Messaging and Communication Strategies for Fire Alarm Systems

Building occupants often react slowly, or not at all, when the fire alarm sounds. Many factors contribute to this behavior, including:

- inadequate audibility of a signal or inadequate intelligibility of a voice message;
- uncertainty, misinterpretation, and failure to recognize a fire alarm signal; and
- loss of confidence and trust in the fire alarm system.

This article reviews some of the problems and their causes. Possible solutions are outlined, including those that can be implemented today and those that may be possible in the future. The emphasis is on what technology can and cannot do to address the issues and underlying problems of occupant response to fire alarms.

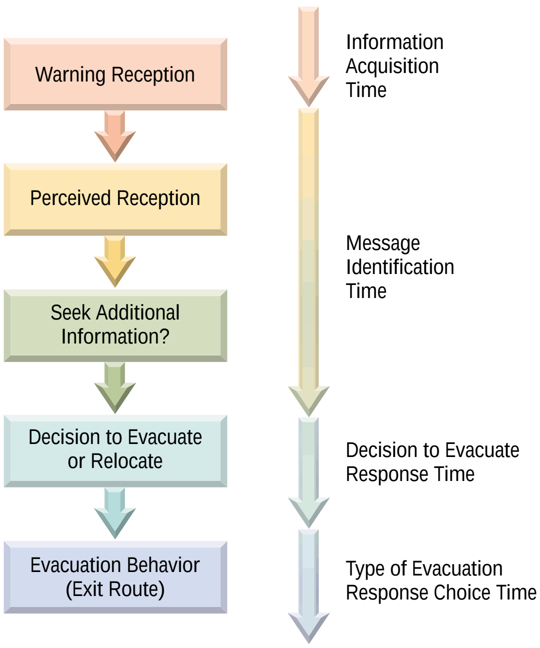

Figure 1. Occupant Decision Process

When a fire occurs in a building, the usual goal is to evacuate the occupants or relocate them so that they are not exposed to hazardous conditions. The exception occurs in occupancies using SIP/DIP[1] (Stay In Place, Defend In Place) strategies. It may also be necessary to alert and provide information to trained staff responsible for assisting evacuation or relocation. Figure 1 shows several key steps in a person's reaction and decision-making process.[2]

Evacuation or relocation cannot begin until the person is aware that there is a problem. Except when there is direct observation by visual, auditory, tactile, or olfactory senses, a fire alarm system is the most prevalent source for alerting occupants. Problems occur when there is inadequate audibility of a signal or inadequate intelligibility of a voice message. For nonvoice signaling, the audibility of tones is well understood and addressed by codes such as NFPA 72.[3] There are methods to measure, analyze, and design for adequate audibility.[4, 5, 6] For voice signaling, it is not possible to measure audibility in the same way as tone signals. The intelligibility of the voice signal is measured in a different way that includes audibility, clarity, distortion, reverberation, and several other important components.[7]

A person can be alerted but not be warned if the signal they hear is not recognized as a fire alarm signal. Codes, such as NFPA 72, require signals to be distinctive and not used for other purposes. When the desired action is evacuation, NFPA 72 also requires that new tone signals use a Temporal Code Three pattern regardless of the sound used – bell, horn, slow whoop, etc., can all use the Temporal Code Three pattern. However, the occupant must be trained to recognize the sound or the pattern as being the fire alarm signal. Thus, there may still be a decision that must be made: "Is that sound a warning of fire?"

Many occupants will seek additional

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information or confirmation of the warning even if they know it is a fire alarm signal. In the absence of other cues, most people do not associate a general fire alarm signal with immediate danger, or they may lack confidence or trust in the fire alarm system. One of the key causes of the lack of confidence is nuisance or unwanted alarms.[8] For the most part, professionally designed and installed fire alarm systems are free of nuisance alarms. One exception is alarms caused by vandals or pranksters. Even alarms during regular testing are perceived as unwanted nuisance alarms to the general occupants of the building. Long testing periods at random times and durations do not allow regular occupants to differentiate testing from real alarms. It is also possible that people "transfer" and rely upon their experience with other alarms, such as smoke alarms in their home, when they experience an alarm in another building. Thus, false and nuisance alarms in one place can affect behavior in other, more stable environments.

