

Smoke Detector Retrofits in Low-Income Multifamily Buildings

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Fires are the third leading cause of unintentional injuries and deaths in U.S. residential buildings, claiming an average of 2,650 lives each year. Annually, 380,000 residential fires cause twice the damage ($US7.8B) as all other building, vehicle and outdoor fires combined. According to the U.S. Fire Administration, residential fire incidence is related to climate, poverty, education and other demographic factors which contribute to improperly used or malfunctioning space heating and electrical equipment, cooking appliances, cigarette smoking, and the absence of operable smoke alarms. With grant funding from the U.S. Federal Emergency Management Agency (FEMA), the University of Nebraska developed a pilot program to 1) identify a retrofit smoke detector capable of sensing both smoldering and flaming fires (e.g. 'dual detection'), and, 2) develop an installation plan that would improve retrofit access and installation efficiency when compared to traditional volunteer programs. Specifically, a graphical information system (GIS) database was used to identify areas of Lincoln with the highest incidence of residential fires; primarily low-income, multi-family housing. Next, site surveys were conducted which determined that roughly 30%-40% of smoke alarms were inoperable; many intentionally disabled because of nuisance (false) alarms. A retrofit program was then developed using a Kidde PI9000 dual-detection technology smoke detector with a visible 'hush' button feature to reduce nuisance alarms and a 10-year lithium battery to improve operability. A total of 3,580 retrofits were achieved by volunteer and direct (mandatory) access installations. Finally, a post-retrofit analysis was conducted to determine the effectiveness of each installation strategy.

Key Words: Residential Fire Safety, Smoke Alarms, Direct Access Installations

Introduction

According to the U.S. Fire Administration (USFA), 390 deaths, 4,050 injuries, and $US1.2B in direct property loss are caused by multi-family residential fires each year (USFA, 2011). Data collected by the Nebraska Department of Health and Human Services (NDHHS) indicates that residential fires are the second leading cause of accidental deaths among children (ages 1-9) in Nebraska from 2003-2007 (NDHHS, 2010). Research conducted by the USFA and the National Fire Protection Association (NFPA) identifies a need for a fire prevention program which addresses the high incidence of multi-family residential fires (Public/Private Fire Safety Council, 2006). In response, a pilot program was conducted from May-Aug, 2011, which utilized a small number of trained, dedicated staff with direct (e.g. mandatory) access to each multi-family unit via landlord, property manager, and/or property owner (e.g. 'property authority'). The effectiveness of this installation plan as well as the dual-detection technology selection was compared to traditional volunteer installation programs using single-detection technology in multi-family residential structures.

Background

U.S. fire departments responded to an estimated 1,348,500 fires nationwide in 2009. These fires resulted in 3,010 civilian fatalities, 17,050 injuries and an estimated $US12.5B in property losses. Residential fires account for approximately 75-80% of all structure fires and are the largest contributor to fire-related property damages, injuries, and deaths. In 2009, there were a reported 377,000 fires involving residential properties, resulting in 2,650 civilian fire deaths, or roughly 85% of all fire deaths for the year. Residential structure fires also accounted for 13,050 (76.5%) of all residential fire injuries as well as an estimated $US7.8B of property loss (Michael J. Karter, 2011). Multi-family structure fires represent 29% of all reported residential fires (Ahrens, 2011), resulting in 390 deaths, 4,050 injuries and $US1.2B of property loss (USFA, 2011). Based on data from the National Fire Incident Reporting System 5.0 (NFIRS 5.0), Smoke alarms were either not present or failed to operate 28.7% of the time for nonconfined fires and 14.1% of the time for confined fires (USFA, 2011). Studies by Fenner (1990); Getz (1979); Munson and Oats (1983); Shaenman et al. (1971) found a positive correlation between fire rates and income/poverty level (Huang, 2009). Istre et al. (2001) found that the lowest median income level (<$US10,000 per year) incurred the highest rate of injury (~ 27.5 injuries per 100,000 population per year). Bukowski et al. (2007) determined that ionization-type smoke alarms were 2.8 times (53 seconds) better suited for detecting flaming fires than photoelectric-type smoke alarms; however, photoelectric smoke alarms responded 1.7 times (27 minutes) more quickly to smoldering fires. Furthermore, Bukowski et al. (2007) determined that dual-detection smoke alarms (photoelectric and ionization detection methods) increased the escape time. As a result, a smoke alarm retrofit program using dual-detection technology was developed to address the inadequacies (and absence) of smoke detectors in low-income multi-family residences.

