Occupant Behavior and Evacuation during the Chicago Cook County Administration Building Fire

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ABSTRACT: The fire in the unsprinklered 36-story Cook County Administration Building on 17 October 2003, resulted in six fatalities and left a dozen people injured. A human behavior study using a questionnaire survey was used to gain an understanding of the existing conditions in the building prior to the fire, past training and occupant awareness of the evacuation procedure, and to document the occupants' behavior and evacuation on the day of the fire. Results show that although 85% of the survey respondents had received fire safety training, only 20% understood the phased-evacuation plan. There were only around 250 occupants still in the building at the time of the fire; half of them used an elevator to exit. Unfortunately, the combination of locked doors that prevented re-entry on to the floors from the stairwells and fire fighting activity taking place from the stairwell, contributed to this tragedy. Various means to improve fire safety management in high-rise office buildings are discussed in this article.

KEY WORDS: evacuation, human behavior, office building, high-rise fire.

INTRODUCTION

STUDYING OCCUPANT BEHAVIOR during a fire incident is one of the best ways to learn about the impact of human factors on the circumstances and outcome of a fire. The survivors of a fire are prime witnesses; they can describe their perception of the event, their interpretation, and their reactions at the time of the fire. A human behavior study was conducted following the Cook County Administration Building Fire at 68 West Washington in Chicago, IL, USA to enhance our

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understanding of conditions in the building prior to the fire, past training, and occupant awareness of the evacuation procedure. Further, information on the conditions encountered in the building at the time of the fire, the response of different occupants during the event, and the rationale behind their decision helped to develop a complete picture of the occupant experience. The data obtained through this human behavior study provides valuable and unique information to building managers, fire prevention officers, and code officials.

The Cook County Administration Building fire on Friday, 17 October 2003, resulted in six fatalities and left a dozen people injured. Although such a catastrophic fire is rare in a high-rise office building, it was essential to study this event in great detail to learn from this tragedy and to minimize the likelihood that such an event should ever recur.

This human behavior study [1] was conducted by the National Research Council Canada (NRC) as part of an overall investigation and evaluation effort (see [2] for a complete report) commissioned by the State of Illinois, USA.

The human behavior study conducted by NRC had two main objectives. The first objective was to document the occupants' behavior and evacuation on the day of the fire. Occupants who were in the building at the time of the fire can provide information on the cues they perceived, their responses, evacuation movement, and their estimated time at key moments. A comprehensive understanding of the conditions in the building at the time of the fire, as perceived by the occupants, should help clarify some of the decisions made by the occupants and help understand the outcome of this fire.

The second objective of this study was to obtain information from all building occupants on their training and fire safety experience prior to the fire. Information was gathered on past drills and exposure to fire alarms and messages from the Public Address (P.A.) system. Particularly interesting were the occupants' perceptions about the building's evacuation procedure, and how these perceptions differed from the official evacuation plan.

THE FIRE INCIDENT

On 17 October 2003 at approximately 5 p.m., there were four employees and a client in Suite 1240 on the 12th floor of the Cook County Administration Building (see the floor plan in Figure 1). One of the employees smelled smoke and mentioned it to her co-workers; according to her watch, it was 4:57 p.m. She moved around to investigate and discovered a yellow-orange flame on the top shelf of a bookcase located inside a storage room that always had its door open. This employee told others,

