sectors: 91% of respondents came from local fire departments (n = 1,198), 1.7% came from local building departments (n = 23), and 3.3% came from other local departments (n = 44). The remaining survey responses came from federal, state, and private entities (n = 56).[3] Because this study focused on the local government environment, respondents from federal, state, and private actors were removed from the final sample. Our final study sample consisted of 1,200 respondents who completed each question on 3E service provision and organization type. This final sample represented 94.9% of the original local government survey respondents. Again, as a convenience sample, it was not necessarily representative of the general firefighting population's cutback behavior during the 2008 global financial crisis.

3E Service Provision

Development of a classification of phenomena is the "most important and basic step" of scientific study (Carper & Snizek, 1980, p. 65). No systematic classification of fire prevention service provision could be found within the existing literature, so our initial task was to create a 3E Index to represent this provision in our convenience sample. The index references five items from the FPC survey (see **Table 1**) that asked which agency provided the specific 3E service for the local jurisdiction.

Table 1

FPC Survey Questions in the 3E Index

Item	FPC Question	Sample (*n*)	Sample Min.	Sample Max.	Sample Std. Dev.
1	Who provides plan review?	1200	1	5	0.88
	Local fire department	815			
	Local building department	258			
	Other local department	70			
	Service is contracted out	23			
	Service not provided	34			
2	Who inspects new construction?	1200	1	5	0.81
	Local fire department	864			
	Local building department	225			
	Other local department	64			
	Service is contracted out	15			
	Service not provided	32			
3	Who inspects existing buildings?	1200	1	4	0.77
	Local fire department	966			
	Local building department	113			
	Other local department	69			
	Service not provided	52			
4	Who provides public education?	1200	1	4	0.53
	Local fire department	1139			
	Local building department	11			
	Other local department	23			
	Service not provided	27			
5	Who provides fire/arson investigation?	1200	1	4	1.18
	Local fire department	889			
	Local building department	11			
	Other local department	98			
	Other (federal, state, private)	202			

Note. The study sample had 1200 observations after listwise deletion of non-responses and response items "Other – please specify" and "Not applicable."

The response sets provided a series of options/locations for each 3E service[4] that were recoded into an ordinal value (see **Table 2**). We recoded and ranked the provision of each 3E service on a scale between 4 and 1. If the local fire department provided the service, it was coded as a 4. If another local department provided the service, it was coded as a 3. Services contracted out, including those provided by another level of government, were coded as a 2, and services not provided were coded as a 1.

Table 2
Calculation of the 3E Index

Item	FPC Question	Response Item	Valuation
1	Who provides plan review?	Local Fire Department	4
		Local Building Department	3
		Other Local Department	3
		Contracted Out	2
		Not Provided	1
2	Who provides new construction inspections?	Local Fire Department	4
		Local Building Department	3
		Other Local Department	3
		Contracted Out	2
		Not Provided	1
3	Who provides existing building inspections?	Local Fire Department	4
		Local Building Department	3
		Other Local Department	3
		Not Provided	1
4	Who provides public education services?	Local Fire Department	4
		Local Building Department	3
		Other Local Department	3
		Not Provided	1
5	Who provides fire/arson investigation?	Local Fire Department	4
		Local Building Department	3
		Other Local Department	3
		Other (Fed. St. Private)	2

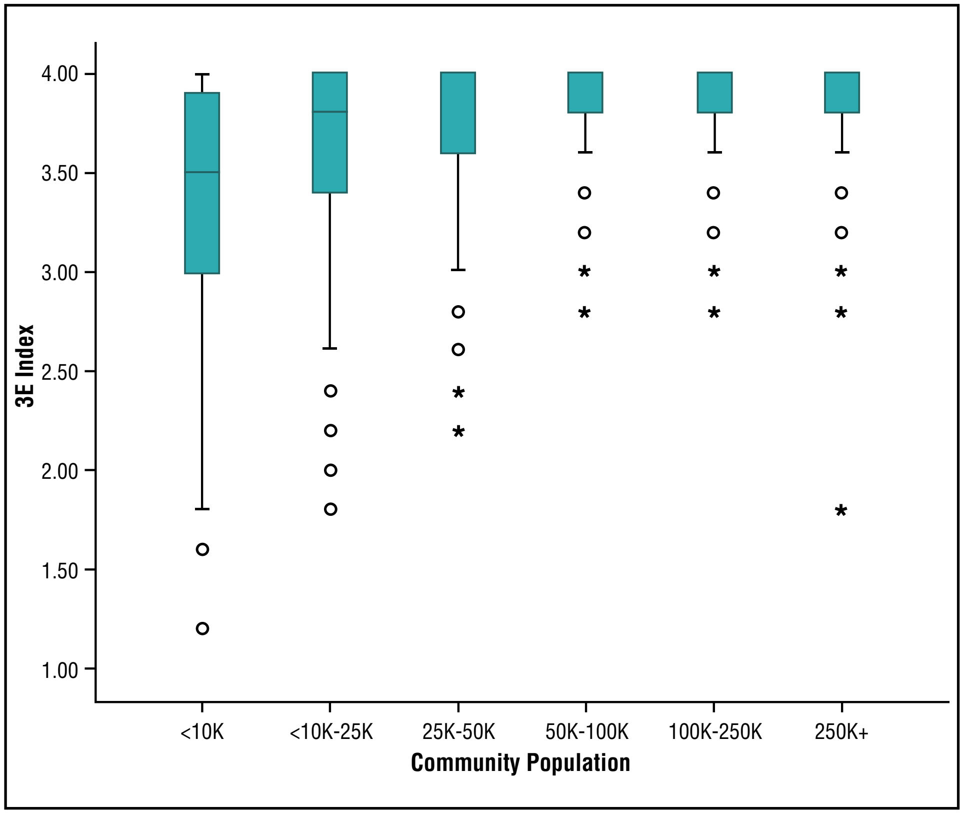
Note. The five items ask who provides the particular 3E fire prevention service. Numeric values were assigned on the relative location of service provision to the fire department. Higher values indicate placement of the service within the domain of the fire department, but do not presume that delivery is inherently greater/better.

The final 3E Index calculation takes the mean value across each of the five different items to create an aggregate service score for each respondent. The index provides an interval level variable for measuring the level and distribution of fire prevention services in the respondents' communities. Lower 3E Index scores imply that fewer services are provided by a greater number of service providers. Higher index values indicate more services are provided with greater levels of consolidation within the local fire department.

