Running head: FALSE ALARM ANALYSIS

Analysis of False Alarms in Commercial Occupancies

for South Metro Fire Rescue Authority

Michael E. Dell'Orfano

South Metro Fire Rescue Authority, Centennial, Colorado

CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

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Abstract

Fire alarm and fire protection systems are critical elements of a building's overall level of safety and so it is essential that they maintain their reliability in order to avoid the risks associated with false alarm activations. The problem was that South Metro Fire Rescue Authority (SMFRA) frequently responded to false alarms. The purpose of this research was to conduct a detailed analysis of false alarm responses in order to focus future efforts toward their reduction. The research questions were (a) what is the service demand created by SMFRA false alarms, (b) what factors contribute to SMFRA's false alarms, and (c) what are the causes of SMFRA's false alarms? A historical research method was utilized that included an analysis of past false alarm response data. General trends were discovered for frequency, distribution, duration, and types of false alarms and more detailed trends were discovered for commercial fire alarms including property use, top offenders, building age, type of devices involved, device locations, and causes. Indexes were created to analyze the contribution of property use and age of building to the frequency of false alarms. SMFRA false alarm frequencies were above national, regional, and state trends, although previous inspection interventions were found to be effective in reducing false alarms overall. Only a slight correlation was found between frequency of alarms and age of building ($r=.20$). Data inaccuracy, missing data, and labor-intensive processes limited the scope of the study and insight into the false alarm problem; however, the systematic approach can be replicated in future studies. Recommendations included re-defining the incident type, type of device, and activation cause fields, improving the merging capabilities of incident, occupancy, and inspection data, and developing site-specific analyses through a partnership with building representatives.

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Analysis of False Alarms in Commercial Occupancies for South Metro Fire Rescue Authority

Introduction

Fire alarm and fire protection systems are critical elements of a building's overall level of safety (Moore, 2003). In fact, model building and fire codes rely heavily on these systems to help establish a reasonable level of life safety and property protection from the hazards of fire and other dangerous conditions (International Code Council, 2009b). Therefore, it is essential that these systems are reliable so that they achieve their desired goals (Cholin, 2003). Unreliable systems that experience frequent false alarms can put building occupants at risk who may not react properly when the system activates in a real fire emergency (Chubb Fire, 2006).

The problem is that South Metro Fire Rescue Authority (SMFRA) frequently responds to false alarms. These false alarms not only put building occupants at risk, but also compromise fire department resources and firefighter confidence in these important systems. The purpose of this research is to conduct a detailed analysis of false alarm responses in order to focus future efforts toward their reduction. The research questions are (a) what is the service demand created by SMFRA false alarms, (b) what factors contribute to SMFRA's false alarms, and (c) what are the causes of SMFRA's false alarms? A historical research method will be utilized that will include an analysis of past false alarm response data.

Background and Significance

SMFRA was formed in May, 2008 as a merger between two adjacent fire districts - South Metro Fire Rescue (SMFR) and Parker Fire Protection District (PFPD). Located south of Denver, Colorado, the new SMFRA serves approximately 176 square miles including the cities of Castle Pines North, Centennial, Cherry Hills Village, Foxfield, Greenwood Village, Lone Tree, and Parker, along with portions of unincorporated Arapahoe and Douglas Counties (see

Figure 1). SMFRA is a career department with 288 full-time firefighters staffing 17 fire stations on a 24-hour basis over three shifts. SMFRA is an all-hazards fire department providing fire suppression, emergency medical services (including advanced life support), patient transport, hazardous materials, technical rescue, aircraft rescue fire fighting, urban search and rescue, wildland firefighting, and water rescue and recovery (dive) capabilities. SMFRA also has 101 staff and uniformed personnel that provide: a) oversight of EMS, training, and special operations; b) support functions including finance, human resources, information technology, fleet, facilities, risk management, and strategic planning support; and c) fire prevention, public education, emergency management, fire investigation, and community relations services.

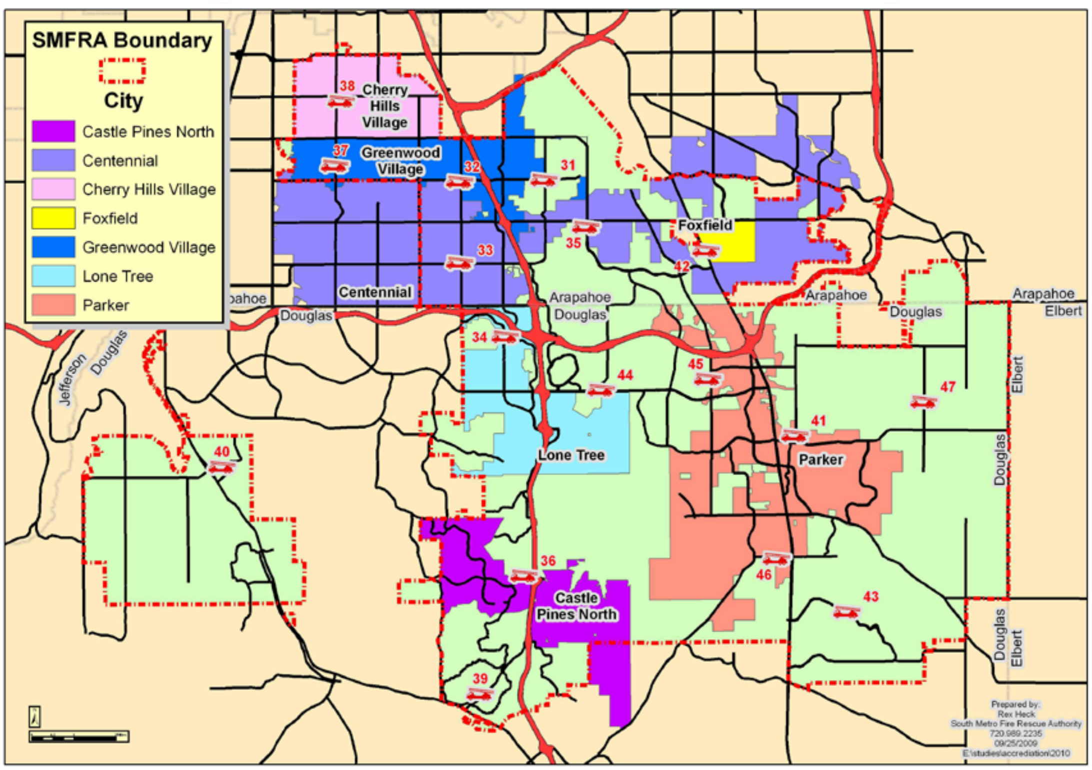

Figure 1. Cities and counties within SMFRA's boundaries.

SMFRA has a residential population of approximately 198,000 occupying over 69,200 households, including multi-family units such as apartments or condominiums (MicroBuild, 2008). According to 2008 estimates of detailed demographic information for the SMFRA jurisdiction (MicroBuild, 2008), the population has a median age of 29.9 years, the adult to child ratio is approximately 3:1, and the male and female populations have nearly the same proportion (51% and 49%, respectively). High-risk populations (United States Fire Administration [USFA], 2004), represent 7% of the overall population in the age group 0-4 and 8% in the age group 65 years old and above. Since the 2000 census, SMFRA's population has grown approximately 51%. During the same period, the toddler population (age 0-4) has experienced a 40% growth and adults 65 and older a 110% growth. The current population is about 89% Caucasian, 5% Hispanic, and less than 4% Asian. The median income is approximately $133,000 and the poverty level is very low (less than 2%). Using the population categories from the Commission on Fire Accreditation International (CFAI, 2009), approximately 63% of the resident population is located in urban areas, 31% in suburban, and 6% in rural (see Figure 2).

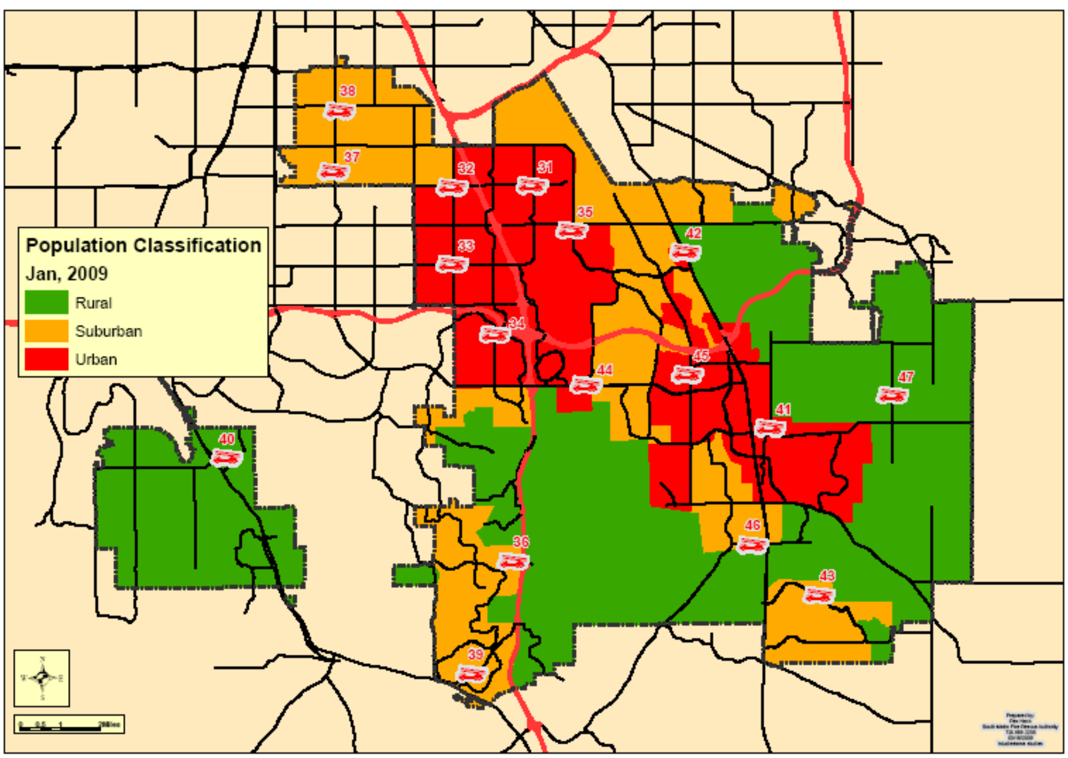

Figure 2. Rural, suburban, and urban populations within SMFRA's boundaries.

SMFRA has an average daily business population of approximately 121,000 (Denver Regional Council of Governments [DRCOG], 2009). This population occupies over 6,200 inspected, commercial occupancies (The FireManager, 2003). The 1980's saw the addition of major business developments located along the I-25 corridor, including the Denver Technological Center, Inverness Business Park, and Meridian International Business Center. These developments are home to 29 high-rise buildings within SMFRA's jurisdiction.

Similar to the resident population, commercial growth has soared over the past couple decades, including businesses, retail, and commercial. Most of that growth has been centered along the same I-25 corridor areas mentioned above, with new high-rise businesses, condominiums and a light-rail corridor. The past decade has also seen the creation of the City of Lone Tree that nearly doubled its population in only eight years. The City of Centennial was formed in 2000 and was the largest city incorporation in U.S. history. The southeast portion of the jurisdiction has also experienced significant growth, particularly in the Parker area. What used to be a small town with a central main street, is now a sprawling suburban/urban community with major housing developments, a hospital, big box chain stores, and other commercial.

Figure 3 shows areas where significant new growth or major developments are expected in the coming years. The I-25 corridor is anticipated to continue to provide commercial growth, with potential large new business and retail establishments in the Ridgegate development of Lone Tree, as well as significant re-development in Greenwood Village and Centennial. The northwest portion of Parker is similarly expected to continue growth with new housing and commercial. The central portion of the jurisdiction along the E470 corridor also contains much vacant land that is expected to produce large commercial and multifamily developments. Other, more sparsely-populated developments are expected in the southern portions of the jurisdiction along the east side of I-25 near the new City of Castle Pines North.

The southwest portion of the jurisdiction (along the Hwy 85 corridor) has much potential for significant growth, pending the ability to deliver a water supply to the area. Already, a large development has been proposed that could bring 12,000 housing units and associated commercial to the area. Water supply remains a critical issue for this area, so it is unknown how quickly it will develop. An expanded Rueter-Hess Reservoir, a multi-use recreation area in the southern portion of the jurisdiction east of I-25, is also projected to be completed by 2013 and is expected to have non-motorized water recreation, hiking trails and other amenities.

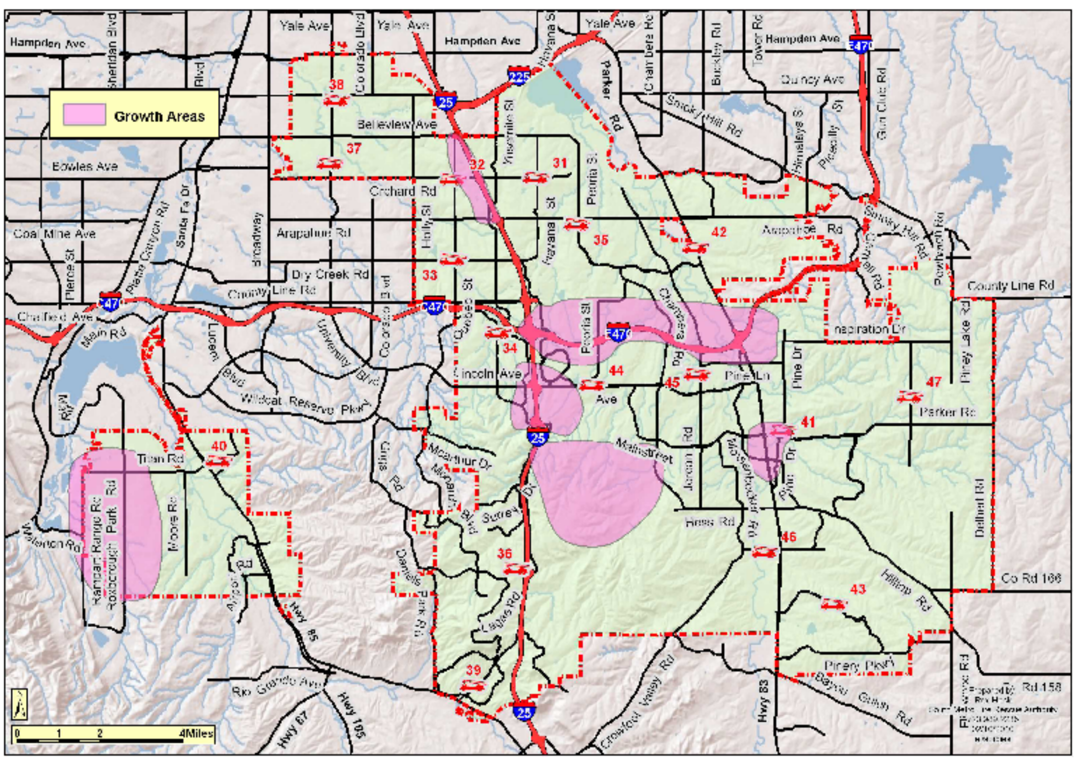

Figure 3. Anticipated major growth areas within SMFRA's boundaries.

Table 1 shows the 2005 - 2030 projections for major population and employment growth (DRCOG, 2009). While SMFRA only protects a portion of Centennial, many of those areas are where growth is most anticipated. Overall, the SMFRA resident population is expected to exceed 250,000 by 2030.

Table 1. *SMFRA Major Population and Employment Change Projections in Year 2030.*

City	Population	% change	Employment	% change
Greenwood Village	21,303	46	71,043	34
Lone Tree	18,206	81	24,961	119
Centennial	122,391	19	78,551	28
Parker	77,900	83	18,101	46

Since a large portion of SMFRA's growth has occurred over the last 20-30 years, many of the commercial occupancies are protected by fire protection and fire alarms systems. High-rise buildings constructed in the early 1980's were required to provide fire sprinklers, smoke control, smoke detection, and a monitored fire alarm system (Castlewood Fire Protection District [CFPD], 1983). At that time, CFPD (the former name of SMFR) also required several occupancies to provide smoke or heat detection throughout the buildings. Today, SMFRA enjoys protection in buildings that have plagued other communities throughout the country with large-scale fires and fatalities, such as apartments, hotels, nursing homes, and schools. In fact, the newest edition of the International Fire Code has established retroactive fire protection and alarm requirements in these high-risk occupancies, but SMFRA's buildings are already protected (International Code Council, 2009b).

Unfortunately, these fire protection and alarm systems can also result in frequent false alarm responses. Prior to the formation of the fire authority, more than 11% of the former PFPD's call volume was attributed to false alarms and as much as 21% or more of the former

SMFR's call volume was attributed to false alarms (Parker Fire District, 2007; South Metro Fire Protection District, 2005). During the recent process of developing a Standard of Cover for the new fire authority, as part of the process of becoming re-accredited by CFAI, it was noted that false alarms still account for a large portion of the organization's call volume, highlighting the need to better understand the false alarm problem.

Frequent false alarms can impact SMFRA's service delivery, as they inflate the call volume in an area and may result in additional resources being deployed to handle the service demand. This is a current dilemma in the Station 32 response area which provides protection to a large portion of the Denver Technological Center. Station 32 is one of the busiest response areas and a large portion of the call volume has traditionally been false alarms. There have been many discussions about expanding the size of the station and potentially adding a second engine to help respond to the large call volume (R. Barron, personal communication, April 15, 2010). However, without analyzing those false alarms and attempting to reduce them, a large amount of funding may be needed for what could be unnecessary apparatus, equipment, and personnel.

A more critical result of frequent false alarms that has been observed by SMFRA firefighters has been the apparent apathy exhibited by occupants of the buildings that experience fire alarm system activations. Often, firefighters arrive on scene and find that only a limited number of occupants have evacuated the building even before the occupants know whether it is a false alarm or real emergency (R. Barron, personal communication, April 19, 2010). Once they learn it is a false alarm, it is feared that the event will only deepen the sense of apathy toward fire alarm activations and result in an improper response during a real emergency. SMFRA has education programs focused on helping businesses develop emergency plans and safety warden programs and learn how to respond appropriately during a fire alarm system activation. Those programs can be strengthened if the occupants have a reasonable assurance that their timely and appropriate response to a fire alarm is necessary because the system has accurately detected an emergency situation (T. Taylor, personal communication, April 16, 2010).