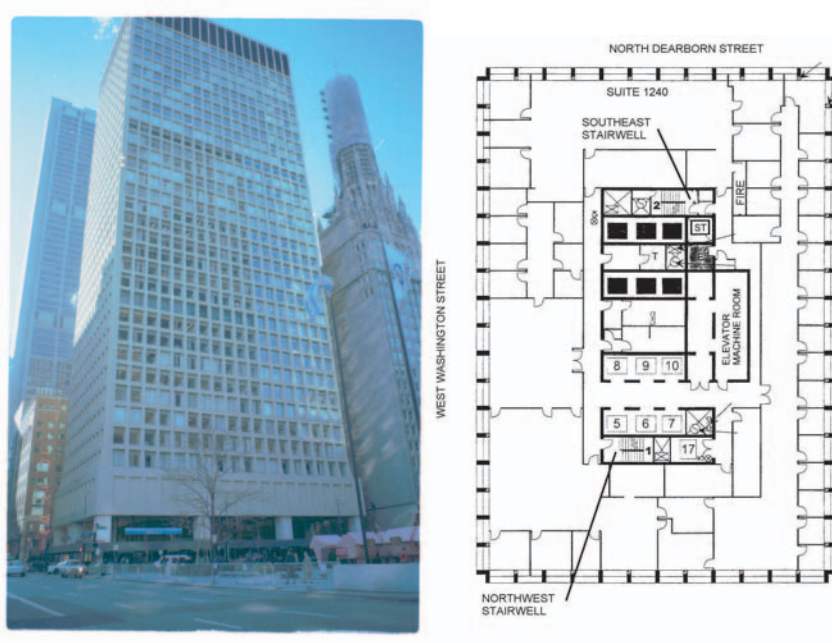

Figure 1. *Cook County Administration Building photograph and floor plan of 12th floor. (The color version of this figure is available online.)*

'there is a fire in there'. She gathered her personal belongings and left. She took the elevator down to the ground floor lobby with five other people from other offices on the 12th floor who were leaving for the day.

Meanwhile, other employees in Suite 1240 had a quick look inside the storage room. One employee called the building emergency number to report the fire. The three remaining employees secured files and money in a safe, took their personal belongings and left the office with the client. By that time, the smoke was down to head-level in the office. They took the elevator to the ground floor lobby.

At the same time, in the ground floor lobby, at the Security Desk, one of the security officers heard an alarm from the Fire Alarm Control Panel; he opened the panel at 5:00:19 p.m. Using a portable radio he contacted the building engineer and advised him of a 5-star alarm and its location. Another security officer in the lobby answered the call from a female occupant on the 12th floor about the fire at 5:01:45 p.m.

A few seconds later, the building engineer arrived by the stairwell on the 12th floor to investigate. Using his key he unlocked the door of Suite 1240. Upon opening the door, he was knocked down by a back draft.

Stumbling down the corridor in thick black smoke, he instructed the front desk by radio to call 911 and to evacuate the 12th floor using the P.A. system. A security officer placed the call to 911 at 5:02:29 p.m.

The first P.A. message was issued to 'evacuate the 12th floor' at 5:03:15 p.m. The building engineer radioed in shortly thereafter, giving instructions to evacuate the two floors above and the five floors below the 12th floor. Almost immediately after this message he gave orders to evacuate the whole building. At the same time, a female guard, who worked in another area of the building, came over to the Security Desk and began making P.A. messages at 5:05:05 p.m. advising occupants to evacuate the entire building by using stairs not the elevator. Similar messages were repeated every 15 s over a period of 2 h.

Fire fighters from the Chicago Fire Department arrived at the building at 5:06:29 p.m. According to the fire department personnel, fire fighters took the elevators to the 9th floor and then walked up the Southeast stairwell to investigate; they soon found the fire on the 12th floor. Fire fighters then connected a hose line to the building's standpipe system on the 11th and 9th floors and advanced up to the 12th floor using the Southeast stairwell. They attacked the fire from the stairwell but were unable to advance further than the door from the stairwell vestibule because of the quantity of heat and smoke.

During that period occupants began evacuating the building using the two stairwells and elevators. An undetermined number of people used the Southeast stairwell. According to some accounts, there was no smoke or only light smoke when occupants initially entered that stairwell. As they moved downward, however, the smoke became heavier. When some people reached the 12th floor, they met fire fighters who were preparing to advance hose lines into the 12th floor; according to their accounts, these fire fighters instructed them to go back up the stairwell.

Occupants descending from above the 12th floor turned around to go back up the stairs. As they moved upward, the smoke conditions deteriorated and they attempted to re-enter the building. However, the doors from the stairwell were locked and they were unable to re-enter. In trying every door on the way up, one of the evacuees found a door, which was not locked, on the 27th floor. He opened the door and forced a wooden wedge under the door to hold it open. He then yelled down the stairwell to the other occupants that he had found an open door on the 27th floor. Several occupants managed the climb up the stairs to the 27th floor and move on to the Northwest stairwell; however, some were unable to continue up and lay down with their faces near the cracks of the doors, attempting to breathe clean air. There were several cell phone calls made to 911 by trapped occupants in the stairwell.

At 6:39:30 p.m., a progress report was provided by the fire department stating that the fire was out. Primary and secondary searches were completed and a final top to bottom search was initiated. During this search, fire fighters found six fatalities in the Southeast stairwell near the 20th to 24th floors as well as several injured occupants.