Methodology

As part of a Federal Emergency Management Agency (FEMA) grant, the University of Nebraska-Lincoln (UNL) partnered with Safe Kids of Lincoln/Lancaster County and Lincoln Fire and Rescue (LFR) to 1) identify populations at greatest risk of household fire and 2) design and implement a smoke alarm retrofit program (*Figure 1*).

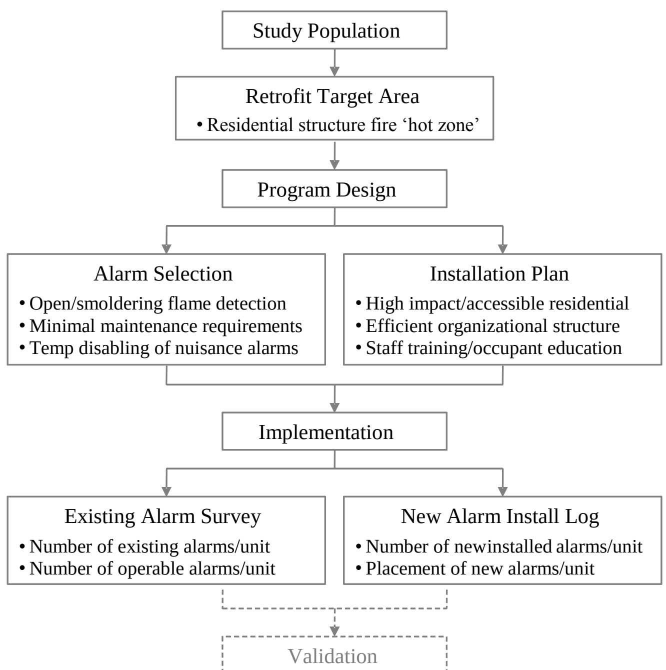

Figure 1. Methodology.

Study Population

Information was first collected from LFR on all types of fire calls (e.g., structure, automotive, property and environmental) in Lincoln, Nebraska during 2007. Fire call data was then superimposed onto city maps to identify clusters of call activity (i.e., a 'hot zone'). Once the hot zone was identified, call data within the hot zone was filtered to include only data corresponding to residential and commercial structure fires. A secondary filter was then applied to isolate residential structures within the hot zone and to establish a retrofit target area. Finally, county property tax assessor records were used to segregate single-family and multi-family parcels within the target area.

Program Design and Development

Once the retrofit target area was defined, program design and development was initiated. Program design and development consisted of two key components; 1) the selection of an effective retrofit smoke detector technology that resolves deficiencies of common household detectors, and, 2) the design of an effective retrofit installation plan. Factors considered in the selection of a retrofit smoke detector included a) the limitations of ionization technology to detect smoldering fires, b) proper detector placement, c) minimal detector maintenance (e.g. battery replacement and testing), and, d) the ability to temporarily silence nuisance alarms without permanently disabling the device. Factors considered in the design of a retrofit installation plan included a) the type(s) of residential buildings to retrofit in the established target area (e.g. single vs. multi-family), b) an effective organizational structure (volunteer vs. dedicated staff), and, c) necessary training and education (installers, property owners/managers, and occupants).

Program Implementation

The implementation of the program design consisted of two additional key elements; 1) a survey of existing smoke detectors, and, 2) the installation of new and improved smoke detectors in each residential unit. Implementation was initiated by LFR representatives contacting prospective participants (e.g. property owners/property managers) within the retrofit target area. A list of prospective participants including participant property address, contact person, contact number, number and size of units (i.e., zero, one, two or more bedrooms) was provided to UNL student-staff who then contacted each prospective participant to schedule an installation. Since the program required a new alarm to be installed in each room designated as sleeping space (e.g. bedrooms), any other room that may be used for sleeping space (e.g. living rooms), and, at least one (1) alarm on each story of the structure (independent of any existing alarms), the number of alarms for each installation was calculated (*Equation 1*). UNL staff then mobilized sufficient materials, equipment and staffing to perform the installation.

$$\sum_{i=0}^{n}[(i+1)k_i] + 1 \qquad (1)$$

Where, the number of bedrooms is represented by (i) and the number of units with (i) bedrooms is represented by (k_i).