Frequent false alarms have resulted in a similar sense of apathy to fire alarm system activations by the firefighters. R. Barron (personal communication, April 7, 2010) remembered a time back in the early 1990’s when firefighters responded to a fire alarm system activation at a restaurant where a fund-raising dinner was being held with the State of Colorado’s Governor. The kitchen cook tried to quickly dismiss the firefighters, stating it was a false alarm, but he didn’t know why it was false or what activated the system. So, the fire officer evacuated the building until they could verify the cause of the alarm. These actions resulted in a complaint to the fire chief who, in turn, scolded the fire officer for evacuating the building. The fire chief was more concerned with the political nature of the event and felt the evacuation was unnecessary based on the slim chance that there was a real fire, even though the dinner was held on the second floor of a building that was not protected by fire sprinklers.

Currently, SMFRA is careful to ensure that all alarms are treated seriously and has developed a deployment plan that attempts to balance the high frequency and relatively low risk of these calls with the potential that it could be an actual emergency. Also, the deployment plan attempts to limit the number of apparatus responding emergent to the call so that there is less wear-and-tear on the apparatus and less likelihood of a vehicle collision that would endanger the lives of citizens and firefighters. Therefore, only one engine and one ladder are dispatched to a commercial fire alarm and one engine to a residential fire alarm (Metropolitan Area Communications Center, 2010).

In recent years, the former SMFR and PFPD had not conducted a detailed analysis of false alarm trends or causes in order to better plan for their reduction. However, both organizations had conducted business inspections on an annual basis to confirm on-going compliance with adopted fire codes and verify fire protection and alarm system maintenance. SMFR had also established several Life Safety Technician staff positions to conduct existing business inspections and follow up on citizen complaints, firefighter inquiries, and fire alarm system problems (M. Dell'Orfano, personal communication, June 6, 2005). The success of these programs had not been measured to determine if they were having a positive impact on the frequency of false alarms.

The former CFPD and SMFR also established a fee schedule in order to assess a fine for occupancies that had excessive false alarms. During much of the early commercial growth in the 1980's, CFPD charged a $750 fine when there were three or more false alarms in a year (CFPD, 1983). SMFR's fee schedule established a $500 fine when there were more than six false alarms in a three-month period (South Metro Fire Rescue, 2002), although those fines were rarely assessed (V. Seela, personal communication, April 16, 2010).

With the expected growth in the jurisdiction, new fire protection and alarm systems are anticipated and present a potential source of additional false alarms over time. Therefore, it is important to more fully understand the details of false alarms, including the demands they place on service, the factors that contribute to false alarms, and their causes. This information can be used to better assess the effectiveness of current and future programs focused on the reduction of the frequency and risks associated with false alarms. In addition, this understanding will help avoid potentially expensive decisions to deploy more resources to respond to these preventable calls. The ultimate goal of this study is to improve the reliability of these important systems in order to support their main purpose of early notification and mitigation of an emergency. Further, citizen and firefighter confidence in the systems' reliability will be strengthened so that they respond appropriately in an actual emergency.

This study aligns with the Executive Fire Officer Program's Executive Analysis of Community Risk Reduction course that focuses on the assessment and understanding of community risk in order to focus, and more systematically approach, risk reduction efforts. This study also aligns with the United States Fire Administration's Operational Objective #4 – to promote within communities a comprehensive, multi-hazard risk-reduction plan led by the fire service organization.

Literature Review

Protecting a building and its occupants from the effects of fire requires a balanced approach to fire protection (Hall & Cote, 2003). Balance is achieved when all aspects of the building design are integrated to create a redundant and effective system that accomplishes the desired fire safety objectives. Those objectives may include life safety, property protection, continuity of operations (or protection of the business's mission), environmental protection, and heritage conservation (Moore, 2003; Schifiliti, Meacham, & Custer, 2002; Watts, 2003).

When a fire event occurs, fire safety objectives can be achieved through various strategies of slowing the fire's growth, limiting the spread of the fire and products of combustion throughout the building, quickly detecting the fire and warning occupants, and automatically or manually suppressing the fire (Watts, 2003). Fire growth and spread can be controlled through passive fire protection features, such as fire walls, fire doors, and smoke dampers, as well as active fire protection features, such as fire sprinklers, kitchen hood suppression systems, fire extinguishers, and standpipes (Hall & Cote, 2003). In the early stages of fire, fire detection and alarm systems can sense the presence of smoke and then perform critical functions such as alerting occupants to evacuate, notifying the fire department to respond, and controlling other active or passive systems, such as closing fire doors or activating the smoke control system. Manual pull stations provide another means for building occupants to activate the fire alarm system to alert others of a fire. All of these systems combined, along with fire-safe product designs and safe practices, are critical to the successful outcome of a fire event (Hall & Cote, 2003).

The minimum levels of building protection and acceptable risk are often dictated by fire and building codes (Cote & Harrington, 2006; International Code Council, 2009a, 2009b). These documents, adopted at the local, state and national levels, establish a threshold at which certain fire protection features need to be included in a building. For instance, the 2009 International Fire Code requires all new schools over 12,000 square feet to be protected by fire sprinklers and all new business occupancies to be protected by a manual fire alarm system when the occupant load exceeds 500 (International Code Council, 2009b). National standards are then followed to properly design and install the systems.

Once a building is constructed and occupied, it is incumbent on the owner of the building that the fire protection systems be maintained (International Code Council, 2009b). Fire suppression systems such as fire sprinklers need to be periodically inspected and tested to prevent pipes from freezing, remove obstructions to sprinkler flow, and replace damaged sprinkler heads (National Fire Protection Association [NFPA], 2007). Similarly, fire detection and alarm systems need to have dust and dirt removed from smoke detectors, correct system troubles, and ensure the system will correctly activate the building’s active and passive systems (NFPA, 2009).

A quality design, installation, and maintenance program is intended to ensure these critical systems continue to be reliable and prevent any unwanted system activations and false alarms (Craig & Moore, 2002). However, Cholin (2003) stated that "it is an inescapable fact that any 'system' will suffer a failure of one of its constituent components at some moment during its design lifetime." When a failure occurs, it will typically result in some trouble signal in the fire alarm system that needs to be addressed by building maintenance staff and/or an actual alarm signal that activates the building fire alarm system, warns occupants to evacuate, and notifies the fire department to respond to the false alarm (Moore, 2003).

Responding to false alarms is a common occurrence for the fire service. In fact, the U.S. fire service responded to over 2.2 million false alarms in 2008, or 2.5 times more than the number reported in 1980 (Ahrens, 2009). False alarms in recent years have accounted for about 9-12% of the overall call volume (Karter, 2009; USFA, 2007). Colorado's fire service has experienced a similar trend, with almost 41,000 false alarm responses in 2008, or about 9.5% of the total call volume (Division of Fire Safety, n.d.).

There are several risks associated with frequent false alarms, which can have a financial impact to the business and the fire department. When a business experiences a false alarm, there is an interruption in business productivity and a corresponding reduction in revenues (Craig & Moore, 2002; Kitteringham, 2007; Mrazik, 2004). In addition, Kitteringham stated that building management's time and efforts need to be redirected to focus on the false alarm and any construction work conducted in the building may also become delayed. Craig and Moore further noted that, if the false alarm resulted in a discharge of a fire suppression system, there are costs associated with replacement of the suppression agent and the risk of that portion of the facility being unprotected. Additional costs result when fire departments charge a fine for excessive false alarms (Craig & Moore; Mrazik) and when fire alarm service companies need to respond to correct the problem (National Electrical Manufacturer's Association [NEMA], 2010). NEMA warned that service costs can escalate quickly when the replacement of old devices with newer ones necessitates more extensive system upgrades due to incompatibility of equipment or fire department mandates.

The costs to the fire departments responding to false alarms can also be high. Volunteer fire departments are challenged to retain volunteers, as the support of a volunteer's "normal job" employer often wanes when they notice that the volunteer is frequently leaving work to respond to false alarms (Finley, 2001; Mrazik, 2004; Thornburg, 2000). This, in turn, causes volunteers to fear losing wages, causing fire department employee retention problems. Mrazik stated that each time a fire department responds on a call, there is associated wear-and-tear on apparatus. There is also the cost to dedicate resources to the false alarm. Pannell (2005) estimated that a single false alarm response costs the Memphis Fire Department about $105 per engine. Similarly, Thornburg estimated that the costs associated with all apparatus assigned to a false alarm in Montgomery County, MS was about $350 per call or over $54,000 per year and Lohof (2007) estimated that the cost for Billings, MT was about $340 per call or over $160,000 per year. About 24% of the Grandview, MO Fire Department's budget was dedicated to false alarm response (Toone, 2008).

Reece (2008) added that a risk for both the fire department and citizens is the potential that another, more serious emergency is dispatched while firefighters are busy handling a false alarm. This was estimated to occur about 14% of the time in Appleton, WI. Mrazik (2004) also mentioned the possibility of traffic collisions between the fire apparatus and a citizen's vehicle while responding to a false alarm. Indeed, vehicle crashes consistently account for the second largest share of overall firefighter deaths each year (Fahy, 2008). While only one of the 148 firefighter deaths from 1998 to 2007 were directly related to a false alarm, in general four out of five were related to responding to or returning from some type of emergency call, supporting Mrazik's assumption that, with each response to a false alarm, there is an increased chance for a vehicle collision.

If false alarms occur only rarely, there may be some benefit to the event, as it provides an opportunity for a business to ensure a fire alarm system is functioning properly, practice evacuation procedures, and correct any problems with emergency plans (Craig & Moore, 2002). This is similar to a weather warning, which can occur infrequently and provide a good opportunity to educate the public and test communication methods (Barnes, Gruntfest, Hayden, Schultz, & Benight, 2006). However, persistent false alarms can result in a loss in confidence and trust in a fire alarm system, a sense of complacency, and ultimately the unsafe practices of occupants ignoring or reacting slowly to the alarm (Chubb Fire, 2006; Craig & Moore, 2002; Kitteringham, 2007; NEMA, 2007; Proulx, 2000).

Roberts, Curtis, Liabo, Rowland, Diguiseppi, and Roberts (2004) conducted a study where smoke alarms were installed in a low-income and high-risk population housing development in London. Over a 15-month period, individual units experienced several false alarms and only about 50% of the smoke alarms were still functioning at the end of the study period. Although the occupants considered themselves at high risk for fires, the distress caused by the false alarms caused them to decide to disable the smoke alarms anyways. Roberts et al. concluded that "people balance immediate and long term risks to their health and wellbeing when they disable alarms."

A similar danger exists when firefighters and other emergency responders grow complacent toward fire alarm system responses (Craig & Moore, 2002; Peeples, 2000; Thornburg, 2000; Toone, 2008). Peeples cited an incident in 1994 where firefighters responded to an alarm in a high-rise residential building in Memphis, TN. Because there had been several false alarm responses to the building, firefighters were expecting to do a quick walk-through, find no emergency, and then return to the fire station. So they took an elevator (which did not have proper fire service features) to the fire floor without ensuring that proper breathing apparatus and firefighting equipment were ready. They were caught off-guard when they discovered serious fire conditions and, before the event was over, two firefighters and two civilians lost their lives.

Breznitz (1984) stated that "with the rise of sophisticated early warning systems, false alarms are inevitably on the increase, and their psychological impact may well turn out to be the most vulnerable link of many warning systems" (p. xiii). Breznitz referred to a warning system's loss of credibility due to false alarms and the human behaviors associated with them as the *false alarm effect*, or the cry-wolf theory. Breznitz stated that since humans can learn from experience, each false alarm may receive less attention and elicit less fear reactions. Also, the threat is perceived as less probable, people overestimate their ability to cope with the danger, and people are less willing to engage in protective behavior.

The false alarm effect has been studied widely outside of the fire alarm system industry, showing how several variables can affect the extent to which the false alarm effect occurs. The effectiveness of a warning system depends largely on a person's perceived control over the danger and the imminence of the threat (Breznitz, 1984). Frey, Savage, and Torgler (2010) agreed that time pressure is critical when explaining human behavior under extreme conditions of life and death; noting the contrast between the sinking of the Lusitania, where passengers exhibited a flight-impulse behavior during the available 18 minutes, and the sinking of the Titanic, where social norms and social status dominated passenger behavior during the available 2 hours and 40 minutes. Frey et al. concluded that human behavior can vary widely depending on differing external conditions.

Atwood and Major (1998) found a false alarm effect when earthquake warnings were canceled, where almost 47% of respondents stated that they would pay less attention to future earthquake predictions and only 17% said that they would pay more attention. The attention that the mass media gave to the earthquake warning appeared to have a large impact on the false alarm effect. Smith (2003) and Barnes et al. (2006) studied the false alarm effect of tornado warnings, which suffer not only from low accuracy, but the warning systems also present a weakness as they often have to alert an entire county rather than just the specific area that has the threat. Smith estimated that a Sedgwick County, KS tornado warning resulted in at least $1 Million in interrupted business costs in the City of Wichita even though the tornado was far away from the city. Because of the infrequent nature of tornado warnings, Barnes et al. concluded that there may be less of a false alarm effect, but that weather warnings are complicated by the fact that there are several “close calls” that need to be accounted for rather than just true alarms and false alarms. Barnes (2006) also studied the false alarm effect for flash flood warnings, which similarly had less of a false alarm effect, but gender and age had a significant impact where men and younger respondents had less tolerance of false alarms.

Breznitz (1984) stated that the false alarm effect may be greater with more sensitive warning systems. This was supported by Graham and Cvach (2010) in a study with highly-sensitive cardiac monitor alarms that resulted in numerous false alarms in a progressive care unit.

Because of the high false alarm rate, clinicians lost trust in the monitors, were disrupted in caring for other patients, and frequently ignored or disabled the alarms. It was estimated that the cardiac alarms resulted in the clinicians changing their patient management only about 1% of the time. By carefully studying the frequency and causes of the alarms, customizing the monitor settings to individual patients, and enhancing monitoring capabilities for clinicians, Graham and Cvach were able to lower the false alarm rate by 43% and improve the quality of the alarms that were received. It was suggested that the success of any false alarm reduction program relies on zero tolerance for false alarms and troubleshooting the alarms as soon as they occur.

Having zero tolerance not only for the occurrence of a false alarm but also people's reaction to the false alarm can help to create a successful outcome to the event during a *fire alarm system* activation, despite the false alarm effect. Proulx (2000) observed that schools often completely evacuate their buildings during a fire alarm system activation since their evacuation is led by staff as part of a mandated evacuation procedure. Conversely, a shopping center or business occupancy shows lower compliance and firefighters often show up finding little or no evacuation. NEMA (2007) reported on a college campus that experienced frequent dormitory false fire alarms, but took a zero tolerance stance by requiring everyone to evacuate the building in the event of a fire alarm and for the building horns to continue sounding until the fire department arrived and verified that there was total evacuation. This mandate resulted in the successful evacuation of a dormitory during an arson fire, despite being the third fire alarm activation within a couple hours that night.

Proulx (2000) found little research to determine how many false alarms can lead to the false alarm effect, but recommended that more than three false alarms per year can undermine a fire alarm system's credibility. Similarly, Lohof (2007) classified repeat false fire alarm offenders as having an average of three per year over 10 years. Barnes (2006) also noted that respondents perceived that three or more false alarms may begin to reduce their confidence in flash flood warnings.

Based on the impact that false fire alarms can have on the safety of the community and emergency responders, Chubb Fire (2006) stated that “we have a moral and social responsibility to help reduce [the number of false alarms]” and discussed the importance of a formal risk assessment to help with that effort. Figure 4 shows a typical community risk reduction model, where an appreciation and vision for the risk reduction effort is achieved, an analysis of the risk is performed, goals and strategies are developed, plans are put into action, the results are evaluated, and the plan continually adjusted as the effort moves forward (USFA, n.d.). A critical aspect of the *assessing community risk* step is to thoroughly understand the frequency, patterns, causes and other factors contributing to the severity of false alarms (USFA, 2009).

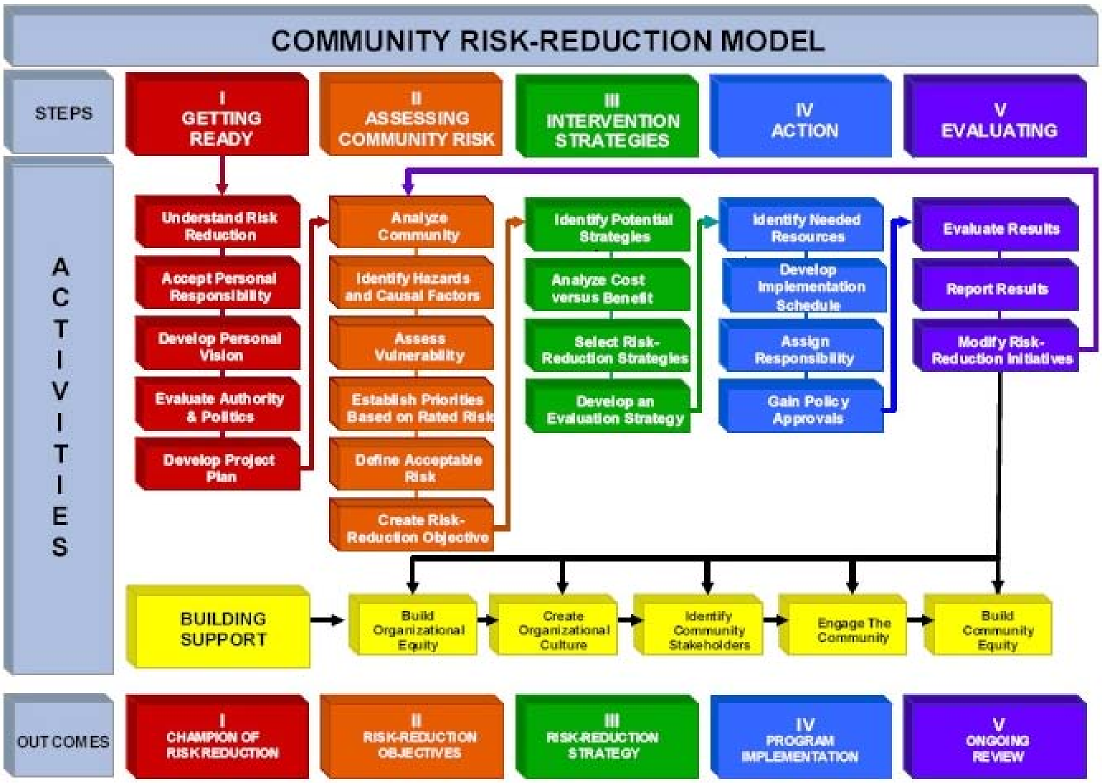

Figure 4. Community risk reduction model.