Once an occupant is alerted, warned, and confident in the reason for the alarm, they still undergo a thought process regarding whether to evacuate, relocate, or stay in place. If they do decide to move, they must then choose an exit path.

Occupants rarely panic in fire situations.[9, 10] The behavior that they adopt is based on the information they have, the perceived threat, and the decisions they make. The entire decision path is full of thought and decisions on the part of the occupant, all of which take time before leading to the development of adaptive behavior. In hindsight, the actions of many occupants in real fires are sometimes less than optimal. However, their decisions may have been the best choices given the information they had.

Fire alarm systems that only use audible tones and/or flashing strobe lights impart only one bit of information: Fire Alarm. It has long been recognized that environments having complex egress situations or high hazard potentials require occupant notification systems that provide more than one bit of information.[11] To reduce the response time of the occupants and to effect the desired behavior, the message should contain several key elements.[9, 12] These include:

- Tell them what has happened and where.
- Tell them what they should do.
- Tell them why they should do it.

There does not seem to be any research that has tested actual message content to determine the best way to inform occupants. The problem is that each building and each fire are unique. Messaging is further complicated by the need to give different information to different people depending on their location relative to the fire, their training, and their physical/mental capabilities.

In the United States, most codes use a message strategy that warns occupants on the fire floor, floor above, and floor below. They may be told to leave the building or to relocate three or four floors below their current level. This requires only one "channel" of messaging. The fire alarm system decides which floors get the message (receive the channel) based on the origin of the fire alarm initiating device. Other designs may utilize a second channel to broadcast a different message to other, nonaffected occupants. This may be done to warn them to prepare to accept relocation of occupants from other areas or to allay any anxieties caused by seeing fire apparatus and personnel or other occupants leaving. Even though the message is different, the same three key elements are required.

If the fire alarm system only knows that a waterflow alarm has been activated for the 16th floor, it cannot direct occupants to one exit versus another more remote from the fire. As the resolution of input to the fire alarm increase, so can the resolution of output. Resolution, and hence information content, can be increased by the use of more fire alarm initiating devices, such as addressable smoke detectors and by splitting sprinkler systems with waterflow alarms serving smaller, distinct areas. Multichannel systems can then send specific messages directing some occupants to certain stairs and telling others to move horizontally or to stay in place.

As the number and resolution of inputs to the fire alarm increase, the complexity of the output matrix (programming logic) and number of output channels increase also. Because fires are so complex, it is possible that the automated system response could tell occupants to move in a direction that places them in a more dangerous situation. This occurred during the fire at the Dusseldorf airport.[13] Messaging strategies must include provisions for manual override and for changes based on the real dynamics of the emergency. The use of operators who have access to information and are trained to make decisions and broadcast appropriate messages can reduce the likelihood of error.[14] The information sources can include more than just the fire alarm – for example, CCTV, energy management systems, and security sensors. The National Electrical Manufacturer's Association (NEMA) is sponsoring a research program at NIST that is investigating the use of multiple sensor data to show fire department personnel the origin and real progress of a fire.[15] The system could also use the real sensor data in a model to predict possible changes in conditions. The same research program is investigating a common panel interface as is NFPA's National Fire Alarm Code Task Group on User Interfaces.

When the message delivery mode is by voice communication, an Emergency Voice Alarm Communication System (EVAC) is most often used. Even when voice communication is not required by code, it should be considered because of its higher success rate in motivating people to move.[16] The cost of an EVAC system is not any greater than tone-only systems for moderately sized projects and may be less costly for large projects. The actual crossover point depends on many factors. Designers should explore the costs and benefits of voice signaling for most projects before assuming that a tone-only system is more economical. For example, circuit size and capacity are greater for voice systems. Also, voice systems use speakers that have adjustable power taps allowing adjustment of system loudness after installation. A tone-only system would require adding or eliminating appliances to adjust audibility.