Once in the field, student-staff were organized into installation ‘teams’ of two persons per residential unit. One member of the staff was responsible for all administrative duties which included 1) obtaining signed indemnity waiver forms from each property owner/property manager, 2) surveying the number and condition of existing alarms (e.g. number of operable alarms vs. total number of alarms) in each unit, 3) recording the number and placement of new alarms installed in each unit, and, 4) providing educational materials on the safe operation and maintenance of new alarms in each unit. The second member of the staff was responsible for new alarm placement, installation and testing.

Results

Study Population

Fire incidence data collected from LFR on all types of fire calls in 2007 was superimposed onto a city map. Structure fire data was isolated from non-structure fire data then categorized into two groups; residential and nonresidential. Data was then filtered to include only residential fires. Once residential fire incidents were isolated, information from county property tax assessor records were used to further isolate multi-family structures from single-family structures. A 'target area' was then identified as having the highest incidence of fire activity which consisted largely of multi-family and converted structures (~65%). Converted structures are defined as single-family dwellings converted to multi-family dwellings.

The resulting target area was 17 city blocks east-to-west and 11 city blocks north-to-south, or, roughly an area approximately one square mile (*Figure 2*). Utilizing the 2007 structure fire data, it was determined that the city of Lincoln experienced 2.51 structure fire calls per square mile. By comparison, the target area experienced 27 fire calls in a 1.04 square mile area, more than 10 times the city average.