Note. From “Executive Analysis of Community Risk Reduction: Precourse Assignment,” by United States Fire Administration, n.d. Retrieved on April 19, 2010, from http://www.usfa.dhs.gov/downloads/pdf/pcm/pcm-R274.pdf

Nationally, false alarms were evenly distributed throughout 2004 and followed the daily pattern shown in Figure 5. In 2004, the western region of the United States had the lowest percentage of false alarms (8.1%) compared to the northeast (17%) (USFA, 2007). For communities with populations from 100,000 to 249,999, false alarms represented about 7.7% of all calls in 2008 (Karter, 2010).

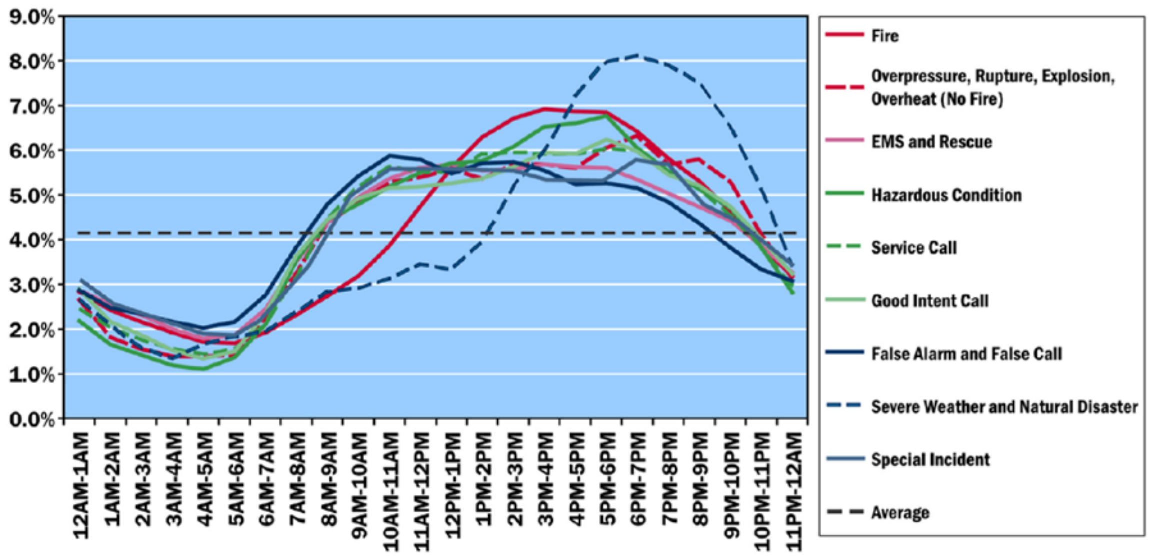

Figure 5. U.S. fire department overall runs by time of day, 2004.

Note. From "Fire Department Overall Run Profile," by United States Fire Administration, 2007, *Topical Fire Research Series Vol. 7, Issue 4*. Retrieved on April 18, 2010, from http://www.usfa.dhs.gov/downloads/pdf/tfrs/v7i4.pdf

The National Fire Incident Reporting System (NFIRS) 5.0 includes several categories of false alarms in the "700 Series" of incident types (see Appendix A; USFA, 2008). NFPA further groups these incident types into four general false alarm categories – *malicious/mischievous*, *system malfunctions*, *unintentional*, and *other false calls* (Karter, 2009). Malicious false alarms accounted for 8.5% of false alarms in 2008 and have been steadily declining since the 1980's. System malfunctions accounted for 34.1% of false alarms in 2008 and have been generally declining since 2000. Unintentional false alarms, including carbon monoxide detectors, accounted for 43.8% of false alarms in 2008 and other false alarms, including bomb scares, accounted for 13.6% of false alarms in 2008. Both unintentional and other false alarms have been steadily increasing since the 1980's. See Figure 6 for a graphical representation of these trends.

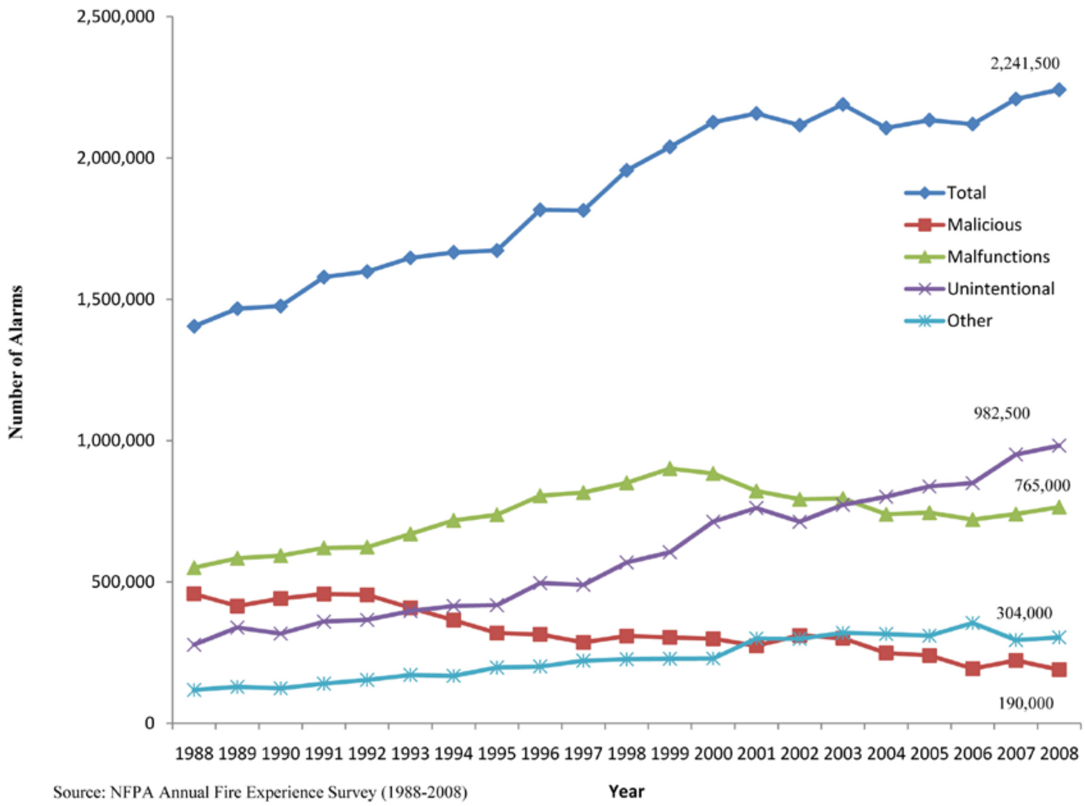

Figure 6. U.S. false alarm trends by type, 1988-2009.

Note. From "*False alarm activity in the U.S. 2008*" by M. J. Karter, Jr., 2009, retrieved April 18, 2010, from http://www.nfpa.org/assets/files//PDF/OSFDcalls.pdf. Reprinted with permission.

Several fire departments have analyzed their own false alarms to determine the common trends, locations and causes (Finley, 2001; Killalea, 1998; Lohof, 2007; Mrazik, 2004; Reece, 2008; Thornburg, 2000; Toone, 2008). Killalea found that most false alarms were occurring in hospitals, schools, business offices, and aged-care facilities, while Lohof's repeat offenders were multi-family residences, medical buildings, places of gathering, business offices, and hotels. Chicca, Shroeder, Thorness, and Shaw (2001) suggested that the use of GIS-based mapping software would provide a powerful tool to help illustrate the impact and severity of the local false alarm problem. Charts, graphs, and maps could show patterns and trends of false alarms and help present the information to management and community leaders. None of the fire department literature found appeared to utilize this technology in their analysis.

Mrazik (2004) found that the most frequent incident types were NFIRS code 730 *system malfunction, other* and 740 *unintentional transmission of alarm*. More specifically, Reece (2008) grouped false alarms into human errors (NFIRS codes 710-715, 740), system malfunctions (NFIRS codes 730-736, 741, 742), and unknown (NFIRS codes 700, 743-745) and found that 50% of false alarms were due to human errors, such as burnt food, manual pull stations, and contractors conducting maintenance, and 35% were due to system malfunctions, including smoke detector and general alarm system malfunctions. Thornburg (2000) found that common causes included improperly placed equipment, such as detectors too close to showers or other sources of heat or steam, and improperly installed or maintained devices. Finley (2001) found similar results for residential false alarms, where the top causes were system malfunctions, smoke from cooking or burnt food, and other accidental activations.

Reece (2008) noted that it is often difficult to extract root causes of false alarms from a fire department database. However, individual businesses may be able to conduct their own detailed cause analysis, which is important information to help facility planners make decisions regarding fire prevention efforts, insurance coverage, and the need for an on-site fire brigade (Cadwallader, 2009). For instance, Cadwallader evaluated 70 buildings at the Idaho National Laboratory and their false alarm history, which accounted for about 56% of all calls. It was found that the facility's remote location made it susceptible to blowing dust and, therefore, several smoke detection activations. The facility was also supplied by a private water system which resulted in false alarms when the pumps started. Trends also showed more false alarms in November due to end-of-year alarm system testing and in February due to system freezes. More false alarms also occurred during daytime hours and during the week, which were more prone to system testing and construction activities. Chow, Fong, and Ho (1999) similarly analyzed 17 facilities located adjacent to railway stations in Hong Kong, which were experiencing about 66% false alarms. It was found that dust and construction processes accounted for much of the smoke detector activations. Also, trends showed peaks of false alarms in June, July and August, as well as during morning rush hours. Chow et al. concluded that these false alarms were occurring during periods of high passenger flow rates and the associated peak electrical loading and electromagnetic interference caused by cell phones and pagers.

When determining the causes of false alarms, it is also helpful to understand how individual components within a complicated fire alarm system can contribute to the failure rate. Cholin (2003) stated that the product failure rate over time is highest both at the time the product is made and at the design lifetime of the product. When a product is made, it can experience *infant mortality* where failure is due to product design and manufacturing defects. Most manufacturers "burn in" their products prior to shipping to discover defects. The design lifetime, or *end-of-life,* occurs when the frequency of failures becomes so high that it is difficult to maintain system operability. The lifetime can be extended by increasing inspection, testing and maintenance procedures. Between the infant mortality and end-of-life failure rates is a fairly constant period where failures will occur with some predictability. It is during this period that system design and installation errors will show up and affect the inherent failure rate of the system over its lifetime.

Cholin (2003) stated that common sources of failure in system components, along with their common causes, include semiconductors (internal flaws, overcurrent, overvoltage), relays (dust, corrosion, wear, contamination), switches (human error), screw terminals (vibration, installation), fuses, batteries (lose capacity or output voltage), and wires (installation error). Circuit board solder bonds, or the bonds between electronic components and the circuit board, account for a significant portion of fire alarm system failure rates and do not always show up immediately. Solder bond failures can result when the solder becomes brittle from temperature variations, vibrations, and excessive moisture. Cholin also described common sources of failure in initiating devices, including heat detectors (physical damage, insulating detector from fire through paint or other covering), smoke detectors (dust, dirt, paint), supervisory signal initiating devices (corrosion of electronic contacts, fatigue of copper wiring conductors and mounting brackets), and audible notification appliances (corrosion, metal fatigue, paint, clogging, mechanical damage, electrical contact erosion, electrical conductor failure).

From this information about the various components of a fire alarm system, Cholin (2003) stated that a designer can compute the required maintenance frequency in order to maintain a desired reliability of the system. This varies from the prescriptive inspection, testing and maintenance schedules in NFPA 72 which are not based on reliability calculations, but rather a consensus opinion of what the average fire alarm system requires. As the size or complexity of the system increases, more frequent inspection and testing may be required to maintain the desired reliability.

Understanding the trends and causes of false alarms can help lead to effective programs to reduce the number of false alarms and their associated risks. Kitteringham (2007) reported that a property management company of several commercial high-rise buildings conducted an analysis of false alarm causes and implemented a reduction plan. During an 18-month study period, staff investigated the cause of each incident, instead of just resetting the panel and going back to work. Operations, construction, and security staff also met weekly to determine root causes, determine a course of action, create a manual of operations, and implement recommendations. These actions resulted in less unknown causes and a 50% reduction in false alarms over a five-year period, even including some legitimate alarms. Similarly, Alfred University had an increase in false alarms due to students burning popcorn in the microwave. This discovery inspired staff to develop a basic cooking class for students to not only help reduce the number of false alarms, but also give them the life skills they may not have had going into college (Schuman, 2005). The airline industry has also benefited from understanding the specific reasons for their smoke detector activations in order to develop a new technology that requires the input of both smoke and products of combustion, then compares the characteristics of an actual fire to the inputted particle sizes and concentration of various gases ("Avoiding False Alarms", 2005). Finally, understanding the serious impact that the false alarm effect has on occupant safety has led to the recommendations to use care when retrofitting fire alarms systems, especially in occupancies such as apartments where frequent testing is required during installation (NEMA, 2003b), and to provide occupants with information on the cause of the false alarm and the actions being taken to remedy the problem (NEMA, 2003a; Proulx, 2000).

This literature review provides much of the information necessary to appreciate the global risks associated with false alarms, the vulnerability of communities and fire departments, and the vision or "moral and social responsibility" (Chubb Fire, 2006) to begin a community risk reduction program focused on false alarm reduction. However, before continuing to the third step of the model in Figure 4, it is necessary to more thoroughly understand the specific trends occurring within SMFRA's jurisdiction in order to better define an acceptable level of risk, evaluate the effectiveness of current programs focused on false alarm reduction, and provide direction to future efforts. Therefore, this study will focus its analysis on three main categories:

(a) service demand, or the call types, frequencies, patterns, and locations associated with false alarms; (b) contributory factors, or the property use/building characteristics, system components, and inspection histories that might influence the rate of false alarms; and (c) causal factors, or the specific reasons that the false alarm event occurred. Gaps in the literature, such as utilizing GIS techniques, will also be explored.

Procedures

General Procedures

The SMFRA dispatch center, MetCom, utilized the TriTech VisiCAD Command Computer-Aided Dispatch (CAD) system to record all incident information (V. Zecher, personal communication, May 28, 2009). That information was then sent to SMFRA's records management system (RMS), The FireManager (2003). All of the incident data used in the analysis was taken from the RMS and then downloaded into an ArcGIS 9.3 geodatabase, where the data was "geocoded", or validated for proper address, including city, county, station district, and fire jurisdiction. PFPD and SMFR calls were recorded in separate RMS databases throughout 2007 and until December 27, 2008. That separate data was combined with the SMFRA data to create a database that would provide a historical view of service demand, as if the fire authority had been operating since January 1, 2007. In order to achieve the combined database, any duplicate records where a PFPD and SMFR unit responded to the same incident were removed by keeping only the record corresponding to the responsible jurisdiction. All data was still sortable by jurisdiction so that separate trends for SMFR, PFPD, and SMFRA could be analyzed.

An additional field was added to the data indicating whether the call occurred in an urban, suburban, or rural area of the fire authority, as defined by CFAI (2009). That information was generated using the MicroBuild (2008) database which provides population and demographic data at the street block level. The validated data was then used to create maps to display spatial information and exported to spreadsheets for analysis. Microsoft Excel 2003/2007 spreadsheets and Crystal Reports 11 were used to conduct specific analyses of the data and produce charts and graphs.

Each company officer was responsible for completing a report for each incident, which included verifying the general incident information, such as correct incident type, location, property use, actions taken, and responding units. Specific fields for false alarm responses were then completed, such as type of device, activation cause, device location, and system status. Finally, a narrative report was completed that described the event and actions taken (R. Nelson, personal communication, April, 16, 2010).

What is the Service Demand Created by SMFRA False Alarms?

All incidents, including in and out of jurisdiction, from January 1, 2007 through December 31, 2009 were used to show the overall call counts and percentages of calls assigned to the *fire, EMS, alarm*, and *other* categories. Other calls included public assists, other agency assists, canceled en-route, vehicle collisions without injuries, and similar call types. Calls dispatched as an alarm that turned into an actual fire were determined by querying all fire incidents from 2007-2009. The *incident type from CAD* was compared to the *correct incident type*, both of which varied over the years depending on the original database. The only incident types from CAD selected were *1 and 1 investigation (alarm – commercial fire)*, *1 and 1 investigation (alarm – water flow), 1 engine (alarm – residential fire), alpha medical (alarm – reset), alpha medical (alarm – residential fire)*, *alpha medical (fire alarm – residential),* *commercial fire alarm, fire alarm residential*, and *special 2 unit E/L or E (fire alarm – commercial)*. There were 1,161 fires from 2007-2009.

Only in-jurisdiction alarm incidents were used for the remainder of the service demand analysis. A total of 6,830 calls were included in the in-jurisdiction data set.

The alarm density map was created with the FireView extension in ArcGIS. These “hot spot” maps provide a visual indication of how the data is distributed. The values for *very high*, *high*, *moderate*, and *low* categories were calculated by the software and were relative to the specific data set (C. Robinson, personal communication, April 29, 2010). Only 2009 data was used in order to show the distribution of alarm incidents in a typical year.

Day of week, hour, and month distributions were available within the alarm incident data from the RMS. However, the original data extracted from the RMS did not have the updated station district information that was determined from the geocoding process. Therefore, several were found to be incorrect or blank. So, the correct station districts were re-inserted into the spreadsheet into a column labeled *updated station district value*. This information was used to determine the frequency of alarms by station district and as a percent of station call volume. Values for Station 47 did not appear until 2009 since it was not constructed until early 2009.