Lower 3E Index scores may indicate an increased vulnerability of 3E services to budget cuts. For instance, Rubin (2010) suggests that other city departments may not place the same budgetary priority on fire prevention as they do on the fire department. Building departments often operate as self-supporting enterprise funds, so 3E services that do not generate revenue, such as public education, are at a much higher risk of elimination during economic downturns. On the other hand, departments with fewer services may be less vulnerable because additional cuts are unlikely to generate significant savings. Furthermore, it becomes difficult to cut funding specific to fire prevention when the emergency response force is also responsible for building inspections and/or other services. During times of cutback management, departments with higher scores often have a greater opportunity to engage in smoothing strategies such as the transfer of 3E service responsibility.

Figure 1

The 3E Index Versus Community Population



Note. Results are from a convenience sample of local government survey respondents answering all five 3E service questions. A score of 1 = service is not provided, 2 = service is contracted out, 3 = service is provided by other local department, and 4 = service is provided by local fire department. *n* = 1200. Confidence interval = 95%.

We began with observations (see **Figure 1**) about the aggregate 3E Index in relation to community size. The initial evidence suggested a great deal of path dependency in the provision of 3E services because we tend to find a lack of variation within the sample of respondents. Respondents from larger communities (i.e., more than 25,000 inhabitants) most often indicated that 3E services were provided only through the local fire department. The categorical mean values were all at the maximum 4.0 value of department responsibility. We only found substantive levels of variation for respondents from the smallest communities (i.e., fewer than 10,000 inhabitants) where fire prevention services were assigned to other entities or not provided at all. We also observed a transition point for respondents with populations greater than 50,000 where 3E delivery schemes became remarkably uniform. These relationships were likely related to variance in department type, and we present that type of variance in **Figure 2**.

To present more meaningful levels of variance we disaggregated the different 3E services and presented them versus department type (see Figure 2).[5] In this plot, we were better able to distinguish systematic differences in the provision strategies. Initially, we observed that responsibilities for fire service public education were almost always conducted by the local fire department. Respondents from each department type indicated that education was a departmental responsibility. Despite scarce levels of resources, rural communities with volunteer departments typically were responsible for public education efforts.

Respondents from volunteer and mostly volunteer departments indicated that plan review, building inspections (both new construction and existing), and fire investigations were the services most likely to be assigned to organizations outside the local fire department. This external provision substantively declined in mostly career departments. Participants from large communities with career departments answered that fire/arson investigation – followed by plan review and inspection of new construction – were the most commonly outsourced prevention services.

As departments transition from all-volunteer to all-career organizations, more 3E services are consolidated under the local fire department. This trend, evident throughout the service categories, was found in the decreasing range of the confidence intervals of respondents from all-career departments. Figure 2 suggests a statistically significant break in the confidence intervals between mostly volunteer and mostly career departments. This consolidation of responsibility for 3E services suggests that a critical mass of career personnel enables departments to cover the range of fire prevention services. Although the mixture of provided services stayed mostly the same, variance was visibly constricted for all-career departments. This may indicate a remarkable amount of uniformity (and potential path dependency) in the provision of 3E services by our largest fire departments.

Figure 2

3E Service Components Versus Fire Department Type

Note. Results are from a convenience sample of local government survey respondents. A score of 1 = service is not provided, 2 = service is contracted out, 3 = service is provided by other local department, and 4 = service is provided by local fire department. *n* = 1200. Confidence interval = 95%. The reference line indicates the combined mean (3.59) of all services provided across all respondents.

Department type appeared to have little effect on the provision of public education. We observed no evidence of a statistically significant difference across the four groups of fire departments shown in Figure 2 and anticipate several explanations for this phenomenon. Fire service public education is a less well-defined concept compared to the other 3E services. Although NFPA 1035 (National Fire Protection Association, 2015) does publish guidance on requirements, there is little regulation of the provision of fire public education services.

Opportunities to educate the public range from informal community events to programs with systematic and structured curricula. The NFPA, FEMA, and several insurance companies provide free public education materials that minimize costs for smaller communities most often represented by volunteer firefighters. According to most respondents in the sample, public education is the responsibility of the local fire department. However, we expect that the structure of provision may differ considerably across department types.

Understanding Cuts to 3E Services

To evaluate how the provision of 3E services was affected by substantial budgetary constraints, we ran an initial set of models that predicted whether budget cuts were made to fire prevention programs in respondents' departments. The dependent variable in these models was a dichotomous response item: "Has your organization made cuts to fire prevention services in the last two years?" Variance in this dichotomous variable was evaluated with a Maximum Likelihood Estimation (MLE) of a logit model (Aldrich & Nelson, 1984). Logit models were useful in this context as they helped us associate systematic variance in a dichotomous variable (i.e., whether budget cuts occurred) with a range of independent variables of different constructs (e.g., dichotomous, ordinal, and ratio-level control variables). We could also express estimated values in predicted probabilities (Liao, 1994), making the strategy useful in terms of interpretation.

Table 3 presents results from two models: one with the combined 3E Index (left side of table) and one disaggregated by 3E services (right side of table). Initially, we observed that the likelihood of cuts was clearly a function of departmental characteristics. Both staffing and type of department[6] significantly affected the likelihood of 3E budget cuts. Respondents from the largest all-career departments were most likely to report fire prevention cutbacks during the Great Recession. Both coefficients were positive (β = .17 for total staffing and β = .30 for department type) and significant at a high confidence interval ($p < .01$), suggesting that the more career-oriented a department was, the more likely its 3E services would face budgetary constraints.

Table 3

Logit Estimates of the Likelihood of Fire Prevention Budget Cuts

	Index			Individual Services		
Control Variable	β	(s.e.)	*p*	β	(s.e.)	*p*
Total Staffing	.17	.06	.01	.18	.06	.01
Department Type	.30	.09	.00	.28	.09	.00
3E Index	-.26	.25	.28			
Plan Review				-.39	.19	.04
Inspection – New				.10	.25	.68
Inspection - Existing				.07	.22	.75
Public Education				-.32	.18	.08
Fire/Arson Investigation				.19	.12	.12
Constant	-.54	.84	.52	-.09	.95	.92
Observations		827			827	
-2 Log Likelihood		1115.86			1106.44	
Chi-square		30.59			40.02	
P-value		.00			.00	
AIC		1.36			1.36	
PRE		18.0			17.0	

Note. Budget outlook is a dichotomous variable (i.e., Has your organization made cuts to fire prevention services in the last two years?) with values: 0 = no cuts, 1 = budget cuts. The control variables tested are ordinal variables. Total Staffing: 1 = <24, 2 = 25-49, 3 = 50-99, 4 = 100-250, 5 = 250+. Department Type: 1 = All Volunteer, 2 = Mostly Volunteer, 3 = Mostly Career, 4 = All Career. 3E Services Provided (Plan Review, New Construction Inspection, Existing Building Inspection, Public Education, Fire/Arson Investigation): 1 = service is not provided, 2 = service is contracted out, 3 = service is provided by other local department, 4 = service is provided by local fire department.