Paging zones →				Bsmt speakers and strobes	G floor speakers and strobes	1st floor speakers and strobes	2nd floor speakers and strobes	3rd floor speakers and strobes	4th floor speakers and strobes	5th floor speakers and strobes	M floor speakers and strobes	6th Connector floor speakers and strobes	7th Connector floor speakers and strobes	S floor speakers and strobes	Connector elev. pent. speakers and strobes	6th floor speakers and strobes	7th floor speakers and strobes	8th floor speakers and strobes	9th floor speakers and strobes	10th floor speakers and strobes	11th floor speakers and strobes	12th floor speakers and strobes	Penthouse 1N speakers and strobes	Penthouse 1S speakers and strobes	Penthouse 2N speakers and strobes	Penthouse 2S speakers and strobes
	Floor	**Device/Input** s - smoke h - heat	**Qty**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**
27	Bsmt	s/h detection	1	●	●																					
28	G	s/h detection	8	●	●	●																				
29	1st	s/h detection	8		●	●	●																			
30	2nd	s/h detection	6			●	●	●																		
31	3rd	s/h detection	4				●	●	●																	
32	4th	s/h detection	6					●	●	●																
33	5th	s/h detection	5						●	●	●	●														
34	M Level	s/h detection	12							●	●	●	●	●												
35	6th Connector	s/h detection	2							●	●	●	●													
36	7th Connector	s/h detection	3							●	●	●	●	●	●											
37	S Level	s/h detection	9								●		●	●		●										
38	Conn. Elev. Pent.	s/h detection	0										●		●											
39	6th	s/h detection	9											●		●	●									
40	7th	s/h detection	6													●	●	●								
41	8th	s/h detection	1														●	●	●							
42	9th	s/h detection	4															●	●	●						
43	10th	s/h detection	6																●	●	●					
44	11th	s/h detection	6																	●	●	●				
45	12th	s/h detection	7																		●	●	●	●	●	●
46	Penthouse 1N	s/h detection	0																			●	●		●	
47	Penthouse 1S	s/h detection	1																			●		●		●

System Outputs
Occupant Notification & Information

Evacuation zone for ground floor smoke detection (rows 28, columns A–C highlighted).

Evacuation zone for simultaneous M level and 6th fl. Connector smoke detection. (rows 34–35, columns G–K highlighted).

Figure 2. Sample Input/Output Matrix (partial).

Messaging and communication strategies also require attention to installation and programming details. For example, stair towers, elevator lobbies, different fire zones, and, in some cases, different smoke zones require separate notification appliance circuits (NACs) if it is desired to send different channels of information to different spaces.

Early in the planning process, the designer should list all areas where it might be desirable to provide a discrete message. Each of these areas is a paging zone. Depending on the size and hazards present, a single paging zone may be served by more than one notification appliance circuit (NAC). When more than one circuit is used, they must be programmed to act as a single paging zone. The designer then prepares an input/output matrix to show how paging zones are grouped into evacuation zones when certain inputs (initiating devices) are received. A sample matrix is shown in Figure 2 with paging zones and evacuation zones highlighted.

The designer of the messaging strategy must determine which initiating devices trigger which messages. Should a waterflow switch serving the hallway trigger the same message as the waterflow switch serving the apartments on the same floor? Should a smoke detector in an exit stair tower trigger any automatic message at all? One jurisdiction requires smoke detectors in stairs to activate the alarm sequence as if they were on that floor. So, a smoke detector on the 10th floor of the stair would send a message to the 9th through the 11th floors plus in the stair tower. This will not give occupants accurate information about the fire or about their best course of action. Communications in stairs should be manual only, not automatic, and only when there is a need to reassure or change occupant behavior. Communication between occupants in hallways and stairs is an important part of their ability to obtain and exchange information and confirm their behavioral choices.[8]

While an EVAC system is the most common method of communicating information to occupants, it is not the only method. Research has shown that text and graphical messaging greatly enhance occupant movement during evacuation and relocation.[2] The message delivery can be via large screens used in sports arenas or by small LCD display or CRT information kiosks located throughout a property.