The duration of alarm calls was calculated by subtracting the *first unit arrived* time stamp from the *last unit cleared* time stamp for each incident. Only one record (incident #08-4331) was removed since the first unit arrived time stamp was blank. Averages were then computed by year and RMS incident type.

An analysis was conducted to determine how often an apparatus misses another call in its station district while it is committed to a false alarm. A Crystal Report was created to search all in-jurisdiction incident records from 2007-2009 for instances where a call was dispatched prior to the last unit clearing from a previous incident, in the same station district as the previous incident, and the previous incident was an alarm. The frequency of this occurrence was then determined by station district.

Incidents were sorted by NFIRS incident type codes in order to group into the NFPA false alarm categories – malicious/mischievous, system malfunction, unintentional, and other false calls. The incident type codes in the RMS did not always match the corresponding NFIRS incident type codes since SMFR, PFPD, and SMFRA did not use every NFIRS code and each organization also created additional codes to capture more specific information, such as a false alarm due to cooking or burnt food. It should be noted, however, that SMFR, PFPD, and SMFRA matched up the RMS incident type codes with a similar NFIRS incident type code prior to submitting NFIRS data to the State of Colorado. For the purposes of this study, some of those matches were changed to more closely reflect the similar NFIRS code. Appendix B shows the RMS incident type code, corresponding incident type description (including which organization used that code and description), and matching NFIRS incident type code. NFPA false alarm categories were then assigned the following NFIRS codes (M. J. Karter Jr., personal communication, April 21, 2010): a) malicious/mischievous – 710 to 715; b) system malfunction – 730 to 739; c) unintentional – 740 to 749; and d) other false calls – 700, 721, 751.

What Factors Contribute to SMFRA's False Alarms?

Contributing factors examined included the type of use conducted in a building, specific addresses that experience frequent false alarms, the characteristics of buildings that experience false alarms (such as age or high rise), the types of devices prone to false alarms, the location of devices, and the effectiveness of interventions by SMFRA personnel. The analysis started with the in-jurisdiction data set discussed previously.

Alarms were divided into residential and commercial categories to determine the percentages that occur in each. Residential was defined only as a one- and two-family dwelling. During that process, it was observed that several multi-family buildings (e.g., apartments) were incorrectly classified as a *1 or 2 family residence*, so the list was sorted to include only the 1 or 2 family residence and multi-family residence property uses and corrections were made wherever it was obvious that the two classifications were incorrectly mixed. After determining the percentage of alarms that originated in commercial versus residential occupancies, the analysis was narrowed to include only commercial occupancies by removing the property use type 1 or 2 family residence from the data set. The focus was further narrowed to include only those incident types that were related to fire alarm or fire protection system activations. RMS incident type codes 700, 721, 743, and 751 were removed from the data set.

There were a total of 4,342 incidents included in the in-jurisdiction, commercial fire alarm data set. Types of uses with the most frequent false fire alarms were determined by sorting by the *property use/type* RMS field and grouping similar uses as follows: a) *hotel/motel, commercial* and *boarding/rooming house, residential hotels*; b) *restaurant or cafeteria* and *eating, drinking places, other* and *bar or nightclub*; c) *Elementary school, including kindergarten* and *high school/junior high school/middle school* and *day care, in commercial property* and *schools, non-adult, other* and *preschool*; d) *mercantile, business, other* and *general retail, other* and *department or discount store* and *food and beverage sales, grocery store* and *specialty shop* and *household goods, sales, repair* and *recreational, hobby, home repair sales, pet store* and *textile, wearing apparel sales* and *convenience store*; and e) *24-hour care nursing homes, 4 or more persons* and *residential board and care*. In order to compare the relative contribution of each property use to false alarms, an index (referred to as the *property use alarm* *index*) was created by dividing the *% of alarms* by the *% of property use*. The % of alarms was a measure of the frequency of false fire alarms that occurred in each property use, measured as a percent of all commercial, false fire alarms. The % of property use was a measure of the frequency of each property use, measured as a percent of all property uses with a fire alarm system. The % of property use was obtained by querying all addresses and their corresponding property use from the Life Safety module of the RMS. That list was then filtered to include only those with a *has fire alarm* field value of *true*. This field was chosen as a filter based on the assumption that it would include all systems that automatically notify the fire department, including stand-alone fire suppression systems with only a dialer. This method presents a potential limitation to the study, as it may not have covered all monitored systems and would not account for notification of the fire department by other means such as a citizen phone call. There were 2,835 property uses with fire alarm systems.

High-rise buildings were also analyzed to evaluate their tendency toward false fire alarms. A high-rise was defined as “a building with an occupied floor located more than 75 feet above the lowest level of fire department vehicle access” (International Code Council, 2009a). There were a total of 29 high rises.

Commercial fire alarms were sorted by *incident location* to determine the addresses with the most frequent false alarms. Since addresses were entered by the person completing the incident report, there were some inconsistencies in how addresses were entered for the same location. For instance, the incident location *9800 Meridian Boulevard* may also have been entered as *9800 S Meridian Boulevard*, resulting in these addresses being shown as separate locations. These addresses were merged by verifying through the RMS that they referred to the same building, picking one format, then changing the others so they would all match. Addresses with the most frequent false alarms were defined as having an average of three or more per year (i.e., nine total or more), based on the suggestion from the literature that the false alarm effect may be a risk at this frequency. This group was referred to as the *top offenders*.

In order to investigate the relationship between the age of a building and the frequency of false alarms, the *year constructed* data from the Life Safety module of the RMS was queried in order to match the information to the addresses that had false alarms. Initially, however, it was discovered that the current RMS, as well as previous archived versions, only had year constructed information less than 10% of the time (M. Heath, personal communication, April 27, 2010). Therefore, the Arapahoe and Douglas County Assessors' data was queried, which contained *year built* and other information for each parcel in the county. The parcel year built value from the assessors was joined with the corresponding parcel in SMFRA's geodatabase. That information was loaded into the Life Safety module of the RMS by matching parcel information with the addresses in the RMS. This was not always successful due to differing addressing schemes, but it was estimated that approximately 75% of the RMS included year constructed information upon completion (V. Zecher, personal communication, May 2, 2010). In order to get the year constructed information into the spreadsheet containing the false alarm data, the incident locations for each of the alarms first had to be matched up with a parcel in the geodatabase. This was accomplished by using the ArcGIS software through a process called a spacial join. The final parcel location was then inserted into the false alarm spreadsheet by matching addresses. Because the incident location did not always match with a parcel, several of the year constructed values in the spreadsheet appeared as N/A. To remedy this, the year constructed was filled in manually by attempting to match with either the years that were successfully filled in for the same address or by checking the newly-populated RMS. This process was only performed for addresses that had two or more false alarms, but approximately 84% of the commercial, false fire alarm addresses included year constructed upon completion. The GIS parcel/address matching process and the hand corrections present a potential limitation to the study. A total of 1,058 addresses and 4,064 incidents were used in the analysis of the relationship between the age of a building and frequency of false alarms.

The total number of alarms was plotted by each year of construction for all buildings in the commercial, false fire alarm database. Realizing that the frequency of alarms in a given year was relative to how many buildings were constructed that same year, a *year constructed alarm index* was developed as a means to compare alarm frequency between years. The index was calculated by dividing the number of alarms for a specific year by the number of buildings constructed in that same year. The year constructed was converted to *age of building* (2010 – year constructed) and plotted with the year constructed alarm index for visual comparison.

In order to quantify the relationship between age of building and year constructed alarm index, the Pearson Product Moment Correlation Coefficient, *r*, was calculated (Glass & Hopkins, 1996). Values of *r* range from -1 to +1, where a -1 or +1 indicates a perfectly negative or positive linear relationship and 0 indicates no correlation. This measure of correlation is appropriate when there is a linear relationship between age of building and year constructed alarm index, which was evaluated by plotting an X-coordinate representing the age of building and a corresponding Y-coordinate representing the year constructed alarm index. A limitation in the analysis will be present if that linear relationship is less than perfect. It is also important to note that a correlation between two variables does not necessarily suggest a causal relationship (Glass & Hopkins, 1996). Rather, it shows that, to some degree, the frequency of alarms (as normalized by the index) can be predicted by knowing something about the age of the building.

The Pearson Product Moment Correlation Coefficient, *r*, was calculated as:

$$r = \frac{s_{xy}}{s_x s_y} \tag{1}$$

where s_x and s_y were the standard deviations of the two variables and s_{xy} was the covariance of variable X and Y, defined as:

$$s_{xy} = \frac{\sum_i (X_i - \overline{X})(Y_i - \overline{Y})}{n-1} \tag{2}$$

where $\overline{X}$ was the mean age of building, $\overline{Y}$ was the mean year constructed alarm index, and *n* was the number of ages represented in the data set (n = 49).

In order to investigate other factors that contribute to false alarms, the *type of device* and *device location* fields were queried for all commercial fire alarms. The SMFRA RMS contained pre-designated choices for the type of device field, including unknown, smoke detector, heat detector, manual pull station, water flow detector, multiple types of devices activated, and type of device not classified. Additional descriptions appeared in the query since the former SMFR and PFPD RMS's contained different descriptions. These were combined into the current descriptions unless the match was not obvious. Device location was a text field where anything could be entered by the person completing the report. Type of device and device location were matched up with the incidents located at addresses with nine or more total false alarms to provide more insight into the top offenders.

In order to analyze what fire department actions contribute to the decrease in false alarms, inspection histories for the top offenders were examined. The *last inspection* fields of the SMFR, PFPD, and SMFRA RMS (Life Safety module) were queried to determine if one or more business inspections had been conducted at a top offender address between 2007 and 2009. Also, inspections performed to follow-up on specific fire alarm system problems were also queried from the *via complaint* inspection type in the SMFR, PFPD, and SMFRA RMS's (Life Safety module). There were a total of 456 via complaint inspections related to fire alarm system problems at 294 addresses from 2007 to 2009. Those inspections were then matched up with top offender addresses. The frequencies of business and complaint inspections for each year were then compared to the total number of false alarms at the top offender addresses to discover any relationship between the two variables.

What are the Causes of SMFRA's False Alarms?

To analyze the causes of false alarms, the *activation cause* field of the RMS was queried for all in-jurisdiction, commercial false fire alarms. The SMFRA RMS contained pre-designated choices for the activation cause field, including fire or smoke caused activation, carbon monoxide caused activation, no activation occurred, multiple activation causes were found, and activation cause not classified. Additional descriptions appeared in the query since the former SMFR and PFPD RMS's contained different descriptions. These were only combined if the descriptions were similar; however, the remainder were left in the analysis since they were not adequately accounted for in the new SMFRA database.

Contractors who install and service fire alarm systems were also contacted to determine if they had any insight into common causes of fire alarm activations within the SMFRA area. The Life Safety module of the RMS was queried to determine the contractors who maintained the most fire protection and alarm systems. There were 151 contractors that were shown to maintain systems within 1,991 addresses. Four contractors were chosen, including the top three since they all maintained more than 100 addresses and the fifth contractor was also chosen based on recent, positive interactions on other projects (see Table 2 for top five). All were contacted by phone and three were contacted by follow-up e-mails and were asked for any information that would help determine the causes of false fire alarms in SMFRA's jurisdiction. Suggested information included databases that contained the situation found, actions taken, devices ordered, cause of alarm, monitoring company data, or similar information that would indicate what happened after an alarm technician was assigned to reset, restore, repair, or otherwise trouble-shoot a system.

Table 2. *Most Frequent Fire Protection and Alarm System Maintenance Contractors.*

Contractor	# of Addresses
CINTAS FIRE PROTECTION	366
FIRE ALARM SERVICES	179
SIMPLEX GRINNELL - DENVER	122
FIRE SYSTEMS WEST - CO	99
WESTERN STATES FIRE PROTECTION	92

General Limitations

Some of the specific limitations of this study have been identified in the various procedures discussed above. In addition, much of this study relied on the data available from the RMS's of SMFR, PFPD, and SMFRA. Each of the former databases was used and interpreted differently, presenting some limitations when combining them in this study. It was also apparent that the process of creating the new SMFRA Life Safety RMS (through combining and converting the former SMFR and PFPD data) resulted in some incorrect classifications of various fields. Data entry problems were also obvious, raising doubt as to the accuracy of fields such as property use, has fire alarm, and inspection dates. Similarly, incident data was prone to errors in data entry and the large amount of blank fields complicated the analysis. Also, despite the details available in the Incident and Life Safety RMS's and the advanced GIS analytical techniques available, much of the analysis was performed using hand calculations or manually combining the two databases, which was difficult due to the large amount of data and presented additional opportunities for error.

While analyzing the incident types, it was observed that several sprinkler system pipe freezes were inadvertently found to have been logged in as a service call under NFIRS code 522: *water or steam leak*, even when the call was dispatched as a waterflow alarm. These calls would have been more appropriately entered as a 731 code. This indicated that all false alarm data was not included in the analysis.

When analyzing the frequency of false alarms at individual addresses, a limitation was introduced by the fact that it was not obvious if various addresses were part of the same complex, such as an apartment complex. Combining those false alarms would have changed the top offender list and given a more accurate picture of the false alarm problem within a complex. For instance, apartment complexes have separate fire alarm systems in each building, but often share a common panel/dialer in the clubhouse (which may make each building prone to the same system problems) and are maintained by the same property management (which may reflect how each building's system is maintained and problems corrected). Ideally, it would have been better to use the *occupancy id* or *complex id* fields in the RMS that are unique to each address/complex to sort data, but most of those were found to be blank.

Results

What is the Service Demand Created by SMFRA's False Alarms?

SMFRA responded to a total of 14,424 calls in 2007, 14,055 in 2008, and 13,886 in 2009. Figure 7 shows the distribution of fire, EMS, alarm, and other call categories in 2007, 2008, and 2009. Overall, there was a decrease in the number of calls each year, with a corresponding decrease in each category, except EMS which had a slight increase. There were 31 instances from 2007-2009 where a call was dispatched as an alarm but turned out to be an actual fire emergency (2.7% of all fires).

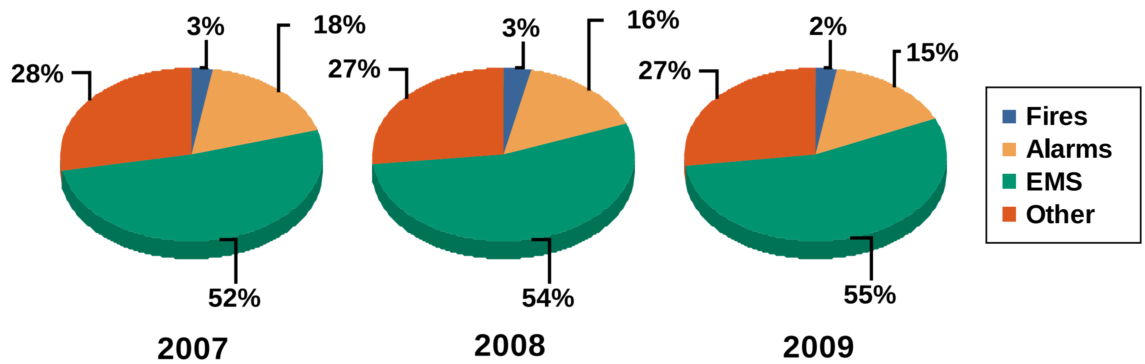

Figure 7. SMFRA call type distribution, 2007-2009.

Table 3 shows the number of alarm responses each year and break-down of in and out of jurisdiction. Overall, about 98% of alarm responses were in SMFRA's jurisdiction. In-jurisdiction alarms decreased 14.2% from 2007 to 2008 and an additional 3.3% from 2008 to 2009. More specifically, from 2007 to 2008 there was a 16.3% decrease in alarms in the former SMFR jurisdiction and a 10.4% decrease in PFPD alarms (see Table 4).

Table 3. *SMFRA Alarm Counts, 2007-2009.*

	2007	2008	2009
Total	2,584	2,231	2,145
In Jurisdiction	2,542	2,180	2,108
Out of Jurisdiction	42	51	37

Table 4. *In-Jurisdiction SMFR, PFPD, and SMFRA Alarm Counts, 2007-2009.*

	2007	2008	2009
SMFR	1,891	1,583	
PFPD	651	583	
SMFRA		14	2,108

Figure 8 shows the distribution of alarm calls across the jurisdiction, showing a higher concentration of alarms in the high-density commercial areas along I-25 between Lincoln Ave. and Belleview Ave. There were also a large number of alarms in the primarily residential areas at the far southern (Castle Pines) and far northwestern (Cherry Hills Village, Greenwood Village) portions of the jurisdiction.