Predicted probabilities for 3E budget cuts (see **Table 4**) showed a consistent and moderate-sized effect versus departmental staffing. Departments with staffs of fewer than 24 people had a 0.41 probability of a fire prevention cut. Departments with more than 100 people on staff were more likely than not to have a fire prevention cut (i.e., 0.54), and the largest departments exhibited a 0.58 likelihood of a cut. The same positive relationship was found versus department type. All-career departments were more likely than not (i.e., 0.56) to have a 3E budget cut whereas the likelihood for all other types was less than 0.50. In conclusion, the citizens in large urban areas that supported large, all-career fire departments were more likely to bear the effects of potential cuts to fire prevention services.

The combined 3E Index shown in the model on the left side of Table 3 was not significant (p =.28). This finding suggested that the general consolidation of 3E services within a department did not affect the reported likelihood of a budget cut. However, one relationship in the disaggregated, individual fire prevention services model, shown on the right side of Table 3, was statistically significant. This finding suggested that departments with particular preventive services might be more resistant to budget cuts than others without them. The parameter controlling for departments with plan review was negative (β = -.39) and statistically significant ($p < .05$). This result indicated that the departments covering plan review responsibilities might have had additional fee-service revenue to help forestall broader cuts to fire prevention units. Predicted probabilities (see Table 4) suggested that departments outsourcing plan review services were more likely to experience fire prevention cuts (0.66) than departments that retained control over plan review (0.48).

Table 4

Predicted Probabilities of Fire Prevention Budget Cuts

	Probability Value
Departmental Staffing	
> 250	.58
100 – 250	.54
50 – 99	.49
25 – 49	.45
< 24	.41
Department Type	
All Career	.56
Mostly Career	.48
Mostly Volunteer	.41
All Volunteer	.34
Plan Review Responsibility	
Contracted Out	.66
Other Local Department	.57
Local Fire Department	.48

Note. Probabilities calculated with all other independent variables set to their mean values. Departmental staffing and department type reference the first model specification in Table 3 that includes the 3E Index. Plan review responsibility uses the second model specification in Table 3.

The remaining prevention services shown on the right side of Table 3 were not significant at the traditional confidence interval ($p < .05$). We did find some marginal strength related to fire/arson investigation ($p = .12$),[7] but this variable's relationship to budget cuts was better understood within the analysis of subsequent models. Neither new nor existing building inspection services were systematically related to respondents' reporting of fire prevention cuts.

Predicting Cuts to Fire Prevention Personnel

According to extant cutback management literature (Scorsone & Plerhoples, 2010), local government managers normally choose to cut personnel when faced with budget shortfalls. Personnel cuts done through furloughs or layoffs can close shortfalls quickly because employee compensation makes up the bulk of local government expenditures. All personnel cuts have long-term consequences for organizations, including an increased workload for the remaining employees, decreased overall productivity, and sinking morale (Berne & Stiefel, 1993; Olson et al., 2004). Most importantly, personnel cuts frequently lead to the loss of the organization's most talented and resourceful employees (Cayer, 1986). Employees are the institutional memory of an organization. They have extensive knowledge of what customers expect and how to provide services that meet those expectations. After personnel cuts, an organization tends to be less effective and efficient.

To better understand the status of fire prevention personnel during the Great Recession, we present two additional models (shown on the left side of **Table 5**). These models explain survey responses about fire prevention personnel cuts. The dependent variable in these models was the response item: "Were personnel cut from the fire prevention work unit(s)?" As in Table 3, these responses were evaluated with logit models controlling for the aggregate and disaggregated individual 3E services. Again, we found positive and significant relationships in the variables for total staffing ($\beta = .38$; $p < .001$) and department types ($\beta = .50$; $p < .001$). After controlling for these two factors, we found some marginal evidence that consolidation of fire prevention services within local departments might be negatively related to reductions in the number of fire prevention personnel. The associated parameter controlling for the aggregate 3E Index was negative and just missed the $p < .05$ confidence interval with a more lenient one-tailed test.

This borderline result for the aggregate index could suggest that more robust fire prevention programs are more resistant to personnel cuts. For instance, established departments in large communities should have prevention program responsibilities that are clearly delineated and, to some extent, entrenched. When resource scarcity is shared among all subunits, efforts to realign fire prevention services can meet structural resistance (i.e., the fire prevention units are stakeholders that can make effective cases for fire prevention efforts). To better assess whether comprehensive fire prevention programs demonstrate some resistance to personnel cuts, we disaggregated the prevention services within a second model specification as shown on the left side of Table 5.

The disaggregate results pointed to the effects of fee-service revenue within the observed resistance to prevention personnel cuts. The parameter for plan review was both negative ($\beta = -.48$) and statistically significant ($p < .05$). Because plan review had the added benefit of being a potential revenue generator, it seemed to offer a better explanation than general structural resistance. Departments that bring revenue

Table 5
Logit Estimates of the Likelihood of Fire Prevention Personnel Cuts and Compensatory Action

	Fire Prevention Personnel Cuts						Compensatory Action					
	3E Index			Individual Services			3E Index			Individual Services		
Control Variable	β	(s.e.)	*p*	β	(s.e.)	*p*	β	(s.e.)	*p*	β	(s.e.)	*p*
Total Staffing	.38	.07	.00	.38	.07	.00	.01	.06	.92	.01	.06	.94
Department Type	.50	.10	.00	.46	.11	.00	-.03	.08	.69	-.04	.07	.61
3E Index	-.44	.29	.13				.73	.19	.00			
Plan Review				-.48	.21	.02				.06	.15	.70
Inspection - New				-.12	.28	.66				-.16	.18	.36
Inspection - Existing				.56	.31	.07				.48	.16	.00
Public Education				-.58	.21	.01				.17	.17	.30
Fire/Arson Investigation				.24	.15	.11				.25	.10	.01
Constant	-.20	1.00	.05	-2.00	1.23	.10	-3.38	.62	.00	-3.66	.78	.00
Observations		812			812			1148			1148	
-2 Log Likelihood		954.16			935.79			1421.77			1412.77	
Chi-square		81.38			99.74			21.48			30.65	
P-value		.000			.000			.000			.000	
AIC		1.18			1.17			1.25			1.24	
PRE		10.0			12.9			.00			.00	