BUILDING AND OCCUPANT DESCRIPTION

The Cook County Administration Building was constructed in 1964. The 36-story high office building housed mainly Cook County Offices as well as a few other organizations. The area of each floor was approximately 1579 m^2. The central core common to all floors contained 16 passenger elevators as well as the two stairwells called Southeast and Northwest, which traveled the full length of the building (see Figure 1). The Southeast stairwell had a smoke tower using a natural ventilation shaft. The doors between the stairwell and the tenant were permanently locked from the inside; once a person entered the stairwell they had to travel the full length of the stairwell to the ground floor lobby to exit. Re-entry was not possible on any floor and no access to the roof was available. The locked doors in the stairwells did not unlock upon alarm activation or power failure; these doors could be unlocked only with a master key. The building engineer held one master key and another was kept in the security office on the 3rd floor.

There was a structure adjacent to the main building, called the Bustle, which ran from the ground floor lobby area to the 9th floor. This structure added 557 m^2 of office space. The Bustle had a stairwell running from the 9th floor to the lobby, which also had doors locked in the same fashion as those in the main structure.

In October 2003, there was no sprinkler system in this building except for the ground floor lobby area and the Day Care Center located on the first (ground level) and second floor of the Bustle. The building was equipped with smoke and heat detectors that were connected to the Fire Alarm Control Panel located in the lobby. The building fire alarm could only be manually activated from the Fire Alarm Control Panel. There were no pull-stations in the building. Live P.A. messages could be broadcast in specific areas or throughout the building using a handset in this same Fire Alarm Control Panel.

The overall occupancy of the Cook County Administration Building was approximately 2000 during office hours. Except for the children of the Day Care Center, the building was occupied by office workers. A few occupants had visible disabilities, and were using a wheelchair or a cane. It is expected that some might have had visual or hearing impairments as

well as health conditions that could impede their safe evacuation during an emergency. The exact number of occupants with limitations is unknown.

At the time of the fire, because it occurred at approximately 5:00 p.m. on a Friday (many County employees typically finished work between 3:30 and 5:00 p.m.), the building was not at its full capacity. It is estimated that around 250 occupants were in the building at the time the evacuation order was issued. This estimate is based on security video recordings from cameras located on the ground floor lobby.

DESCRIPTION OF THE HUMAN BEHAVIOR STUDY

Following a building visit a few days after the fire, it was decided that it would be very difficult to specifically identify the individuals who were in the building at the time of the fire and arrange to meet with them all for a face-to-face interview. Therefore, the study was conducted through a survey distributed to all the building occupants.

Since the objective of the study was to develop recommendations related to the fire safety education and training received by occupants prior to this fire, it was appropriate to survey the whole population of the building and not only the occupants who were in the building at the time of the fire. By interviewing the whole building population, information could be gathered from a much larger pool of respondents, allowing general conclusions to be drawn regarding the state of the respondents, training and experience. Consequently, the survey was developed in two parts: the first section questioned occupants on their past evacuation drills and training received at the building, and the second section, to be completed only by occupants who were on location at the time of the fire, dealt specifically with the occupant's experiences during the event [1].

In total, 1862 surveys were distributed to employees. There were 551 surveys returned which represents a return rate of 30%. Among the returned surveys, 462 were from occupants who worked in the building but were not present at the time of the fire. The remaining 89 responses were from occupants who were in the building at the time of the fire and provided information on their evacuation experience.

RESULTS OF THE HUMAN BEHAVIOR STUDY

Among the 551 surveys received, all the occupied floors were represented. The mean number of respondents per floor was 19.18 (standard deviation or SD = 9.21). For analysis purposes, the building was divided into three levels: a 'Lower Level' including the ground floor lobby through the 11th floor, a 'Mid Level' from the 12th to the 21st floor, and an 'Upper Level'