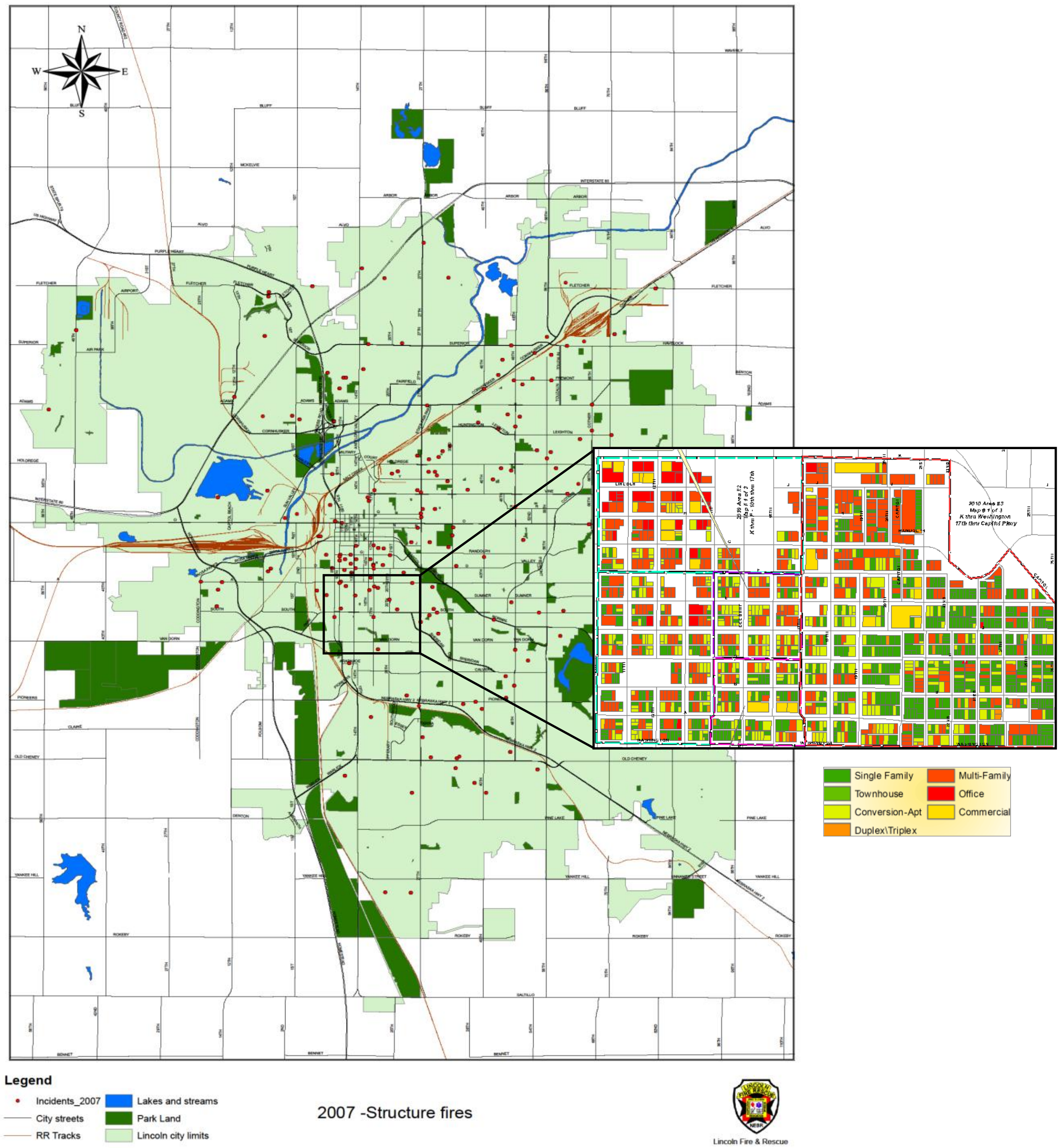

Figure 2: Retrofit target area defined by 2007 structure fire incidence, Lincoln, NE.

Program Design and Development

During the program design and development phase, two key tasks were accomplished including the 1) selection of a smoke detector technology, and, 2) development of an installation plan. The selected retrofit smoke detector technology needed to overcome the limitations of single-detection technology (i.e., solely ionization or solely photoelectric), allow for optimized placement, require little to no maintenance, and allow for temporary silencing of nuisance alarms. The retrofit installation plan was to address the most effective organizational structure, types of residential buildings to retrofit, and the required training for project participants (i.e., installers, property owners/managers, and occupants).

Retrofit Smoke Detector Technology

Currently, two types of detection methods are most often utilized in residential structures; 1) ionization detection, or 2) photoelectric detection. According to the NFPA, "ionization-type smoke alarms have a small amount of radioactive material between two electrically charged plates, which ionizes the air and causes current to flow between the plates. When smoke enters the chamber, it disrupts the flow of ions, thus reducing the flow of current and activating the alarm." In contrast, "Photoelectric-type alarms aim a light source into a sensing chamber at an angle away from the sensor. Smoke enters the chamber, reflecting light onto the light sensor; triggering the alarm," (Ionization vs. Photoelectric, 2011). As shown (Figures 3 and 4), ionization alarms are better suited for detecting fast moving, flaming fires, while photoelectric alarms are more effective for detecting smoldering fires (USFA, 2007). Since both flaming and smoldering fires are common in residential structures, the USFA recommends the installation of both technologies. However, installing two alarms beside each other is not required by code and generally neither practical or cost effective; therefore the use of a single dual-detection smoke alarm (DDSA) is recommended.

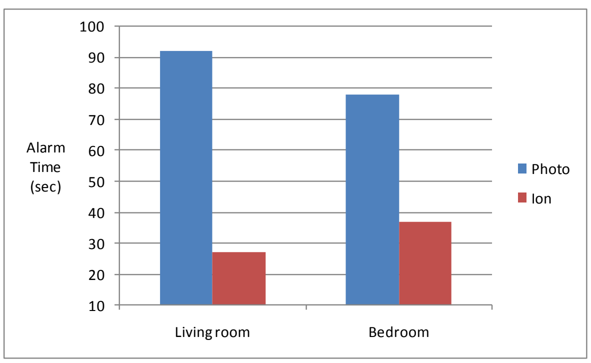

Figure 3: Photoelectric vs. ionization alarm detection times for *flaming fires* in 'small' single-family (e.g. apartments, condominiums, manufactured housing units, and single-family/single-level detached) dwellings.