Note. Fire prevention personnel cuts (i.e., Were personnel cut from the fire prevention work unit(s)?) is a dichotomous dependent variable: 0 = no personnel cuts, 1 = personnel cuts. In the second two models for compensatory action (i.e., Did your department take steps to compensate for fire prevention activity cutbacks?), the dichotomous dependent variable is: 0 = no compensatory action taken, 1 = compensatory action taken. The tested control variables are ordinal variables. Total Staffing: 1 = <24, 2 = 25-49, 3 = 50-99, 4 = 100-250, 5 = 250+. Department Type: 1 = All Volunteer, 2 = Mostly Volunteer, 3 = Mostly Career, 4 = All Career. 3E Services Provided (Plan Review, New Construction Inspection, Existing Building Inspection, Public Education, Fire/Arson Investigation): 1 = service is not provided, 2 = service is contracted out, 3 = service is provided by other local department, 4 = service is provided by local fire department.

generators like plan review into the unit may be more resistant to personnel cuts in times of economic peril. The fee revenue helps to preserve jobs in other fire prevention services, such as inspections, education, and investigation.

We found other supporting evidence in the model results. Looking at the control for existing building inspections, the coefficient was positive (β = .56) and at $p = .07$ would meet the $p < .05$ confidence interval with a one-tailed test (i.e., the result would be $p = .04$ with the single-tail test). After controlling for plan review responsibilities, the isolated effect of existing building inspections on the likelihood of personnel cuts was positive. When an opportunity for fee-service revenue did not readily exist, we observed a positive relationship between prevention service provision and the likelihood of personnel cuts. This makes sense if the path-dependent strategy is for across-the-board cuts. Without revenue generation capacity, personnel doing existing building inspection (or potential fire/arson investigation)[8] may be subject to a reduction in force consistent with other department personnel. Existing building inspection showed some vulnerability to personnel cuts. Fire/arson investigation showed very moderate evidence of this vulnerability (β = .24).[9]

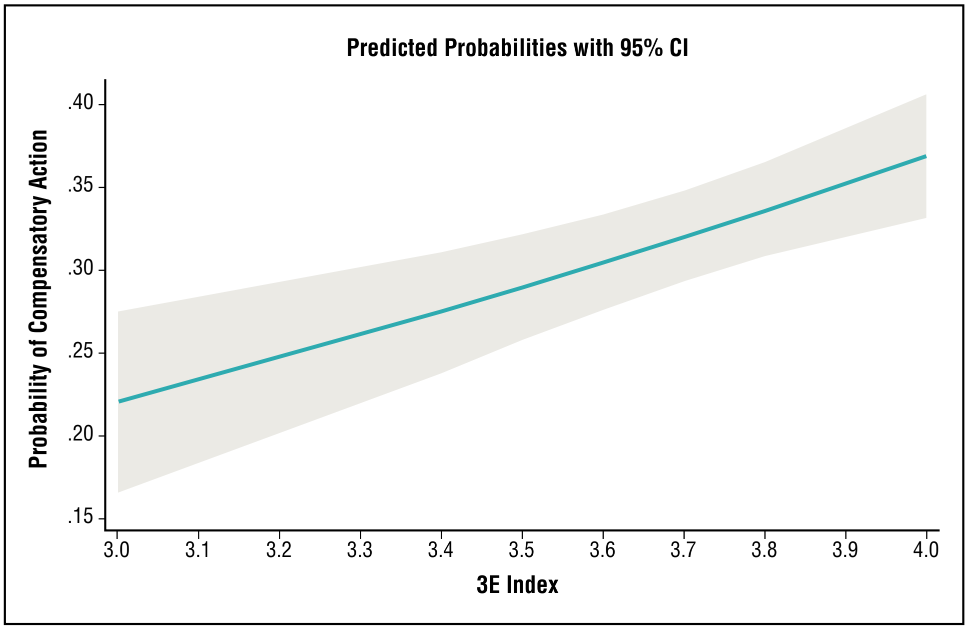
Predicting Compensatory Actions for Fire Prevention

Personnel cuts provide immediate and, hopefully, short-term responses to economic constraints, but departments must also find ways to counter the long-term effects of cutbacks. To gain some final insights on fire prevention provision, we modeled the likelihood of compensatory actions (see right-hand columns of Table 5). The dependent variable for this section was: "Did your department take steps to compensate for fire prevention activity cutbacks?"

In the model with the aggregate 3E Index, neither department staffing (β = .01; *p* = .92) nor department type (β =-.03; *p* = .69) was related to the likelihood of compensatory actions. However, the parameter controlling for the aggregate 3E Index was statistically significant (*p* < .001) and had a positive parameter coefficient (β = 73). Compensatory actions were a direct function of the breadth of fire prevention services and not necessarily related to staffing size or the ratio of volunteer and career firefighters. The plot of predicted probabilities (i.e., the middle reference line which is surrounded by a 95% confidence interval) showed a moderate-sized relationship versus variance in the 3E Index (see **Figure 3**). The mean value of the 3E Index in this sample was 3.68 and it was associated with a 0.32 likelihood of compensatory action. For a completely in-house 3E prevention strategy of 4.0 on the 3E Index, the likelihood of a compensatory action increased to 0.37. This would suggest that some amount of compensatory action was taking place for approximately one-third of respondents associated with the largest departments.

Figure 3

Predicted Probabilities of Compensatory Actions Versus 3E Index



Note. Probabilities calculated with all other independent variables set to their mean values. Plot references the third model specification in Table 5 that includes the 3E Index. Mean value of the 3E Index in that model specification is 3.68 with standard deviation of .46.

The need to compensate for prevention cuts tends to be a simple function of what the department provides in the first place. Higher 3E Index scores positively influenced the odds that a department would take some form of compensatory action. This result implied that communities with robust, full-spectrum 3E service programs would try to preserve the effectiveness of these programs, even in the face of fiscal stressors. FPC respondents suggested (see **Table 6**) that these departments were implementing long-term strategies such as combining work units, intra-agency transfers of service responsibility, and general process improvements.