The importance of instilling occupant confidence in message reliability cannot be overemphasized. Messaging and communication strategies instill confidence when they consistently provide truthful and accurate information. When a fire alarm system experiences one or two nuisance activations per year and no real alarms, it is 100 percent untrue to the general occupants. In addition to reducing false and nuisance alarms, there are other ways to increase system accuracy and occupant confidence. One way is to always follow up any unwanted alarm by communicating to the occupants the reason for the alarm and, if possible, what is being done to prevent further occurrences. If the system has manual voice capability, use it to convey this message immediately following resolution of any unwanted alarm. In some cases, it may take hours or days to arrive at a root cause for an unwanted alarm. The fire department or site management should immediately share what is known: "A smoke detector in the elevator lobby on the 7th floor alarmed but there was no fire. We are investigating possible causes and will let you know the outcome of that investigation as soon as possible." Of course, it is important to keep this promise and follow up.

If every unwanted alarm is followed up with a voice message, the perceived system error is reduced from 100 percent to 50 percent. Further reductions are possible by using the voice system for more than just fire alarm announcements. Combination paging, announcement, and EVAC systems breed familiarity and instill confidence in the message content. Combination systems require special attention in the planning and design phase to ensure either strict code compliance or compliance with the intent of the code. This includes factors such as operational integrity and precedence, emergency power, survivability, and tamper resistance.

The more any messaging system is used, whether voice, text, or video, the more familiar the operators and the occupants become with it. During any fire incident, repeated truthful communications that correlate with what the occupants are experiencing instill confidence in the messaging. If the occupants are told "There is smoke in Stair A. Evacuate using Stair B", and they smell smoke in Stair B, they will question whether they got the right message or not. Occupants should be told what has happened and where, what they should do, and why they should do it. "There is a fire on the 14th floor. There is heavy smoke in all of Stair A. Evacuate using Stair B. There is some smoke in Stair B. Stair B is safe to use and is the fastest way out."

Messaging strategies require careful coordination with the fire service. During any real fire and during most unwanted alarms, the fire service is the prime user of the system. Their use of stairs, elevators, and cross-connect corridors affects the choice, wording, and delivery of messages to occupants.

Another element of successful messaging and communication is "setting the stage" or preparing the listener. In theaters and concert halls, the show should be stopped to get occupants' attention. A sudden, dramatic change in the environment removes their focus and prepares them to receive new information. The Notification Appliances chapter of NFPA 72 permits, but does not require, the fire alarm system to control and reduce ambient noise. Where it is not possible to have such control or make such drastic changes, an alert tone is often used to precede any voice message. One idea is to use an alert tone that almost everyone who has ever used a telephone is familiar with. It is called the Vacant Code (VC) Special Information Tone and is a standard signal used in the telecommunications industry to indicate that a message is to follow.[17] It uses three tones at different frequencies, which helps persons who have a partial hearing impairment, as many do. It's a signal familiar to many people when they dial a wrong number or forget an area code. We are "trained" to know by experience that a message will follow. This SIT consists of three ascending tones: 985.2 Hz for 380 milliseconds (ms), 1370.6 Hz for 274 ms, and 1776.7 Hz for 380 ms.

Fire alarm systems by themselves cannot be expected to do everything necessary to ensure that occupants are warned, take action, and leave before they meet untenable conditions. However, through careful planning, design, installation, implementation, testing, and use, messaging and communication systems can greatly reduce occupant response times and help to generate the desired occupant behavior.

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Editor's Note – About This Article

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