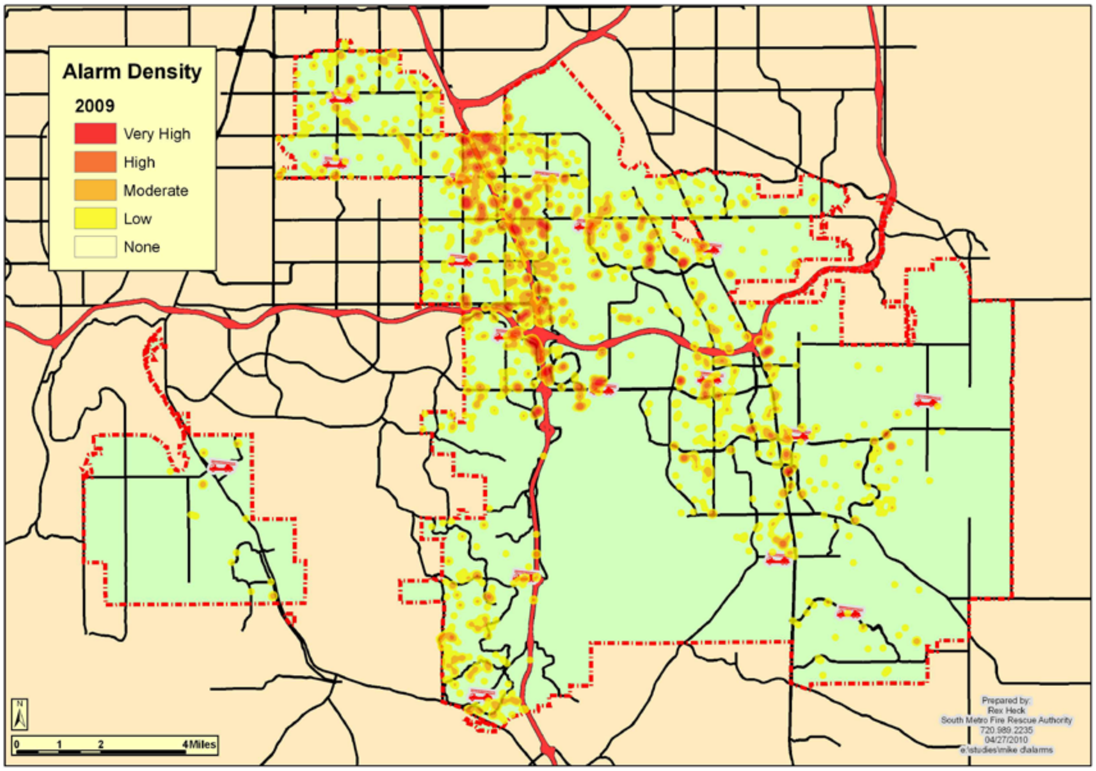

Figure 8. Hot spot map of alarms, 2009.

Figures 9, 10, and 11 show the distribution of alarms across the days of the week, hours of the day, and months of the year, respectively. The results showed that most alarms occurred Monday through Friday, although each year the range from the minimum to maximum throughout the week was about the same at three alarms. This appears to reflect the large urban nature of the false alarm demand where the large resident populations and influx of visitors even out the call volume throughout the week. Results showed a consistent hour of day pattern each year, where the hours that businesses are open and the public are awake are the busiest for false alarms. The results did not show a consistent pattern throughout the months of the year, although 2009 had more false alarms in the summer than the rest of the year, with an additional spike in December.

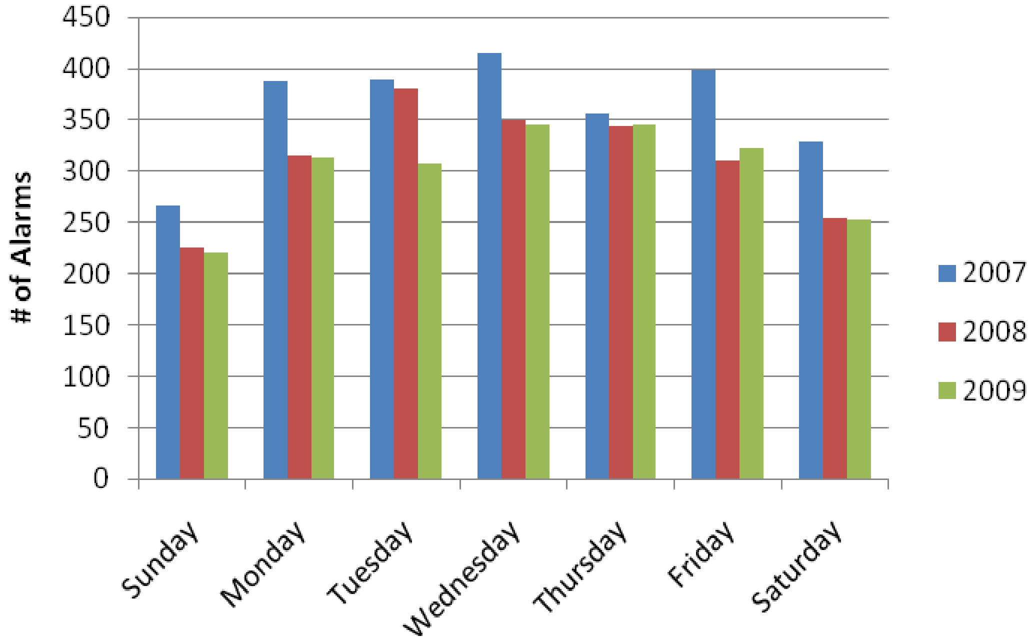

Figure 9. Alarms by day of week, 2007-2009.

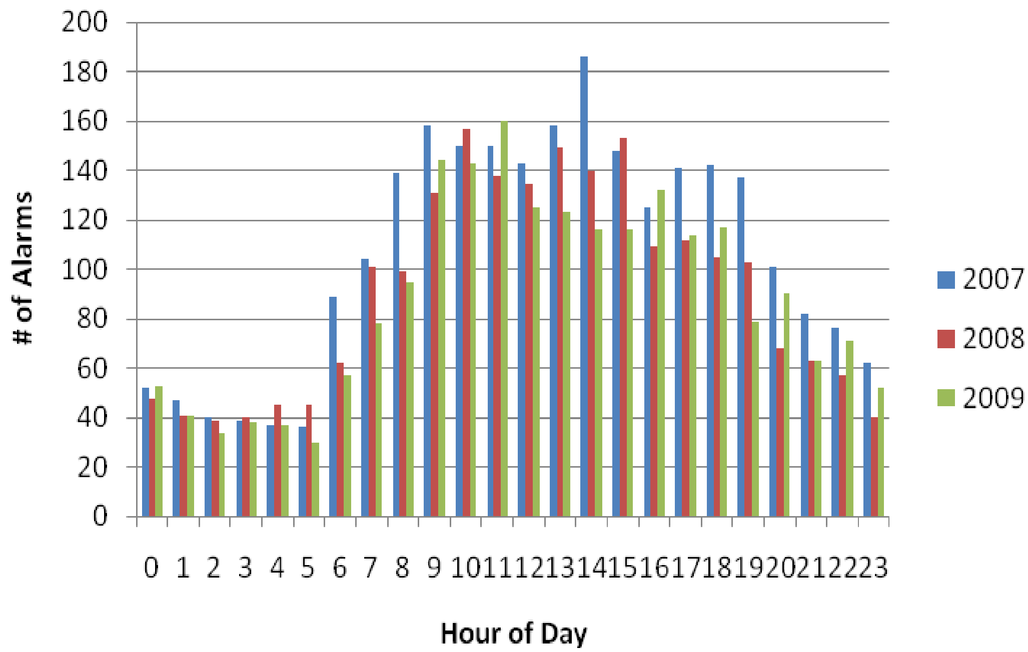

Figure 10. Alarms by hour of day, 2007-2009.

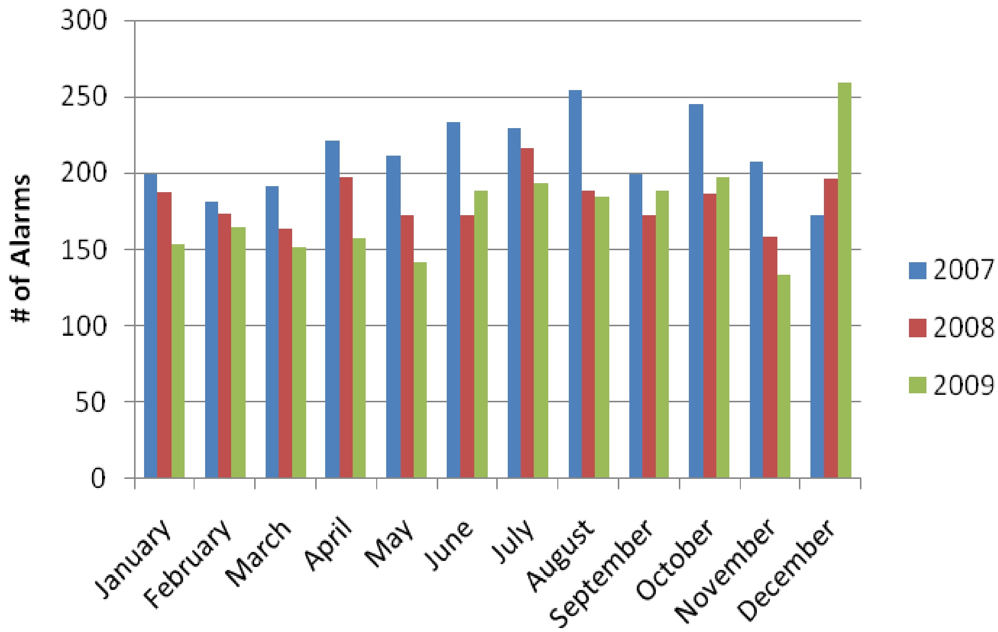

Figure 11. Alarms by month, 2007-2009.

Figure 12 shows the number of alarms within each station district and Figure 13 shows what percent of the stations' in-jurisdiction call volume was alarms. Alarms consistently accounted for more than 20% of the call volume for Stations 32, 35, 38, and 39, with Station 35 over 25% and Stations 38 and 39 spiking over 30% in 2007.

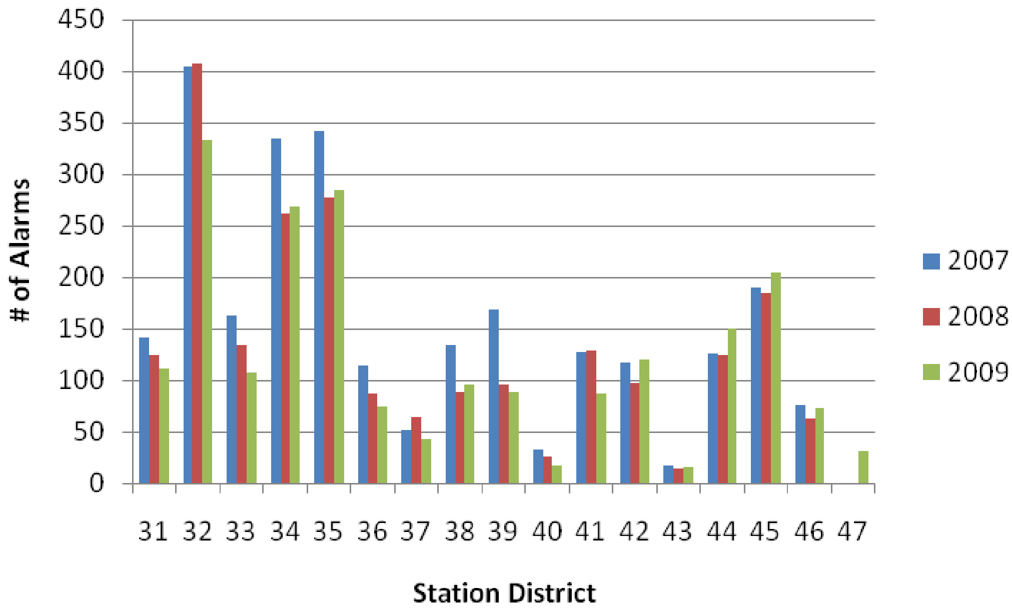

Figure 12. Frequency of alarms by station district, 2007-2009.

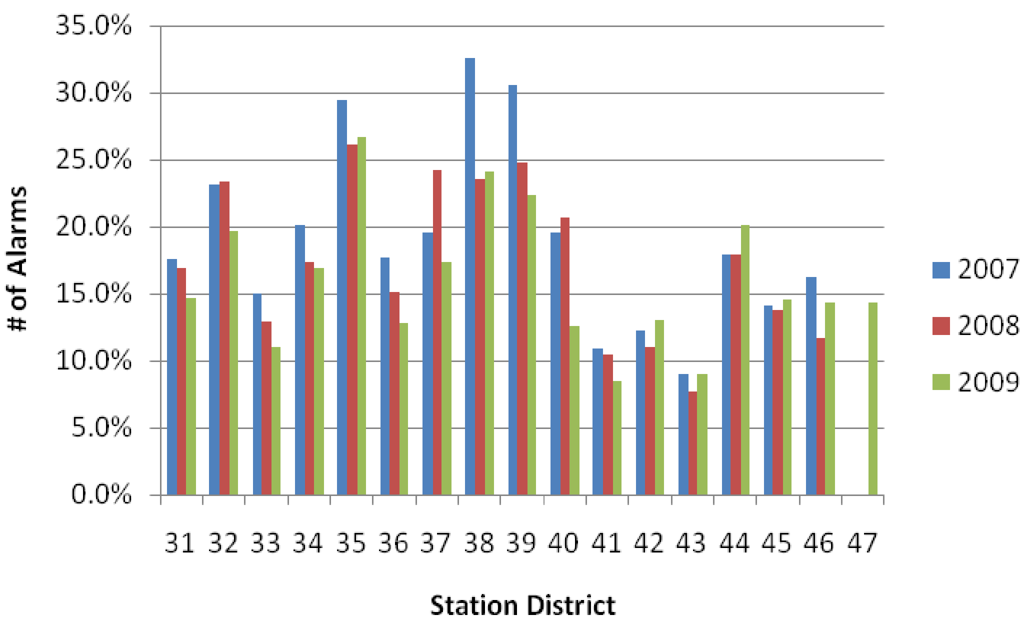

Figure 13. Alarms as a percent of station district call volume, 2007-2009.

On average, the firefighters spent about 12 minutes on alarms in 2007, 13 minutes in 2008, and 14 minutes in 2009, with an overall average of 13 minutes. Durations ranged from zero minutes (e.g., apparatus arrived on scene but immediately went "in service" since they knew it was a false alarm) to 4 hours, 56 minutes, with only 102 (1.5%) incidents taking an hour or more. Bomb scares took the longest amount of time to clear the scene, with an average duration of 1 hour, 12 minutes. Alarms related to activation of a fire alarm, sprinkler, or other extinguishing system ranged from an average of 23 to 45 minutes in duration. There did not appear to be any notable differences in duration when comparing station districts.

There were 249 instances (0.6% of all in-jurisdiction calls; 3.6% of all in-jurisdiction alarms) where a call was dispatched within the same station district where the apparatus was already committed to an alarm incident. This occurred most frequently in the Station 32, 34, 35, and 45 station districts. However, these concurrent calls never occurred more than 1.6% of the time for any particular station district in a single year (see Table 5).

Table 5. Concurrent Call Frequency while Apparatus Committed to an Alarm.

Station	2007	2008	2009	Total
31	1	5	5	11
32	20	20	24	64
33	5	3	5	13
34	20	13	16	49
35	18	6	7	31
36	5	3	1	9
37	1	2	0	3
38	1	0	2	3
39	2	1	0	3
40	1	0	1	2

41	2	4	1	7
42	4	4	1	9
43	0	0	0	0
44	1	2	6	9
45	7	13	11	31
46	4	0	1	5
47	0	0	0	0
Total	92	76	81	249

Appendix C shows the number of alarms separated into RMS incident type codes and the incident type descriptions used by SMFR, PFPD, and/or SMFRA. Table 6 and Figure 14 show SMFRA's false alarms grouped into NFPA's false alarm categories for comparison. Starting in 2008, SMFRA's data started a sharp trend toward grouping false alarms in the unintentional category.

Table 6. *SMFRA Alarm Counts by NFPA False Alarm Category, 2007-2009.*

Year	2007	2008	2009	Total
Malicious/Mischievous	242	192	34	468
System Malfunction	882	485	120	1487
Unintentional	1293	1399	1871	4563
Other False Call	125	104	83	312
Total	2542	2180	2108	6830

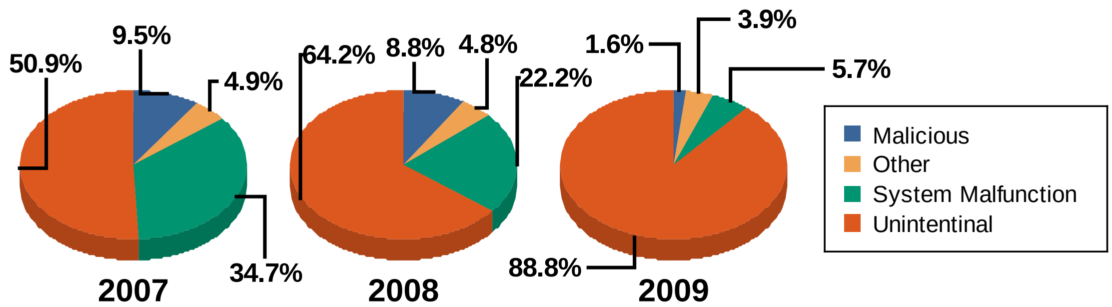

Figure 14. NFPA false alarm categories by percent, 2007-2009.

Examining the trend toward unintentional alarms further, Appendix C shows there was an increase in the use of one particular RMS incident type code; namely, 745 – *alarm system activation (no fire), unintentional*. At the same time, there was a near complete drop in the use of RMS codes such as 710, 730, 734, 735, and 740. Since 740 and 745 are similar, there was no concern with their consolidation. However, 734 and 735 provided a more specific type of unintentional alarm, so that detail was lost in the 2008 and 2009 data. More concerning was the fact that malicious alarms (710) and system malfunctions (730) were being categorized as unintentional. Further research showed that alarm system activation (no fire), unintentional started being the default correct incident type whenever an officer opened an incident report for an alarm (V. Zecher, personal communication, April 28, 2010). This began sometime in 2008 and it appears that many officers were not changing that incident type to a more accurate description of the call while completing their report. These errors in incident type classifications limited the understanding of the service demand trends, such as determining what types of false alarms were common in a particular station district, day of the week, or month of the year.

What Factors Contribute to SMFRA's False Alarms?

From 2007 to 2009, false alarms were associated with a commercial occupancy approximately 68% of the time and the remainder in a one- and two-family dwelling. Of those commercial occupancies, alarms associated with fire alarm and fire protection systems occurred most frequently in the occupancies listed in Table 7. The property use alarm index showed that hotels/motels, schools, churches, and nursing facilities had a service demand that was disproportionately high. Conversely, the service demand for retail was low. Therefore, the type of occupancy appeared to be a contributor to false fire alarms. Most high rises (90%) experienced one or more false fire alarms, with an average of 10.2 over three years. High-rise false alarms accounted for 6.1% of all commercial false fire alarms. High rises account for about 1.0% of all buildings with a fire alarm system, so high rises could be viewed as having an index of 6.1, although not exactly the same as the property use alarm index.