The 3E program goals and objectives are important to local fire department decision-makers. However, when these leaders must make cuts, they tend to target public education materials, internal training, and reference materials. Although the resulting effects of these cuts are more difficult to discern, they clearly exist.

The final model specification with the disaggregated, individual 3E services (shown in the far right column of Table 5) helps to identify the provision schemes where compensatory action is most likely. Only two of the seven control variables — existing building inspections (β = .48, *p* < .001) and fire/arson investigation (β = .25, *p* <. 01) — were statistically significant. Both variables had positive coefficients, suggesting that fire prevention units with existing building inspections and fire/arson investigation show an increased likelihood of compensatory action.

These two results seem intuitive. Responsibility for basic-level, existing building inspections can be easily transferred to emergency response units. Many departments normally assign this responsibility to front-line companies and leave the technically detailed inspections to specialists. Departments also commonly outsource fire/arson investigation with the potential for criminal involvement as the referral factor. The remaining parameters indicate that none of the other variables contributed to our understanding of compensatory actions.

Table 6

Fire Prevention Resource Cuts and Compensatory Actions

	N	% Respondents
Compensatory Actions for Fire Prevention Cuts	370	32.2%
Combined Work Units	145	12.6%
Internal Transfer of Responsibility	115	10.0%
Process Improvements	91	7.9%
Formal Discontinuation of FP Service	71	6.2%
Technological Improvements	63	5.5%
Increased Use of Community Volunteers	49	4.2%
External Transfer of Responsibility	26	2.3%
Contracted Out Specific FP Activity	13	1.1%
Other	63	5.5%
Fire Prevention Resource Cuts	592	51.1%
Public Education Materials	415	35.8%
Training for Employees	311	26.8%
Reference Materials	243	21.0%
Training for Clientele	207	17.9%
Organization and Infrastructure	176	15.2%
Other	34	2.9%

Note. Fire prevention resource cuts (i.e., Were fire prevention activity resources cut back?) is a dichotomous variable followed by a breakdown query (i.e., What types of fire prevention resources were cut back? Check all that apply). 1159 respondents completed these prompts. Compensatory actions (i.e., Did your department take steps to compensate for fire prevention activity cutbacks?) is a dichotomous variable followed by a breakdown query (i.e., Which, if any, of the following actions did your department take? Check all that apply). 1148 respondents completed these prompts.

Fire Prevention Services under Economic Constraint

Our analysis of 3E services during the Great Recession reflects an environment of path-dependent solutions for the provision of fire prevention services. The Vision 20/20 FPC survey results indicated that a substantial amount of uniformity existed in the provision of 3E services, and these services were most often the responsibility of the local fire department. The consolidation of fire prevention responsibilities under department leadership tended to occur in relatively small communities. The greatest changes in 3E provision occurred in communities with 25,000–50,000 inhabitants.

Answers from respondents in these larger communities indicated a substantial amount of uniformity in internal fire prevention provision strategies that became standardized as the percentage of career firefighters increased within the department. Mostly career and all-career departments had a very similar 3E provision structure. However, public education was almost always the responsibility of the local fire department, including in all-volunteer and mostly volunteer departments. The first component to be outsourced appeared to be fire/arson investigation, followed by plan review and new construction inspection.

We also found that the fire prevention provision structure was systematically related to the need for cutbacks. Communities that had implemented plan review within the local fire department appeared more resilient to newly emerging economic constraints. Fee-service revenue from plan review appeared to counteract the need to cut services and/or to force reductions in prevention personnel.

Thus, a stable and effective 3E provision strategy may be a function of fire service leaders' ability to bring plan review within the department. To the extent possible, this consolidation may create a more stable funding foundation for building inspection, fire investigation, and public education efforts. Without this additional support, financial hardship likely will result in path-dependent cuts to prevention personnel and/or compensatory actions such as combined work units and internal transfers.

Building inspection responsibilities may be assigned to response personnel. Budgetary constraints are likely to result in some form of adjustment to public education and internal training resources. However, public education is an area of fire prevention that can be scaled back quietly, and the consequences of cutbacks are difficult to connect to observed fire losses.

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Footnotes

[1] Like most survey projects, the FPC has some particular strengths and some inherent weaknesses. This survey uses a convenience sampling technique, so it is not representative of the general firefighting population nor can the results be generalized. However, the response rate for the FPC survey was extremely high (e.g., FPC has a 95% response rate when survey research projects are satisfied with 20%). Thus, it provides details of cutback activity within a sizeable sample of experts who clearly are concerned about the topic. One of the limiting aspects of the data is that it did not have a lot of breadth in terms of available independent variables. Our models are often limited to a couple of descriptive control strategies (e.g., staffing and department type because of inherent levels of correlation). Given the lack of hard data in this area and the terrific response rate, our strategy was to get the most out of the valuable data at hand. Along those lines, we present figures of different relationships and model results that may have limited numbers of control variables within the underlying specifications.

[2] Vision 20/20 proposes six strategies for improving fire prevention actions in the United States. Strategy 1 is to "Increase advocacy for fire prevention." Additional information can be found at http://toolkit.strategicfire.org.

[3] Respondents who selected "Other – please specify" or "Not applicable" were listwise deleted from the study sample.

[4] We designed the scale to reflect the fire department's level of control over the fire prevention service and arrange it from the most controlled situation (4), where the service is provided within the department, to those situations where the service is not provided within the local jurisdiction (1). We set the lower end of the scale at 1 to avoid mathematical problems associated with the zero point of the scale. Theoretically, we could establish lack of provision of the service as a zero point, but we chose to set it as a 1 to avoid algebraic manipulation problems such as dividing by zero. The estimated variance is the same under either scale configuration.

[5] To save print space, we do not present the 3E service components versus community size, but that plot is very similar to Figure 2. It shows a similar transition with Figure 1 where a more uniform 3E service strategy emerges for communities with more than 50,000 residents.

[6] We limited the control variable strategy to departmental staffing and department type as well as substitution of the aggregate 3E Index and individual 3E components. Staffing and department type were correlated at .41 in the sample and tended to perform better than alternative variables such as community size. The correlations between those two variables and the 3E variables were all substantially less than .70. A correlation of .70 or greater is the level at which we begin to have concerns about multicollinearity. Only one pair of variables had a correlation greater than .70. The relationship between plan review and new inspections had a pairwise correlation of .75, which was relatively mild. Thus, the effects of multicollinearity within the model specifications were within acceptable boundaries and practices.