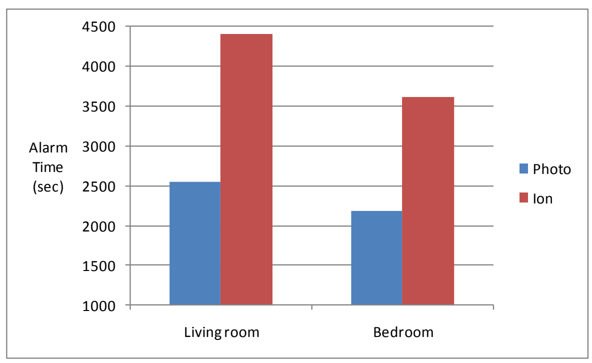

Figure 4: Photoelectric vs. ionization alarm detection times for *smoldering fires* in 'small' single-family (e.g. apartments, condominiums, manufactured housing units, and single-family/single-level detached) dwellings.

Along with the detection technology, another parameter for selecting the retrofit smoke alarm was finding a unit that addressed nuisance alarms. A nuisance alarm is an unwanted activation of a smoke alarm as a result of non-fire aerosols (Lee & Pineda, 2010). The two largest sources of nuisance alarms are cooking (80%) and steam from bathrooms (6%) (Bukowski, et al., 2007). Additionally, ionization detectors were more likely to have nuisance alarms (97%) than photoelectric detectors (3%) according to the U.S. Consumer Product Safety Commission (CPSC). In order to allow the resident to disable nuisance alarms without permanently disabling the alarm, the CPSC recommends installing an alarm with a silencing or "hush" feature. For this project the Kidde Dual Sensor

Nighthawk smoke alarm (model # PI9000) was utilized along with a 10-year, 9 volt lithium-ion battery. The PI9000 was selected because it met the criteria for 1) the detection technology (i.e., the alarm had both ionization and photoelectric sensors), and, 2) the silencing or 'hush' feature for nuisance alarms.

In addition to alarm technology, Bukowski et al. (2007) found that, "alarm placement had the greatest impact on reducing alarm [response] time." In this study, placement locations were tested using three different scenarios; 1) an alarm (1) on every floor level (minimum code requirement), 2) every level plus an alarm (1) in every bedroom (recommended), and, 3) an alarm in every room (exaggerated scenario). In the 'every level' scenario, alarms were placed in the hallways of each level. In the 'every level and bedrooms' scenario, alarms were placed in every hallway and every bedroom. Finally, in the 'every room' scenario, alarms were placed in every room of the structure. The study tested the response time of photoelectric, ionization, dual, and aspirated detectors in each of the scenarios. Comparing the first (minimum) scenario to the second (recommended) scenario, alarm response times were reduced by up to 13 minutes. The third scenario offered no additional reductions in alarm response times. For this project, alarms were placed in every sleeping area (i.e., bedroom) and hallway. Alarms mounted to the ceiling were a minimum of four inches (4 in.) from each sidewall and alarms mounted to the sidewalls were a minimum of four inches (4 in.), but not more than twelve inches (12 in.) down from the ceiling (Wolf, 2010).

Retrofit Installation Plan

The first step in developing a retrofit installation plan was to determine the most efficient and effective staffing method. A volunteer staff was found to be more appropriate when the goal is to canvas a large area in a short period of time (usually one day). In three previous installation 'campaigns', more than 700 volunteers were granted voluntary access by homeowners and renters to install 2,140 alarms. For this project, however, a small, dedicated staff was trained to install smoke alarms in the target area via direct (e.g. mandatory) access to multi-family rental units by property management. Direct access installations by trained staff resulted in near 100% coverage of participating multifamily units within the target area and more consistent alarm placement and installation.