Table 7. *Percent of Commercial False Fire Alarms, Percent of Commercial Property Uses with Fire Alarms, & Property Use Alarm Index by Property Use.*

Property Use	% of Alarms	% of Property Use	Property Use Alarm Index
Business offices	29.6	24.1	1.2
Multifamily residences	13.7	20.0	0.7
Hotels/motels	9.7	1.6	6.1
Schools under 12th grade	7.7	3.4	2.3
Retail	7.1	12.5	0.6
Restaurants/bars	6.2	6.5	1.0
Churches	2.8	1.6	1.8
Nursing facilities	2.5	1.0	2.5

There were 1,266 addresses that experienced one or more false fire alarms, or about 45% of all buildings that were shown to have a fire alarm system in the RMS. The average number of false alarms was 3.4, the median was two, and the mode was one. Figure 15 shows the distribution of frequencies. There were only 109 commercial addresses (8.6%) that satisfied the criteria for frequent false fire alarms (see Appendix D). Of the top offenders, approximately 12% were high-rise buildings including both high-rise hospitals in the jurisdiction. Typical property uses were business offices (31%), hotels/motels (20%), schools (13%), and multifamily (13%), with the remainder less than 5% each.

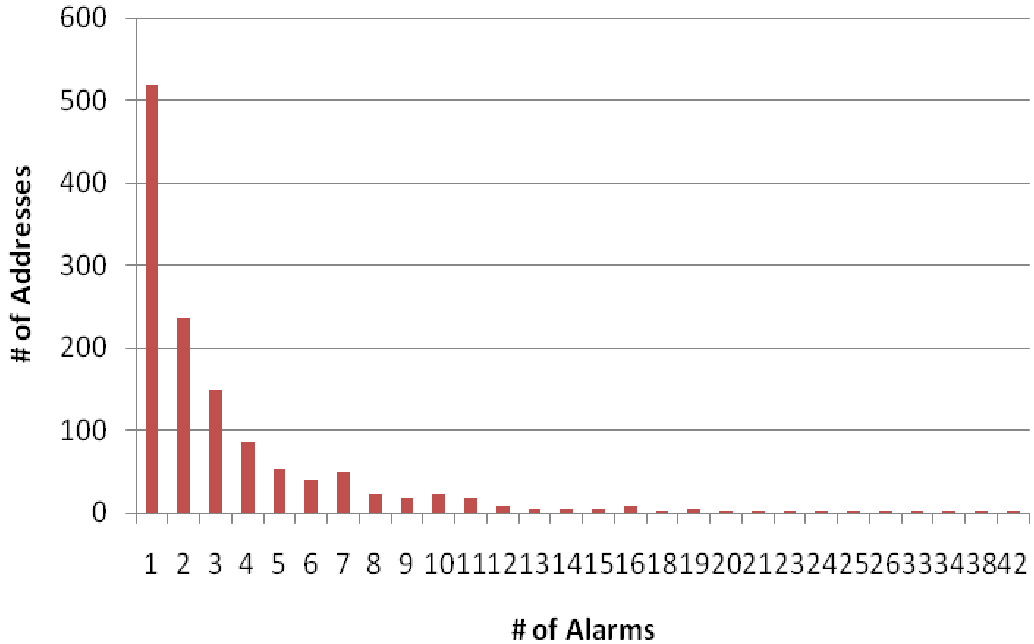

Figure 15. Number of addresses by alarm frequency.

When the year constructed was available, it was found that false fire alarms occurred in buildings constructed between 1951 and 2009. Figure 16 shows the total number of false fire alarms that occurred in buildings during each of those years. The trends suggest that most alarms occur in buildings constructed in the early 1980's and late 1990's/early 2000's. However, Figure 17 shows that the trend may be due to the fact that more buildings were constructed during those same time periods.

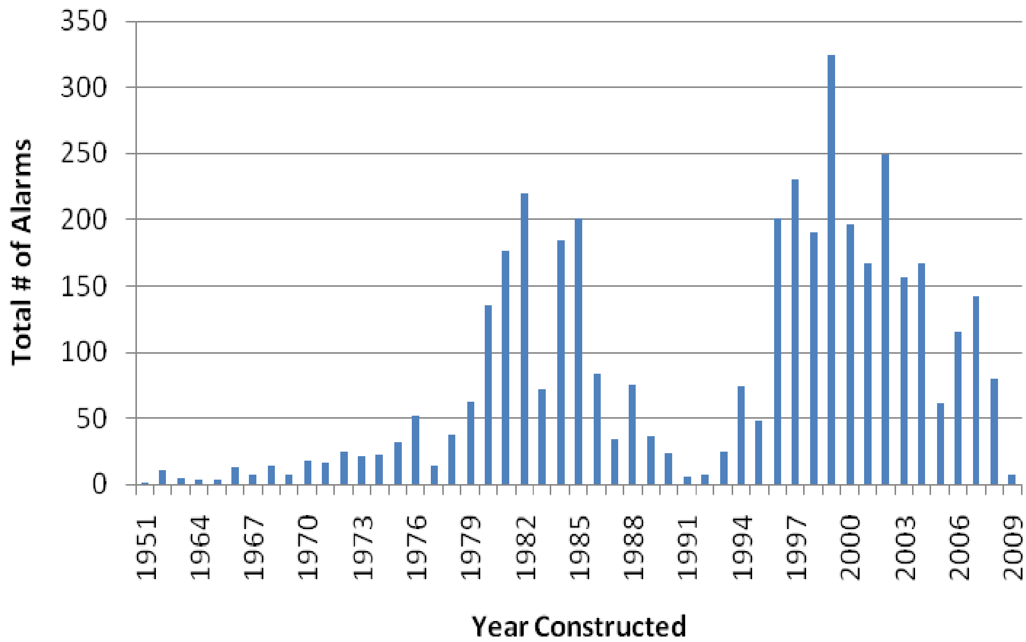

Figure 16. Total number of commercial false alarms by year constructed.

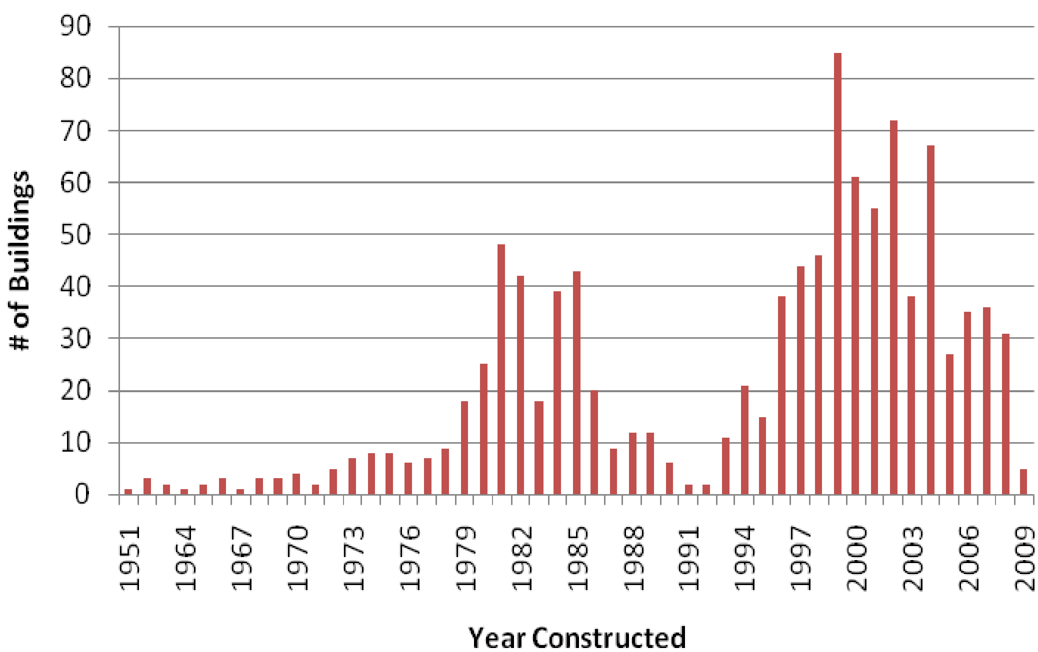

Figure 17. Number of commercial buildings constructed by year.

Figure 18 shows the year constructed alarm index, which indicates the number of alarms that occurred each year relative to the number of buildings constructed each year. The majority of the data appears to range from an index of 2.0 to 5.0. Buildings constructed from 1951-1977 appear to have more spikes, indicating the potential that those older buildings have more false alarms. The lowest index was in 2009, which indicates that the newer, more modern buildings and fire alarm systems may not be as prone to false alarms.

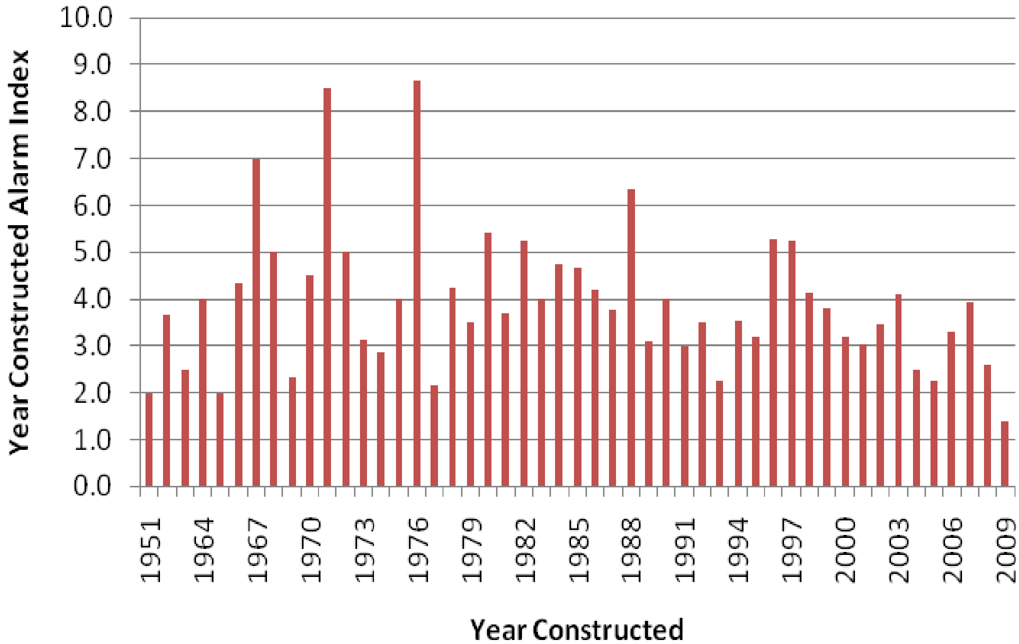

Figure 18. Year constructed alarm index by year constructed.

To quantify these trends, Figure 19 visually shows the relationship between age of building and year constructed alarm index. The concentration of the data appeared to follow a roughly linear relationship, although as noted above, there were some outliers to that trend. However, the linear correlation measurement for the two variables appeared to be an appropriate tool (the trendline was inserted using the *linear trendline* function of Microsoft Excel for illustration purposes). The calculated *r* was .20, supporting Figure 19 that there is a minor, linear, and positive relationship between age of building and year constructed alarm index. Therefore, the age of a building does have a small contribution to alarm frequency, where older buildings tend to have only slightly more false alarms.

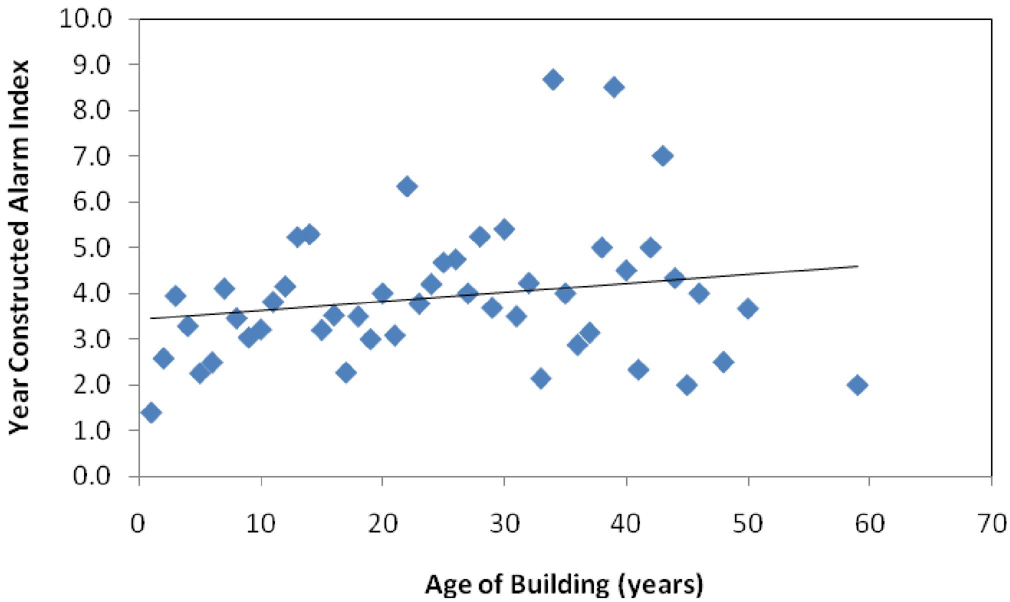

Figure 19. Scatterplot of age of building and year constructed alarm index.

When the extent of contribution to false alarms from type of device was analyzed, it was found that smoke detector activations were the most common method of indicating an alarm (see Figure 20). There was nearly an equal amount that was left blank during the reporting process, which was the equivalent of losing almost 1,300 calls from the analysis. Appendix E shows the most frequent type of device for each of the top offender addresses. Together, these results indicate that the presence of smoke detectors contributed the greatest to the occurrence of false fire alarms. Manual pull stations and water flow detectors also contributed on a lesser scale.

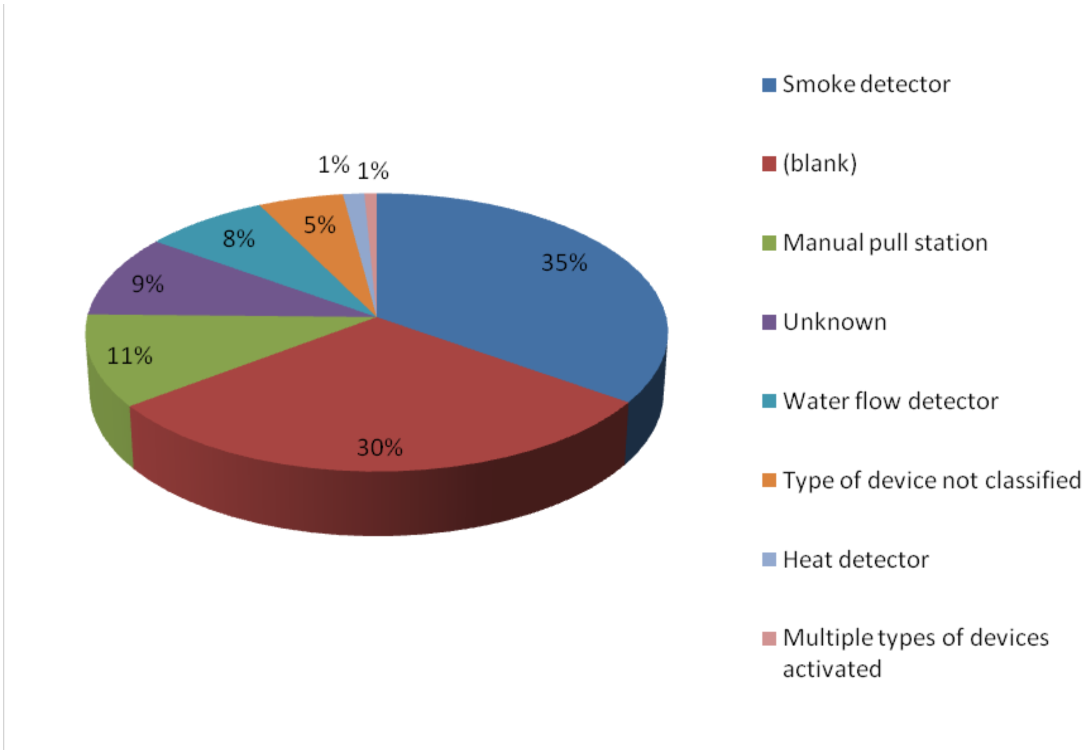

Figure 20. Distribution of type of device entries for all commercial false fire alarms.

Since device location was a text field, the query produced 1,678 different entries, with approximately 36% left blank. The results of matching the device location with top offender addresses were too numerous to re-produce, but when individual addresses were evaluated there were some patterns. For instance, Table 8 shows the results for 6450 S. Boston Street, which is an assisted-living center. When the various device locations were grouped together, it was determined that the most frequent devices activated were located in or near a kitchen. Appendix E also shows that the majority of false alarms were activated by smoke detectors. Therefore, it can be concluded that smoke detectors near the kitchen were a major contributor to false fire alarms at this address.

Table 8. *Device Locations for 6450 S. Boston Street False Fire Alarms.*

Device Location	# of Alarms
1st floor break room	1
1st floor hallway	1
1st floor kitchen	2
1st floor maintenance room	1
1st floor office	1
1st Floor Service Hallway	1
2nd floor telephone room	1
3rd floor	1
3rd Floor common space	1
3rd Floor Hallway	1
cleaning dust M1-34	1
dinning room	1
hall by kitchen	1
In hallway near kitchen	1
Ist floor kitchen, alzheimers unit	1
Kitchen	6
Kitchen area	1
lobby	1
second floor E hall o2 closet	1
(blank)	9
Total	34

When the relationship between frequency of inspections and frequency of alarms was analyzed for the "top offender" addresses, results showed that very few inspections were conducted in 2007, but grew rapidly in 2008 and 2009. With the increase in business and complaint inspections was a corresponding decrease in false alarms for the top offender addresses (see Table 9). The results appear to indicate that the inspection process, either on a routine basis or as a follow-up to a specific problem, contributed to the reduction in the frequency of commercial false fire alarms.