[7] We also found a negative ($\beta = -.32$) and significant relationship ($p = .08$, which meets the $p < .05$ interval with a one-tailed test) with the public education prevention service. We interpreted this parameter result as a spurious relationship. While it could suggest that a department's responsibility for public education is negatively related to unit cuts, we interpreted the result in light of previously presented evidence on public education. Figure 2 showed that fire prevention education is almost always covered by the local department, so the negative parameter result found here was likely a function of volunteer and mostly volunteer departments that did not have dedicated fire prevention units to cut. Separately, we modeled whether the respondent's department was likely to have a dedicated fire prevention unit. The models showed positive and significant relationships for community population, department staffing size, and personnel type. Respondents from smaller departments with more volunteer firefighters were much less likely to have dedicated fire prevention units. The lack of units to cut within these contexts would explain this observed relationship.

As shown in Table 5, public education was also negatively and significantly associated with fire prevention personnel cuts. This relationship also appears to be an artifact of structural differences in the provision of public education between volunteer and career departments.

[8] The parameter result for the provision of fire/arson investigation was also positive and just missed the significance interval at a $p < .05$ one-tailed test. The result for compensatory action likewise suggested that these services were affected by the lack of revenue generation.

[9] A final note on the model for prevention personnel cuts is needed for the effects of public education duties. Like the model in Table 3, the parameter was both negative and significant. Like the earlier results, however, the negative relationship most likely was a latent function of department type and structural differences in public education programs between volunteer and career personnel structures.

Author Note

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Fireground News Article (Editor-Invited)

All *Fireground News* articles are editor-invited and offer information relevant to the well-being, safety, and/or professionalization of the fire service. Most articles are based on research originally presented at the *International Fire Service Journal of Leadership and Management* (*IFSJLM*) Research Symposium (RS). This annual event is held in July at the International Fire Service Training Association (IFSTA) Validation Conference. As Founding Editor of *IFSJLM,* I also invite authors to write about current issues or concerns that affect firefighters and EMS personnel. The guest article below focuses on COVID-19 in the U.S. Fire Service.

Dr. Brittany S. Hollerbach, Associate Scientist, Deputy Director, Center for Fire, Rescue & EMS Health Research, NDRI-USA, Inc.
Dr. Sara A. Jahnke, Director and Senior Scientist, Center for Fire, Rescue & EMS Health Research, NDRI-USA, Inc.

COVID-19 Research Among Firefighters & EMS Personnel

Abstract

Firefighters and EMS personnel are regularly tasked with dangerous and unpredictable incidents, but the COVID-19 pandemic has required an unprecedented response from first responders and continues to change how they operate. This article explains how COVID-19 has impacted the fire service, discusses some of the current research on COVID-19 in the fire service, and presents a research agenda to build on lessons learned during the pandemic.

Keywords: COVID-19, firefighter, EMS, occupation, virus, pandemic

Introduction

The COVID-19 pandemic has required an unprecedented response among first responders in day-to-day operations, patient care, use of personal protective equipment (PPE), and finance/budgetary issues. Emergency rooms have reported seeing "a year's worth of suicide attempts in four weeks" (Miltimore, 2020). Firefighters and paramedics called to suicide scenes have deployed whatever lifesaving tactics were at their disposal. Escalating deaths in assisted-living facilities have captured headlines nationally. Amid strict lockdown requirements to reduce the risk of exposure, firefighters have offered assistance to and interfaced with the highest risk patients (Roy, 2020).

First responders remain on the front lines of the crisis as COVID-19 ravages the nation. As essential workers who serve a vulnerable population, firefighters are also impacted by the virus. According to FireRescue1 (2021), 115 U.S. firefighters died from COVID-19 or complications from the virus between March 16, 2020, and September 20, 2021. In comparison, the number of firefighter line-of-duty deaths in 2018 (64) and 2019 (48) was 112 *combined* (Fahy et al., 2020). As the number of COVID-19 deaths in the U.S. approaches 700,000 (Centers for Disease Control and Prevention, 2021c), first responders continue to administer care on the front line.

Mitigating the COVID-19 risk and protecting the acute and long-term health of fire service personnel has become a national goal of the fire-related organizations and research teams who work diligently to respond to the pandemic. Public health scientists and governments around the world agree that the COVID-19 pandemic is not a one-time event (Disparte, 2021).

We must not forget the lessons learned during the COVID-19 pandemic, only to renew our concerns during the next inevitable outbreak. As first responders, firefighters require evidence-based education regarding: (a) the use of protective strategies to prevent infection, (b) the impact of COVID-19 on fire departments and national fire organizations, and (c) the long-term health impacts of the virus.

The Essential Role of Firefighters and EMS Personnel in the Pandemic

Most state and local stay-at-home orders to reduce the spread of COVID-19 have not applied to firefighters and emergency personnel. Firefighters and others in the protective services — including all medical first responders, emergency medical services, and emergency management officials who anticipate close contact with persons suspected or confirmed to have COVID-19 — rank in the top 10% of exposure risk for two reasons: their interaction with the public and each other. First responders were deemed essential personnel from the beginning of the pandemic. Not only were emergency responders required to go to work, they were expected to enter pandemic "hot spots" and interface regularly with critically ill patients. Furthermore, emergency responders are required to live and work in close quarters, a nexus of disease transmission (Baker et al., 2020).

Impacts of COVID-19 on the U.S. Fire Service

Providing emergency services to the community while protecting the health of first responders in the midst of the COVID-19 pandemic has presented a unique challenge to national fire service organizations, local fire departments, and individual firefighters. This section outlines the pandemic's impact on fire service resources, departmental policies and procedures, firefighter and EMS response calls, finances/budgetary matters, and the behavioral health of fire personnel.

Impact on Resources

National fire service organizations such as the U.S. Fire Administration (USFA), the International Association of Fire Fighters (IAFF), and the International Association of Fire Chiefs (IAFC) are tasked with providing direction to their members and constituents. When the pandemic began, these organizations quickly identified the resources necessary for fire departments to appropriately respond to community needs. It was immediately clear that the fire service needed regular updates on how to protect personnel while responding to the pandemic.