Another consideration related to the retrofit installation plan was developing the training materials necessary to provide 1) installers with the instructions for completing the installation, and, 2) property authorities and unit occupants with effective educational materials on the importance of fire safety, but more specifically, the importance of maintaining functional smoke alarms. Installer training materials were developed as a quick reference rather than a lengthy manual. As a result, installers received a one-page flyer that provided step-by-step instructions of tasks to be completed by the installation team. One of the tasks to be completed by the installers was to provide the property authorities and/or unit occupants with material discussing 1) who is providing the smoke alarms, 2) the smoke alarm instruction manual, and, 3) an informational packet discussing general fire safety practices. Based on the experience during two trial installations, the most effective method for distributing the unit occupant material was to have the property authorities include the information with rent notices. During most installations unit occupants were not present; therefore, would likely not be aware of the informative material provided.

Program Implementation

The program implementation phase consisted of three parts; 1) obtaining a signed indemnity form, 2) recording data on existing smoke alarms, and, 3) recording information on the number and location of new smoke alarms installed. The program was implemented on May 26, 2011 (date of first installation) and concluded on August 26, 2011. A total of 1,440 alarms were installed in 607 units requiring approximately 225 total project man-hours, or, roughly 10-times the efficiency of the previous volunteer efforts. Surveys of existing alarms found that each multi-family unit averaged one alarm each. The majority of existing smoke alarms were installed in the hallway of each unit (76%). Approximately two thirds of all existing smoke alarms were active as verified by the 'test' button, while the remaining alarms were either inactive (but installed), broken, or missing. Once an installation was completed, the indemnity form was filed by the date of installation. The record of existing smoke alarms and installed smoke alarms was then entered into a database (*Figure 5)*. The apparent benefit of the small, trained staff working with property authorities was to ensure access into every unit; however, a variety of factors affect that success rate (e.g., resident changed the existing lock, resident was sleeping, or loose animals prevent entrance). This project achieved an access and installation rate of 96.4% while previous volunteer campaigns achieved access to fewer than 10% of residential units.

Date	Address	Apartment No.	Location and Number of Existing Alarms						Condition of Existing Alarms				Location and Number of Installed Alarms						Notes
			BR	LR	H	K	LA	Total	A	IA	B	M	BR	LR	H	K	LA	Total	
		4	1	1				2	1	1			1					1	
		5	2		2			4	2	2			2		1			3	
26-Aug	1922 K Street	2			1			1	1				2		1			3	
		5			2			2	1	1			2	1				3	
		6			2			2	1	1			1		1			2	
		7			1			1	1				2		1			3	
		11			2			2	1	1			2	1				3	
		12			1			1	1				2	1				3	
		1			1			1	1				2	1				3	
		3		1				1		1			1	1				2	
		10			2			2	2				2	1				3	
		9			1			1	1				2	1				3	
		8			1			1	1				1	1				2	
		15			2			2	1	1			2	1				3	
		14			1			1	1				2	1				3	
		13			1			1	1				1	1				2	
26-Aug	412 S. 24th	5		1	1			2		2			2	1				3	
		9			1			1	1				2	1				3	
		1			1			1		1			2		1			3	
		2			1			1	1				2		1			3	
		3			1			1		1			2		1			3	
		4			1			1	1				2		1			3	
		6			1			1		1			1	1				2	
		7			1			1	1				1	1				2	
		8			1			1	1				2		1			3	
		10			1			1	1				2		1			3	
		607	71	71	496	12	5	655	425	183	22	24	823	481	105	0	17	1426	
			11%	11%	76%	2%	1%	100%	65%	28%	3%	4%							
																		14	* Left with MBA Apartments
																		1440	Total Installed

Figure 5: Sample data entry spreadsheet for existing and newly installed smoke alarms.

Discussion

One goal of this project was to improve the access rate of smoke alarm retrofit installers to low-income multi-family residential units. This goal was accomplished by creating a small group of trained, dedicated staff working directly with property authorities. A second goal was to install the most effective and reliable smoke detection technology commercially available. This goal was accomplished by installing the Kidde PI9000 dual-detection smoke alarm. The dual detection technology will vastly improve the resident's chances of survival in the two most common fire scenarios (i.e., smoldering and flaming fires). The Kidde PI9000 also has a 'hush' feature which allows the residents to silence the alarm when the source is known without permanently disabling the device.
Future activities will include follow-up verification surveys at a representative sample of installation sites to determine the condition and functionality of the dual-technology smoke alarms installed.

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