Table 9. *Top Offender Inspections Completed and Total False Alarms, 2007-2009.*

	2007	2008	2009
Addresses Inspected (Business)	9 (8.3%)	51 (46.8%)	79 (72.5%)
Addresses Inspected (Complaint)	25 (22.9%)	24 (22.0%)	43 (39.4%)
# of False Alarms	532	495	487

Overall, the study showed that specific property uses, specific addresses, and the presence of smoke detectors contributed to the occurrence of false fire alarms. The device location, particularly with smoke detectors, may have also contributed to false fire alarms, but that relationship would have to be analyzed for each address and type of device to determine the specific contribution. The age of a building did not appear to be a significant contributing factor. It was also determined that routine business inspections, as well as a follow-up inspection to specific fire alarm system problems, contributed to the decrease in false fire alarms.

What are the Causes of SMFRA's False Alarms?

When the causes of false alarms from activation cause were analyzed, very little insight was obtained (see Figure 21). Almost one-third of the data was left blank and another half was not classified. Similarly, the results of matching the activation cause with top offender addresses showed that nearly all of them had *activation cause not classified* as a top cause.

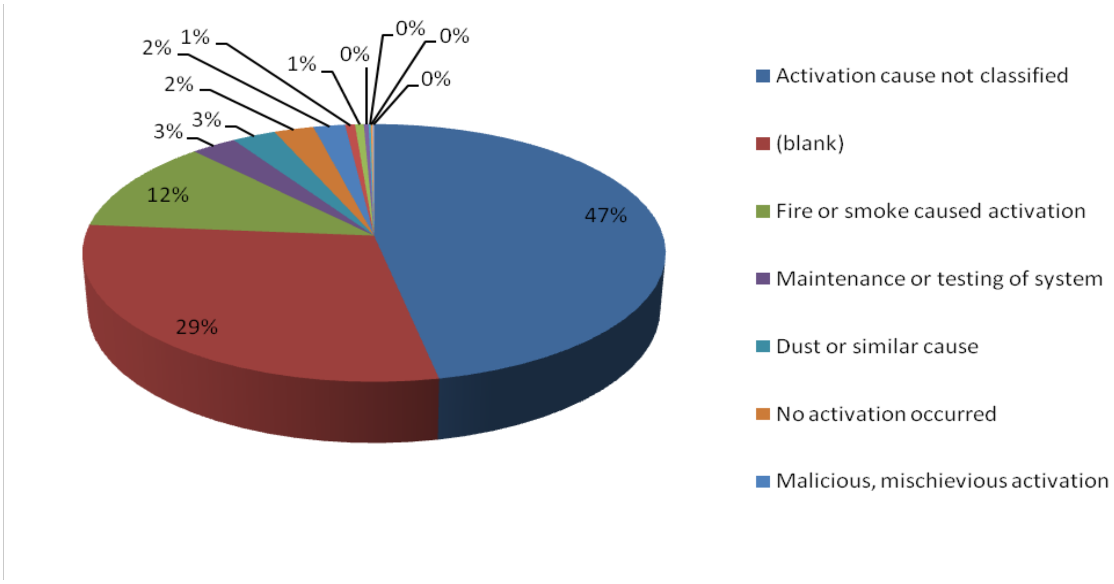

Figure 21. Distribution of activation cause entries for all commercial false fire alarms.

Evaluating each top offender address individually may show some patterns, but very limited. For instance, Table 10 shows the results for 6450 S. Boston Street. The previously-discussed pattern that smoke detectors near kitchens were the most frequent devices activated was supported by the frequent activation cause of *fire or smoke caused activation*. However, all of the smoke detector activations were not accounted for. Overall, while it appeared that the RMS had several fields to help understand the causes of false alarms, the results of the study did not produce any insight.

Table 10. *Activation Causes for 6450 S. Boston Street False Fire Alarms.*

Activation Cause	# of Alarms
Activation cause not classified	14
Fire or smoke caused activation	13
No activation occurred	1
(blank)	6
Total	34

Insight into the causes of false fire alarms was not obtained from the fire alarm system contractors. Each contractor reported that it was not common practice to maintain a database showing the results of service calls performed by technicians in response to fire alarm system problems. One contractor was in the process of creating such as report and intends to share the report with the local fire department when a problem has been addressed (see Appendix F).

Discussion

The primary purpose of this study was to gain a detailed understanding of false alarm responses in order to focus future efforts toward their reduction. That was accomplished by using false alarm responses from 2007-2009 that were analyzed to determine the overall service demand created by false alarms, including the frequency, distribution, duration, and types of false alarms. Further analysis focused on commercial, false fire alarms and showed the extent to which certain factors contribute to the increase or decrease in false alarms, as well as what were the ultimate causes of those false alarms.

The service demand results of this study provided an important understanding of the current call volumes imposed by false alarms. False alarms continue to account for a large portion of SMFRA's call volume, ranging from 15-18% in recent years. This frequency is higher than the U.S. trend of 9-12% (Karter, 2009), the western region trend of 8.1% (USFA, 2007), the Colorado trend of 9.5% (Division of Fire Safety, n.d.), and the trend of similar sized communities of 7.7% (Karter, 2010).

At the station district level, it was also surprising to discover that false alarms frequently account for as much as 20-30% of station call volumes. As discussed earlier, this is significant especially with busy stations such as Station 32, where there have been discussions about adding a second engine to address the call volume. Knowing that 20-25% of its call volume is false alarms, a concentrated effort should be made to reduce that frequency before additional funds are invested. Of course, frequency is not the only factor to analyze. This study also looked at the risk of units missing another emergency because they were "wasting time" on a false alarm. Fortunately, this occurred less than 1.6% of the time for any station district, which was much less than the rate estimated by Reece (2008) of 14% of the time. This is most likely due to the short duration of most alarms, with an overall average of 13 minutes and an average of 23 to 45 minutes for fire protection system problems.

Fortunately, SMFRA's false alarms have been decreasing. Explaining this downward trend is difficult, as it could depend on new technology, improved maintenance, and higher quality designs, plan reviews, installations and inspections. Additionally, the past decade has seen a large amount of tenant finish work in older office buildings, where newer fire alarm devices have been installed and some of the smoke detection that was required in the early 1980's has been eliminated. All of these factors together provide a reasonable explanation of the general downward trend in false alarms. However, it appears the largest decline has occurred in recent years. It was only six years ago that SMFR was experiencing false alarm rates in excess of 20% and those have been decreasing in significant steps over the past four or five years, with a 16% drop between 2007 and 2008 (for SMFR alarms only; see Table 4). The only other program that has occurred within this concentrated timeframe has been the interventions from fire department personnel; specifically, the Life Safety Technician program which gave a focused effort on business inspections, ensuring fire protection system maintenance, and following up on false alarms. That program was started in 2006, struggled to complete all anticipated inspections in 2006 and 2007, but dramatically improved performance in 2008. Those increases in inspection frequencies correspond to the reductions in false alarms. Future additional study of the effectiveness of this program should be pursued. Unfortunately, the data review will be difficult, as much of the data is contained in text fields and it was difficult to match incident data with occupancy or inspection data.

As this study began to analyze deeper than just false alarm frequency, it was continually challenged by data accuracy, missing data, and labor-intensive processes. The 2007 data started out promising, where the percentages of malicious, system malfunction, unintentional, and other false calls were similar to the national trends discussed by Karter (2009). However, starting in 2008, the unintentional incident type became about 40% inflated. This was discovered to be due to the simple act of designating code 745 as the default incident type in the RMS, which unfortunately was not being changed to a more accurate incident type by the officers. This one mistake eliminated many opportunities to learn more about false alarms, without having to hand-sort or read the narrative reports of thousands of incidents. For instance, it was observed that there was a spike in false alarms during the month of December, 2009. One might speculate that this was due to cold winter storms that resulted in sprinkler pipe freezes or snow melt damaging fire alarm devices. This study discovered, however, that many sprinkler pipe freezes were not even designated as an alarm incident type, so those calls would not be found to explain this trend. Also, the more specific incident types such as 731 or 741 were no longer being used to represent these call types, in lieu of 745.

The challenges continued when digging further down to the type of devices involved in false alarm activations and attempting to discover the actual causes of false alarms. Supporting Reece's (2008) claim that it is difficult to extract causes from a fire department database, both of these fields suffered from a large amount of blank, unknown, or not classified entries. Some may have been due to the officer choosing not to fill in the field, as was apparent in the assisted-living facility example where all of the devices and causes were not accounted for in the smoke-detectors-near-kitchens scenario. The trends may also be due to the fact that there were not enough choices to accurately reflect the circumstances of the false alarm. For instance, the SMFRA database only contains five choices for activation cause, only two of them describe a specific cause, and none of them account for common occurrences such as dust, mechanical damage, pipe freezes, or malicious causes. The use of *fire or smoke caused activation* is also confusing since it is not clear if this covers burnt food and dust, and including the term *fire* is not appropriate since, if there was fire, then it probably wasn't a false alarm. Similarly, the type of device field needs to account for the all portions of the system that may have been involved in the activation (e.g., fire alarm panel, control unit, wiring), not just activation devices (e.g., smoke detectors, heat detectors, pull stations). The large number of type of device unknowns may also be appropriate if the firefighters did not know what caused the activation and, therefore, may also not know what device was activated.

Ideally, the incident type would give just enough information to know what type of malicious, malfunction, unintentional, or other alarm occurred, and then the more detailed circumstances of the alarm would be obtained from the type of device and activation cause fields. Instead, SMFRA's database provides an insufficient selection of devices and causes and attempts to compensate by adding more incident types that have the cause built in, such as *smoke detector activation due to cooking or burnt food*. In reality, the detailed incident types don't get used and the more descriptive fields in the incident report are prone to not being filled out; leaving little information about the incident.

All of these limitations made it difficult to perform a comparison of data between fire departments, such as the common incident types found by Mrazik (2004), Reece (2008), Thornburg (2000), and Finley (2001). Similarly, this study found that certain property uses (businesses, multifamily residences, hotels, schools, retail, restaurants, churches, and nursing facilities) presented the greatest false alarm demand. However, Killalea (1998) found that hospitals, schools, business offices, and aged-care facilities accounted for most false alarms, while Lohof (2007) listed multi-family residences, medical buildings, places of gathering, business offices, and hotels. In order to compare these results and have any understanding of the true relationship between property use and false alarm frequency, each fire department would need to know more information.

Therefore, this study introduced a property use alarm index that provides a unique way to compare frequencies of false alarms in specific property uses regardless of jurisdiction. The index also allows each fire department to focus their efforts on the property uses with the true false alarm problems. For instance, initially one might conclude that business occupancies in SMFRA's jurisdiction should receive all of the false alarm reduction efforts, since they account for almost 30% of all false alarms. However, the index shows us that the rate of false alarms in business offices is proportional to the number of businesses offices with alarm systems in the community. Therefore, while the index would ideally be less than one, the index tells us that the property use alone is not the main concern, so a better strategy might be to focus on top offender addresses and give particular attention to high rises. Conversely, the small numbers of hotels in the community provide a high rate of false alarms, many of which are top offenders. Therefore, it might be worthwhile to not only focus on individual addresses, but also communicate with all hotel owners and managers and develop a more wide-spread reduction effort.

The year constructed alarm index was another unique analytical tool introduced by this study. It helped to quantify the relationship between the frequency of alarms and the age of a building and test the assumption that older buildings have more false alarms. To that extent, this study helped to “myth bust” that assumption, as there was only a mild relationship between frequency of alarms and the age of a building. That assumption was primarily based on the concept introduced by Cholin (2003) where a fire alarm system eventually reaches its design lifetime where the system can no longer be maintained and is subject to more failures. However, that end-of-life can be extended through inspection, testing, and replacement of system components over time. These interventions are common for SMFRA buildings and the age of a building may not adequately capture their impact. It would be interesting to compare year constructed alarm indexes with other fire departments that don’t see a lot of system modifications over the years. Those jurisdictions may see more of a correlation between the frequency of false alarms and the age of a building.

An alternative analysis would be to compare false alarm frequency with the age of the *fire alarm system*, but that may be more difficult to determine from an RMS after years of modification. The fire alarm system contractor information was anticipated to shed some light on the life cycles of devices and systems, but they surprisingly track little information on their service calls. It is hoped that more of them will collect this critical information in the future.

The use of GIS-based technology to analyze data was also a valuable tool, as suggested by Chicca et al. (2001). The GIS and RMS technology helped to avoid a lot of the errors introduced in studies such as Pannell (2005) where very simplistic, labor-intensive estimations were necessary to discover the trends of hundreds of thousands of calls. Despite the challenges with the complicated processes of merging data, verifying station districts and year constructed would not have been possible without GIS technology. SMFRA still has the challenge, however, of improving the process of cross-matching incident, occupancy and inspection data so that all aspects of the false alarm problem can be understood and reduction efforts can be better analyzed. A simple, critical start will be to attach occupancy and complex i.d.'s to every incident report to provide a unique identifier that would tie all of the information together.

It is anticipated that SMFRA's RMS will eventually contain a wealth of information to better understand the false alarm trends and causes. This study presented a systematic method for analyzing false alarms that can be replicated over time as the data quality improves. Ultimately, though, the results will primarily be used to focus attention to a specific address or property use, as the exact cause of the alarms may not always be known. However, the inspector will be armed with a greater understanding of the specific circumstances surrounding that building and others like it. It would not be difficult to present a building owner an analysis of SMFRA's understanding of the times of day, days of week, months of year, types of devices, device locations, and activation causes for a specific address or property use, which would serve as a great starting point for developing a site-specific false alarm reduction program. Then, as shown by Cadwallader (2009), Chow et al. (1999), and Kitteringham (2007), any blanks or unknowns can be filled in, intervention strategies developed and implemented, and progress continually monitored through a partnership between the building representatives and SMFRA staff.

During all of these data analyses and reduction efforts, it will be important to evaluate how the occupants are reacting to the false alarms. Keeping them informed of the causes and solutions will be a critical part of reducing the false alarm effect, as suggested by NEMA (2003a) and Proulx (2000). The future study of the false alarm effect for fire alarm system activations appears to be an important and needed component for SMFRA to better understand the risk to its community and more closely tie together its education and enforcement efforts.

This study has provided the critical, preliminary information and systematic method to move past Step 2 and continue through the community risk reduction model (USFA, n.d.). With future replication of this study using improved data, both global and site-specific reduction strategies can be developed and the effectiveness of SMFRA's contribution to the effort can be better measured. Ultimately, the reliability of fire protection and alarm systems will be improved so that they can fill their role as a key component in the protection of life and property (Moore, 2003).

Recommendations

Based on the large amount of data entry and RMS fields that need to be improved, it is assumed that the opportunity for quality data extraction in 2010 has been lost. Therefore, the goal will be to improve those processes and systems during the remainder of the year so that new, accurate data and trends can be captured in 2011. In the next six months, it is recommended that SMFRA improve the incident type, type of device, and activation cause fields of the RMS. It is recommended that only the NFIRS incident type codes be used and the unique custom RMS incident type codes that have been developed over the years be deleted. If possible, the incident type should not be pre-populated when officers begin to fill out the incident report. Instead, the field should be left blank or a placeholder created that forces the officer to choose the most appropriate incident type.

The activation cause field should contain more specific information about the cause, such as dust, lack of maintenance, sprinkler pipe freezes, cooking or burnt food, and lightning. Also, the *fire or smoke caused activation* field should be changed to *smoke caused activation*. The *multiple activation causes were found* and *activation cause not classified* should be removed from the activation cause field. An *activation cause, other* should be added.

Type of device should be modified to include *fire alarm control panel* and *system wiring*. The *multiple types of devices activated* and *type of devices not classified* should be removed from the activation cause field. A *type of device, other* should be added.

It is critical when performing complicated analyses that the incident, occupancy, and inspection databases be more easily merged. In order to help accomplish that, it is recommended that the occupancy and complex i.d.'s be incorporated into the incident data. Currently, there is no place to manually enter them into the report and the RMS only occasionally provides them when downloading incident data. It is recommended that a function be added where the officer can search for the correct i.d. or the addressing format be changed to exactly match addresses in CAD and occupancy databases.

In late 2010 and after changes are made to the database, it is recommended that a formal training session be provided to the personnel that complete incident reports and to inspection staff. The purpose of the training would be to discuss the findings in this study to help establish an appreciation for the reduction of false alarms and the importance of data quality and accuracy.

Once the training has been conducted, the incident report review process needs to be monitored closely to ensure that the improvement recommendations are being implemented.

Starting in 2011, a concentrated effort needs to be made to partner inspection and education staff with building representatives to develop solutions to their false alarm problems. Emphasis should be given to buildings that have experienced three or more false alarms in a year, both historically and through on-going monitoring. Continued contact with system maintenance contractors is also recommended so that information can be shared, with a joint effort toward false alarm reduction.

It is recommended that other researchers attempt to replicate the analyses in this study, particularly to test and add more data to the property use alarm index and year constructed alarm index. Exploring various ways to capture alterations and upgrades to fire alarm systems may help refine the age analysis. An additional and valuable future research topic would be to fill the gap in the literature on the false alarm effect for fire alarm systems. Such a study could discover at what thresholds the false alarm effect begins to appear, which may help drive the methods and timing of intervention strategies.

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Appendix A

NFIRS 5.0 Incident Type Codes

False Alarm and False Call
Malicious, mischievous false alarm
711 Municipal alarm system, malicious false alarm. Includes alarms transmitted on street fire alarm boxes.
712 Direct tie to fire department, malicious false alarm. Includes malicious alarms transmitted via fire alarm system directly tied to the fire department, not via dialed telephone.
713 Telephone, malicious false alarm. Includes false alarms transmitted via the public telephone network using the local emergency reporting number of the fire department or another emergency service agency.
714 Central station, malicious false alarm. Includes malicious false alarms via a central-station-monitored fire alarm system.
715 Local alarm system, malicious false alarm. Includes malicious false alarms reported via telephone or other means as a result of activation of a local fire alarm system.
710 Malicious, mischievous false alarm, other.
Bomb scare
721 Bomb scare (no bomb).
System or detector malfunction. Includes improper performance of fire alarm system that is not a result of a proper system response to environmental stimuli such as smoke or high heat conditions.
731 Sprinkler activated due to the failure or malfunction of the sprinkler system. Includes any failure of sprinkler equipment that leads to sprinkler activation with no fire present.