Although data was limited, local fire and emergency services organizations were required to provide directions and recommendations on maintaining operations, preventing spread of the virus, maintaining infection control, personnel safety, and the selection and procurement of PPE (International Association of Fire Chiefs, n.d.-1). In a separate needs assessment survey of fire chiefs that focused on PPE, almost half of responding departments had less than a 10-day supply of PPE in stock; nearly 10% had a 3-day supply or less (International Association of Fire Chiefs, n.d.-2). A quarter of PPE requests were for N-95 masks and an additional 20% were for gowns. More than 10% of all departments lacked basic necessities such as protective gloves. Many departments had requested PPE supplies from the Strategic National Stockpile, but the majority of survey respondents indicated that 20% or fewer of their requests had been filled.

Impact on Fire Department Policy and Practice

Pandemic-related challenges have required fire departments to reconsider their standard practices, guidelines, and operations in a way that minimizes risks to all firefighters. For example, the USFA updated its pandemic response protocol in March 2020. The revised protocol recommended the following departmental changes to increase personnel safety while maintaining operational readiness: (a) altering responses to minimize the number of personnel in contact with sick individuals; (b) eliminating non-emergency tasks (e.g., inspections, outreach, drills); (c) modifying training schedules; (d) social distancing (a minimum of 6 feet) while conducting patient assessments; (e) meeting patients in the open air rather than in their homes; (f) minimizing shift/station trades to reduce the spread of germs; and (g) limiting personnel interactions at the station (U.S. Fire Administration, 2020). As the pandemic continues, some policies and procedures may require additional updates and revisions.

Impact on Types of Calls

According to data from the International Public Safety Data Institute National Fire Operations Reporting System (IPSDI NFORS), social distancing has significantly impacted the number and type of emergency calls received by fire departments, particularly departments in "hot spot" areas (Buffington, 2020). While motor vehicle-related calls decreased sharply due to limited mobility by the community, residential calls increased.

Research is underway on the amount of stress created by pandemic stay-at-home orders and sheltering in place, as well as the impact of this stress on the *types* of emergency calls received. For example, Khatri and Perrone (2020) have discussed the pandemic's impact on access to treatment for opioid addicts. Some drug-dependent individuals who would typically seek managed medical treatment from their physician and/or in a clinic setting have resorted to street drugs. Public health organizations and peer-reviewed scientific literature also call for awareness and intervention to help with the growing number of pandemic-related domestic violence incidents (Campbell, 2020).

To date, relatively little research is available on changes in call types that firefighters and paramedics have received since the pandemic began. It is important for public health in general and, in particular, the fire service to know how call patterns have changed, how they track across time, and what plans and/or training can be developed to improve response.

Impact on Finances/Budget

The fire service has been hit hard by the financial strain of responding to COVID-19. Causes include the resulting freefall of the economy due to stay-at-home orders, skyrocketing unemployment (Johns Hopkins University, 2020), and shifting resource needs within departments. The IAFC (n.d.-3) conducted a membership survey to estimate the pandemic's financial impact on fire departments. The current estimate, as of June 2021, suggested the economic losses related to COVID-19 approximated $1.9 billion in 2020 and would be at least $2.1 billion in 2021. Faced with substantial budget cuts, departments reported a 29.2% increase in COVID-19-related spending. According to the IAFC, 461 uniformed staff and 604 non-uniformed staff were furloughed in 2020. The IAFC predicts an additional 631 uniformed staff and 1,917 non-uniformed staff will be furloughed throughout 2021.

Impact on Fire Personnel Behavioral Health

Although firefighter resiliency and dedication persist, the COVID-19 pandemic has taken a heavy toll on the fire service. Major fire service organizations such as the First Responder Center for Excellence (FRCE), IAFC, IAFF, and the National Volunteer Fire Council (NVFC) are bracing for the behavioral health challenges that lie ahead.

Captain Frank Leto is a longtime veteran of the Fire Department of New York (FDNY) and has served as Deputy Director of its Counseling Services Unit (CSU) since 1983. Throughout his career, Captain Leto has worked with the IAFF and other national/international organizations to develop behavioral health protocols. He has also assisted departments, firefighters, and their families after traumatic events worldwide. He acknowledges that, during COVID-19, firefighters have experienced unprecedented job stress and uncertainty, personal and family risks, lack of PPE, and unknown exposures. When it comes to the pandemic's impact on the behavioral health of emergency responders, Leto has "never seen anything as bad as this" (F. Leto, personal communication, November 2020).

The IAFF (n.d.) has identified the following issues as impacting firefighter behavioral health: (a) concerns about work-related exposure to COVID-19 and potentially exposing loved ones at home; (b) changes in sleep and appetite; (c) concentration problems due to worry and stress and how reduced focus impacts performance; (d) anxiety related to self-monitoring of potential symptoms; and (e) misuse of alcohol or other substances to manage stress. Chronic stress and worry can increase the risk of additional health problems, including depression, anxiety, post-traumatic stress injury (PTSI), and substance abuse.

Behavioral health experts, medical literature, and fire service leaders are calling for both short- and long-term support for first responders, similar to programs provided post-9/11 (DePierro et al., 2020). Because firefighters and EMS professionals are repeatedly exposed to traumatic events (Harvey et al., 2016), they are continually at a high risk for behavioral health problems. Further research is essential to determine how much the pandemic has increased stressful work conditions for emergency personnel and adversely affected their health. This data will help to identify policies and strategies at the national, departmental, and individual level to mitigate the pandemic's negative impact.

Use of COVID-19 Protective Strategies in the Fire Service

Current research, though limited, shows the fire service has not received clear and consistent guidance about protective strategies such as receiving vaccinations and wearing masks. Misinformation and skepticism about reliable scientific information has been more extreme during the COVID-19 pandemic than during any other public health crises in recent history (Parks, 2020). This misinformation and skepticism has led to inadequate infectious disease control and work conditions that continue to threaten worker safety and health (Bagherpour & Nouri, 2020; Bursztyn et al., 2020).

The USFA and the CDC offer guidance about specific precautions that first responders can take to reduce COVID-19 exposures and help prevent its spread. However, many firefighters question this guidance and are still hesitant to receive vaccines.

Vaccines and Fire Personnel Vaccinations

To date, three COVID-19 vaccines are authorized for emergency use in the United States: Pfizer-BioNTech, Moderna, and Janssen (Johnson and Johnson) (U.S. Food and Drug Administration, 2021). State governments were initially tasked with prioritizing the distribution of vaccines and varied widely in their approach. Although national fire service leaders strongly advocated that firefighters and EMS personnel be placed in Tier 1A for priority access to COVID-19 vaccines (Davis, 2020), many firefighters were not among the first to be vaccinated.

In December 2020, just months before the vaccine rollout, results from a survey of FDNY firefighters showed that over half (55%) of the members of the nation's largest career fire department would refuse to get the COVID-19 vaccine if it were offered (Sturla & Silverman, 2020). In October 2020, our research team, in partnership with the University of Miami, conducted preliminary research via an electronic survey. Approximately half of the firefighters surveyed were skeptical of taking the vaccine (Caban-Martinez et al., 2021).

Because many firefighters still have reservations about the vaccine's effectiveness and safety, they need more information to feel comfortable taking it. To obtain accurate public health information, fire and emergency services personnel must have access to reliable sources. The CDC website is one source of scientifically based information about development of the vaccines, how they work, and the pros and cons of vaccination (Centers for Disease Control and Prevention, 2021a).

Preliminary educational opportunities, such as webinars targeted to firefighters, have also helped share scientific evidence and address firefighter concerns about COVID-19 vaccines. For example, more than 1,000 firefighters signed up for an IAFC educational webinar prior to the day of its airing. Since January 2021, the webinar has been viewed on YouTube more than 2,400 times (Miclette & Rubin, 2020). The overwhelming response and a long list of questions from attendees indicate an *immediate* need for more evidence-based information from trusted sources as the pandemic continues.

Multiple barriers to immunization have been identified in the medical literature related to pandemic response. Healthcare access, cost, and perceptions of safety and trust are all factors that have discouraged immunization (Geoghegan et al., 2020; Macintosh et al., 2017). Safety concerns are fueled by misinformation, fear, and myths propagated through organized antivaccine groups, social media, and celebrity endorsements (Geoghegan et al., 2020; Ozawa et al., 2016). Despite a wealth of scientific data supporting the safety of currently recommended vaccines, counteracting false information to convince vaccine-hesitant populations continues to be a challenge (Geoghegan et al., 2020). *Confirmation bias*, the tendency to embrace information that supports one's beliefs and reject contradicting information (Kahan, 2016), presents a significant barrier to changing opinions with facts alone.

Trust is critical to generating and maintaining support for vaccinations (Ozawa et al., 2016). Public decision-making about vaccines is not driven by scientific or economic evidence alone. Psychological, sociocultural, and political factors must be taken into account when developing a vaccination campaign and providing vaccine information (Larson et al., 2011). Accurate, scientifically based evidence on the risk–benefit ratio of vaccines is crucial, but it is not enough to address the gap between current levels of public confidence in vaccines and the trust level needed to ensure adequate and sustained vaccine coverage. It is important to examine and understand the very real fears and reservations that firefighters and others have regarding vaccination.

Face Masks

The use of face masks has been a hotly contested issue since COVID-19 emerged in the U.S. First responders have been on the front lines of both the pandemic and the mask debate. Most public safety personnel, including firefighters, EMTs, paramedics, police, and corrections officers are, or have been required by a department policy, directive, or standard to wear face masks to reduce COVID-19 transmission. According to the CDC, mouth- and nose-covering face masks reduce the dispersion of droplets from an infected individual, thus helping limit spread of the virus (Centers for Disease Control and Prevention, 2021b). Similarly, scientific evidence indicates that wearing masks reduces transmission of infected respiratory particles in both laboratory and clinical contexts (Bahl et al., 2020; Fischer et al., 2020; Howard et al., 2021; Lindsley et al., 2021; Verma et al., 2020). However, some first responders ignore mask mandates while off-duty or limit mask usage on the job.

FireRescue1 and the editors of Police1, Corrections1, and EMS1 conducted a survey on mask-wearing across public safety disciplines. They received nearly 4,000 responses, and approximately 450 came from fire service personnel (Foskett, 2020). Survey findings show firefighters were the public safety group *least* likely to be required to wear masks in public buildings. The majority (56%) of firefighters reported *not* being required to wear masks in department buildings. Slightly more than half of firefighter respondents said they “Agreed” or “Strongly Agreed” that wearing a face mask keeps them safe. However, when asked to agree or disagree with the statement “A face mask is an effective tool for reducing the spread of COVID-19,” firefighters had the lowest level of agreement across the surveyed disciplines. Only 36% of fire respondents agreed with the statement.

Past and Continuing Research on COVID-19 in the Fire Service

This article, in part, is based on early findings from a larger federally funded research study (Jahnke, 2020-2023). The purpose of the ongoing study is to examine COVID-19 and its impact on the fire service from the perspective of firefighters and fire service leaders at both the departmental and national levels. The study includes interviews with firefighters nationwide to learn more about the impacts of COVID-19 and how the pandemic has led to shifts in fire department operations. A partnership with the International Public Safety Data Institute (IPSDI) allows for large-scale data tracking.

In partnership with various fire service organizations, our team members have organized and hosted three COVID-related webinars. These webinars focused on best practices for vaccine rollout, vaccine hesitancy among firefighters, and the behavioral health impacts of the pandemic. The selection of the webinar topics was based on some of the preliminary data reported in this article.

In addition to studying the short-term impacts of COVID-19, researchers are concerned with the long-term implications of the virus. Some symptoms can last three or more weeks after initial diagnosis, seriously impacting firefighters’ health and their ability to return to work. The research term for post-COVID conditions is post-acute sequalae of SARS-COV-2 infection (PASC) (Centers for Disease Control and Prevention, 2021a). Unofficially, these ongoing symptoms are often referred to as “long COVID-19” or “COVID-long.” People living with these lingering symptoms are sometimes referred to as COVID-19 “long-haulers.”

More research is necessary to examine the effects of COVID-19 on firefighters’ job performance and long-term health. Additional data is needed to understand the impact of this virus on firefighters’ ability to meet the minimal performance standards that impact their safety and the safety of others once they return to work. Long COVID-19, combined with the stressors associated with firefighting, may put fire personnel at an increased risk for COVID-related morbidity and mortality. Future research examining the impact of COVID-long on firefighters must also address: physical fitness (cardiorespiratory fitness, respiratory capacity, and muscular strength and endurance); cognitive functioning (brain fog, delayed response, and mental health); and behavioral health (alcohol and tobacco use, drug use, physical activity, and stress). All of these topics are under investigation in our ongoing research study.

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