Excludes unintentional operation caused by damage to the sprinkler system (740 series).

732 Extinguishing system activation due to malfunction.

733 Smoke detector activation due to malfunction.

734 Heat detector activation due to malfunction.

735 Alarm system activation due to malfunction.

736 Carbon monoxide detector activation due to malfunction.

730 System or detector malfunction, other.

Unintentional system or detector operation (no fire). Includes tripping an interior device accidentally.

741 Sprinkler activation (no fire), unintentional. Includes testing the sprinkler system without fire department notification.

742 Extinguishing system activation. Includes testing the extinguishing system without fire department notification.

743 Smoke detector activation (no fire), unintentional. Includes proper system responses to environmental stimuli such as non-hostile smoke.

744 Detector activation (no fire), unintentional. A result of a proper system response to environmental stimuli such as high heat conditions.

745 Alarm system activation (no fire), unintentional.

746 Carbon monoxide detector activation (no carbon monoxide detected). Excludes carbon monoxide detector malfunction.

740 Unintentional transmission of alarm, other.

Biohazard scare

751 Biological hazard, malicious false report.

False alarm and false call, other

700 False alarm or false call, other.

Appendix B

RMS Incident Type Codes, Descriptions, and Corresponding NFIRS Code.

RMS	Description	NFIRS
700	False call (other than a fire alarm)[c]	700
710	Fire alarm, malicious, mischievous activation, no fire[b]	710
	Fire alarm, malicious activation, no fire[a]	
713	Malicious false alarm made by telephone[c]	713
721	Bomb scare – no bomb[c]	721
730	Alarm system activation due to malfunction[b]	730
	Fire alarm system malfunction, no fire[a]	
731	Sprinkler activation due to malfunction[c]	731
732	Extinguishing system activation due to malfunction[c]	732
733	Smoke detector activation due to malfunction[b]	733
734	Smoke detector activation due to cooking or burnt food[b]	743
	Fire alarm sounded due to cooking or burnt food[a]	
735	Fire alarm sounded due to dust, lack of maintenance, or similar cause[c]	743
736	Carbon monoxide (CO) detector activation due to malfunction[c]	736
740	Unintentional transmission of alarm, other[c]	740
741	Sprinkler activation, no fire, unintentional, incl. testing w/o FD notification[b]	741
	Sprinkler activation, no fire – unintentional[a]	
742	Extinguishing system activation, incl. testing w/o FD notification[b]	742
	Extinguishing system activation[a]	

743	Medical alarm activation, no medical problem	745[d]
744	Sprinkler line break due to freezing[b]	741
745	Alarm system activation (no fire), unintentional[b]	745
746	Heat detector activation due to malfunction[b]	734
747	Sprinkler line break due to mechanical damage[b]	741
748	Carbon monoxide detector activation (no CO detected by FD)[b]	746
749	Smoke detector activation, no fire, unintentional[b]	743
751	Biological hazard, malicious false report[c]	751
752	Detector activation (no fire), unintentional[b]	744
753	Alarm activation due to lightning, no fire[b]	745

[a]Description used only in SMFR database. [b]Description used only in PFPD and SMFRA databases. [c]Description used in SMFR, PFPD, and SMFRA databases. [d](D. Marron, personal communication, April 27, 2010).

Appendix C

Alarm Frequency by RMS Incident Type Code and Description, 2007-2009

Code	Description	2007	2008	2009	Total
700		124	103	82	309
	False call (other than a fire alarm)	124	103	82	309
710		239	191	32	462
	Fire alarm, malicious activation, no fire	200	143		343
	Fire alarm, malicious, mischievious activation, no fire	39	48	32	119
713		3	1	2	6
	Malicious false alarm made by telephone	3	1	2	6
721		1	1	1	3
	Bomb scare - no bomb	1	1	1	3
730		820	409	86	1315
	Alarm system activation due to malfunction	162	19	86	267
	Fire alarm system malfunction, no fire	658	390		1048
731		6	13	14	33
	Sprinkler activation due to malfunction	6	13	14	33
732		1	1		2
	Extinguishing system activation due to malfunction	1	1		2
733		4	14	18	36
	Smoke detector activation due to malfunction	4	14	18	36
734		230	192	48	470
	Fire alarm sounded due to cooking or burnt food	174	152		326

	Smoke detector activation due to cooking or burnt food	56	40	48	144
735		500	345	52	897
	Fire alarm sounded due to dust, lack of maintenance, similar	500	345	52	897
736		51	48	2	101
	Carbon monoxide (CO) detector activation due to malf.	51	48	2	101
740		276	424	26	726
	Unintentional transmission of alarm, other	276	424	26	726
741		17	18	19	54
	Sprinkler activation, no fire - unintentional	8	4		12
	Sprinkler activation, no fire, unintentional, incl. test…	9	14	19	42
742		13	4	3	20
	Extinguishing system activation		1		1
	Extinguishing system activation, incl. testing…	13	3	3	19
743		101	79	87	267
	Medical alarm activation, no medical problem	101	79	87	267
744		11	19	14	44
	Sprinkler line break due to freezing	11	19	14	44
745		26	290	1578	1894
	Alarm system activation (no fire), unintentional	26	290	1578	1894
747		7	2	1	10
	Sprinkler line break due to mechanical damage	7	2	1	10
748		10	4	17	31
	Carbon monoxide detector activation (no CO…)	10	4	17	31

749		71	19	14	104
	Smoke detector activation, no fire, unintentional	71	19	14	104
752		26	2	9	37
	Detector activation (no fire), unintentional	26	2	9	37
753		5	1	3	9
	Alarm activation due to lightning, no fire	5	1	3	9
	Total	2542	2180	2108	6830

Appendix D

Most Frequent False Fire Alarms by Address, 2007-2009

Address	2007	2008	2009	Total
8401 Park Meadows Center Drive	25	5	12	42
4545 S University Boulevard	17	17	4	38
6450 S Boston Street	9	11	14	34
6780 S Galena Street	7	17	9	33
11200 E Orchard Road	14	5	7	26
14400 E Fremont Avenue	9	9	8	26
10101 Ridgegate Parkway	8	7	10	25
9030 Westview Road	10	7	7	24
9395 Crown Crest Boulevard	3	6	15	24
10250 E Costilla Avenue	11	9	3	23
9280 E Costilla Avenue	8	8	7	23
10535 El Diente Court	3	5	13	21
8200 E Belleview Avenue	6	10	5	21
15655 Brookstone Drive	4	7	10	21
9253 E Costilla Avenue	9	3	8	20
10203 Station Way	5	8	7	20
12835 E Arapahoe Road	10	8	1	19
9290 Meridian Boulevard	5	7	7	19
200 Inverness Drive W	4	6	9	19
5655 S Yosemite Street	3	8	8	19

5200 S Quebec Street	3	6	9	18
9100 E Parker Road	4	3	11	18
5445 DTC Parkway	4	8	4	16
6380 S Boston Street	5	5	6	16
199 Inverness Drive W		11	5	16
6300 S Syracuse Way	7	5	4	16
5670 Greenwood Plaza Boulevard	7	5	4	16
10035 S Peoria Street	10	4	2	16
8081 E Orchard Road	14	1	1	16
7686 E Hinsdale Avenue	4	3	8	15
7440 S Blackhawk Street	2	5	8	15
22219 Hilltop Road		12	3	15
7380 S Clinton Street	10	4	1	15
11800 E Oswego Street	7	2	5	14
6535 S Dayton Street	10	1	3	14
8400 E Prentice Avenue	3	6	5	14
5500 S Quebec Street	5	5	4	14
6400 S Fiddlers Green Circle	4	7	3	14
7600 E Caley Avenue	8	3	2	13
8752 S Yosemite Street	9	1	3	13
9257 E Costilla Avenue	4	3	6	13
7007 S Clinton Street	8	3	2	13
10443 E Costilla Avenue	6	5	2	13

7059 S Potomac Street	5	2	5	12
7800 E Orchard Road	7	2	3	12
9155 Park Meadows Drive	6	4	2	12
7075 Shoreham Drive	8		4	12
4620 S Yosemite Street	4	5	3	12
7550 S Blackhawk Street	4	1	7	12
6465 Greenwood Plaza Boulevard	2	4	6	12
9079 E Panorama Circle	7	2	2	11
9250 Crown Crest Boulevard	1	9	1	11
7820 Park Meadows Drive	4	2	5	11
22422 E Mainstreet	3	5	3	11
7100 E Belleview Avenue	4	4	3	11
6855 S Havana Street	2		9	11
9604 E Easter Avenue	3	5	3	11
5150 S Quebec Street	4	5	2	11
9197 S Peoria Street	3	4	4	11
6363 S Fiddlers Green Circle		9	2	11
19600 Clubhouse Drive	2	6	3	11
6025 S Quebec Street		7	4	11
11004 Wildfield Lane	6	3	2	11
6060 S Willow Drive	3	5	3	11
5555 DTC Parkway	5	1	5	11
6200 S Syracuse Way	5	4	2	11

8322 S Valley Highway	4		7	11
6565 S Boston Street	7	2	2	11
9875 Jefferson Parkway	6		4	10
5455 Landmark Place		7	3	10
8100 S Quebec Street	3	5	2	10
10061 Park Meadows Drive	2	3	5	10
6260 S Dayton Street	2	2	6	10
15859 E Jamison Drive	5	2	3	10
7800 S Peoria Street	6	3	1	10
16975 Village Center Drive	4	2	4	10
9697 E Mineral Avenue	2	3	5	10
188 Inverness Drive W	4	2	4	10
6061 S Willow Drive	3	6	1	10
19301 J Morgan Boulevard	5	2	3	10
6651 E Pine Lane	4	5	1	10
19458 E Euclid Drive	3	3	4	10
7400 E Caley Avenue	1		9	10
19650 E Mainstreet	3	6	1	10
8000 E Belleview Avenue	2	2	6	10
19673 Solar Circle			10	10
11755 E Peakview Avenue	1	5	4	10
10111 Inverness Main Street		7	3	10
9785 Maroon Circle	4	6		10

5240 S Ulster Street	3	3	4	10
7150 S Clinton Street	2	5	3	10
9375 Heritage Hills Circle	1	6	2	9
9009 E Arapahoe Road	4	2	3	9
8141 E Arapahoe Road	3	3	3	9
6278 S Troy Circle	5	2	2	9
9100 E Peakview Avenue	4	4	1	9
10472 E Easter Avenue	5	2	2	9
6162 S Willow Drive	6	3		9
16363 E Fremont Avenue	6		3	9
8505 E Orchard Road	2	3	4	9
7510 Parkway Drive	1	3	5	9
19993 E Long Avenue	3	2	4	9
7720 E Belleview Avenue	2	5	2	9
9220 Kimmer Drive	6	1	2	9
7770 S Peoria Street	3	2	4	9
9401 E Arapahoe Road	6	3		9
5335 S Valentia Way	2	3	4	9
5950 S Willow Drive	2	7		9
8310 S Valley Highway	3	3	3	9

Appendix E

Most Frequent Type of Device at Most Frequent Addresses

Address	*Total*
8401 Park Meadows Center Drive	42
Smoke detector	9
4545 S University Boulevard	38
Smoke detector	19
6450 S Boston Street	34
Smoke detector	21
6780 S Galena Street	33
Smoke detector	26
11200 E Orchard Road	26
Smoke detector	13
14400 E Fremont Avenue	26
Manual pull station	5
10101 Ridgegate Parkway	25
Smoke detector	6
9030 Westview Road	24
Smoke detector	13
9395 Crown Crest Boulevard	24
Smoke detector	18
10250 E Costilla Avenue	23
Smoke detector	9

9280 E Costilla Avenue	23
Smoke detector	11
10535 El Diente Court	21
Smoke detector	16
8200 E Belleview Avenue	21
Smoke detector	10
15655 Brookstone Drive	21
Smoke detector	15
9253 E Costilla Avenue	20
Smoke detector	9
10203 Station Way	20
Water flow detector	3
12835 E Arapahoe Road	19
Smoke detector	3
9290 Meridian Boulevard	19
Manual pull station	9
200 Inverness Drive W	19
Smoke detector	9
5655 S Yosemite Street	19
Smoke detector	5
5200 S Quebec Street	18
Manual pull station	8
9100 E Parker Road	18

Smoke detector	13
5445 DTC Parkway	16
Water flow detector	7
6380 S Boston Street	16
Smoke detector	5
199 Inverness Drive W	16
Smoke detector	13
6300 S Syracuse Way	16
Smoke detector	7
5670 Greenwood Plaza Boulevard	16
Water flow detector	6
10035 S Peoria Street	16
Smoke detector	7
8081 E Orchard Road	16
Smoke detector	6
7686 E Hinsdale Avenue	15
Smoke detector	10
7440 S Blackhawk Street	15
Manual pull station	4
22219 Hilltop Road	15
Smoke detector	12
7380 S Clinton Street	15
Smoke detector	3

11800 E Oswego Street	14
Smoke detector	9
6535 S Dayton Street	14
Smoke detector	2
8400 E Prentice Avenue	14
Smoke detector	4
5500 S Quebec Street	14
Smoke detector	9
6400 S Fiddlers Green Circle	14
Smoke detector	5
7600 E Caley Avenue	13
Manual pull station	5
8752 S Yosemite Street	13
Smoke detector	12
9257 E Costilla Avenue	13
Smoke detector	8
7007 S Clinton Street	13
Smoke detector	3
10443 E Costilla Avenue	13
Type of device not classified	2
7059 S Potomac Street	12
Type of device not classified	3
7800 E Orchard Road	12

Smoke detector	10
9155 Park Meadows Drive	12
Smoke detector	4
7075 Shoreham Drive	12
Unknown	3
4620 S Yosemite Street	12
Manual pull station	7
7550 S Blackhawk Street	12
Smoke detector	7
6465 Greenwood Plaza Boulevard	12
Smoke detector	7
9079 E Panorama Circle	11
Smoke detector	1
9250 Crown Crest Boulevard	11
Manual pull station	7
7820 Park Meadows Drive	11
Smoke detector	7
22422 E Mainstreet	11
Smoke detector	5
7100 E Belleview Avenue	11
Smoke detector	4
6855 S Havana Street	11
Unknown	7

9604 E Easter Avenue	11
Smoke detector	6
5150 S Quebec Street	11
Smoke detector	3
9197 S Peoria Street	11
Smoke detector	7
6363 S Fiddlers Green Circle	11
Manual pull station	1
19600 Clubhouse Drive	11
Manual pull station	6
6025 S Quebec Street	11
Smoke detector	3
11004 Wildfield Lane	11
Smoke detector	3
6060 S Willow Drive	11
Smoke detector	6
5555 DTC Parkway	11
Water flow detector	5
6200 S Syracuse Way	11
Smoke detector	8
8322 S Valley Highway	11
Smoke detector	6
6565 S Boston Street	11

Smoke detector	4
9875 Jefferson Parkway	10
Smoke detector	5
5455 Landmark Place	10
Smoke detector	4
8100 S Quebec Street	10
Smoke detector	6
10061 Park Meadows Drive	10
Smoke detector	10
6260 S Dayton Street	10
Smoke detector	9
15859 E Jamison Drive	10
Water flow detector	3
7800 S Peoria Street	10
Smoke detector	5
16975 Village Center Drive	10
Type of device not classified	4
9697 E Mineral Avenue	10
Smoke detector	6
188 Inverness Drive W	10
Smoke detector	3
6061 S Willow Drive	10
Smoke detector	6

19301 J Morgan Boulevard	10
Smoke detector	4
6651 E Pine Lane	10
Smoke detector	8
19458 E Euclid Drive	10
Smoke detector	8
7400 E Caley Avenue	10
Unknown	6
19650 E Mainstreet	10
Smoke detector	9
8000 E Belleview Avenue	10
Smoke detector	3
19673 Solar Circle	10
Heat detector	4
11755 E Peakview Avenue	10
Unknown	2
10111 Inverness Main Street	10
Smoke detector	5
9785 Maroon Circle	10
Sprinkler/water flow detector	3
5240 S Ulster Street	10
Unknown	2
7150 S Clinton Street	10

Smoke detector	4
9375 Heritage Hills Circle	9
Heat detector	1
9009 E Arapahoe Road	9
Smoke detector	3
8141 E Arapahoe Road	9
Smoke detector	7
6278 S Troy Circle	9
Smoke detector	4
9100 E Peakview Avenue	9
Smoke detector	2
10472 E Easter Avenue	9
Smoke detector	3
6162 S Willow Drive	9
Heat detector	1
16363 E Fremont Avenue	9
Manual pull station	3
8505 E Orchard Road	9
Smoke detector	3
7510 Parkway Drive	9
Smoke detector	3
19993 E Long Avenue	9
Smoke detector	7

7720 E Belleview Avenue	9
Smoke detector	5
9220 Kimmer Drive	9
Smoke detector	3
7770 S Peoria Street	9
Smoke detector	5
9401 E Arapahoe Road	9
Water flow detector	3
5335 S Valentia Way	9
Smoke detector	3
5950 S Willow Drive	9
Smoke detector	4
8310 S Valley Highway	9
Smoke detector	6

Appendix F

Example of Future Contractor Documentation of Fire Alarm System Problems

CINTAS
FIRE PROTECTION

Cintas Corporation
11411 E 51st Ave • Denver, Colorado 80239
303-321-0345 • Fax 303-321-1232

Fire Alarm System Deficiency Repair Report

Business ____________________ Building/location ____________________

Street ____________________ Contact ____________________

City & State ____________________ Jurisdiction ____________________

Zip ____________________ Repair Tech ____________________

Phone # ____________________ Date ____________________

Fire Panel	
Panel Manufacturer:	
Model No:	
Software Rev:	

CONDITION OF PANEL UPON ARRIVAL / DEFICIENCY NOTED ON ALARM REPORT TO CORRECT

CORRECTIVE ACTION TAKEN

CONDITION OF PANEL UPON DEPARTURE

Technician Signature ____________________ Date ________

Manager Signature ____________________ Date ________

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