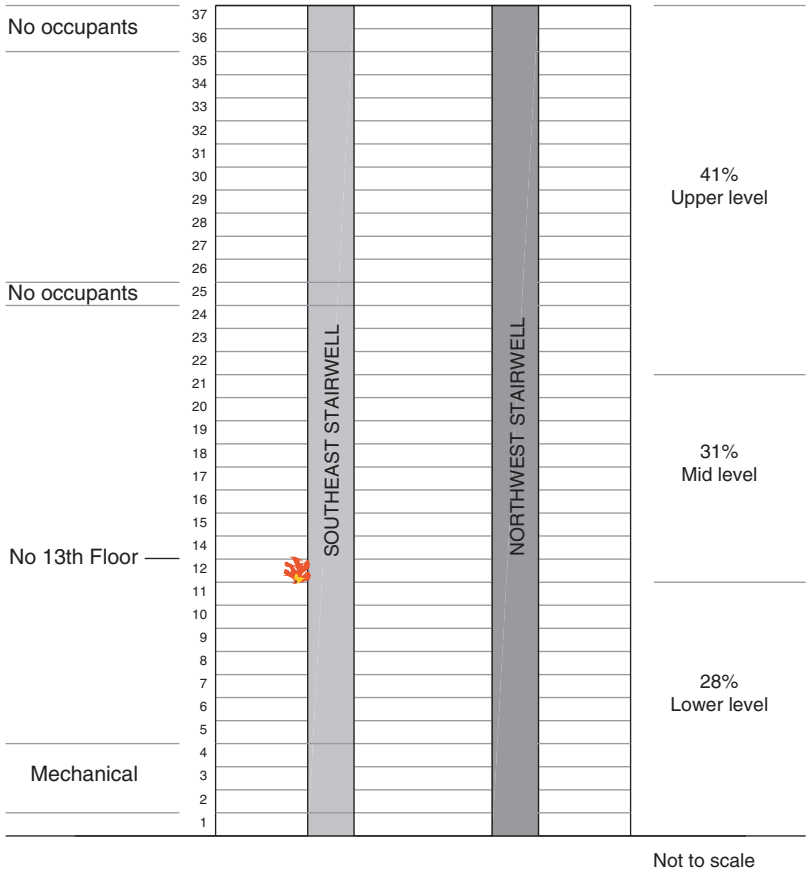

Figure 2. *Distribution of respondents. (The color version of this figure is available online.)*

from the 22nd to the 37th floor. These division points were chosen due to the fire location (12th floor) and the location of the sky lobby (the 22nd floor). The building had six 'high-rise' elevators that served the 22nd floor sky lobby and those floors above it. This distribution also divides the building into three roughly equal segments, as shown in Figure 2. The Lower Level included 28% respondents, 31% were from the Mid Level, and 41% were from the Upper Level.

The length of time respondents had worked in the building ranged from one month to eight years, when the building first began to be used by Cook County. The mean time spent in the building was 4.1 years (SD = 2.1).

Among the respondents, 74% had heard the building's fire alarm in the past. This factor was strongly associated with the length of time employees

had worked in the building. Analysis of the frequency data with a chi square test (χ^2) revealed a significant effect, where $p < 0.05$, at the calculated degree of freedom (df) ($\chi^2 = 94.654$, df = 7, $p = 0.000$). Those who had spent more time in the building were more likely to have heard the alarm.

The building was equipped with a P.A. system that could provide live instructions to occupants. Messages from the P.A. system were reported as 'clear' by 46%, 16% said the messages were 'unclear', and 38% reported messages to have been of 'varying clarity'.

The respondents were asked if they had participated in an evacuation drill in the last 2 years. The vast majority, 85%, reported having participated in a fire drill. There was a strong relationship between the length of time the respondent had worked at the building and whether they had participated in a drill ($\chi^2 = 158.511$, df = 7, $p = 0.000$). Those who had been working in the building for a longer period of time were more likely to have participated in an evacuation drill.

The respondents were then asked to describe their behavior during the fire drills. They were asked if they moved to another floor, and if they had evacuated the building completely. The responses were significantly linked to the respondent's location in the building. Those who worked in the Upper Level were more likely to move to another floor than those who worked in the Mid Level, who were in turn more likely to move to another floor than those who worked in the Lower Level ($\chi^2 = 39.276$, df = 6, $p = 0.000$). Conversely, those who worked in the Lower Level were more likely to evacuate the building during a fire drill than those who worked in the Mid Level or the Upper Level ($\chi^2 = 46.037$, df = 6, $p = 0.000$). There were 10 respondents who reported that they 'never' moved to another floor, and 'never' evacuated the building. Of these respondents, six had a mobility impairment and required assistance to evacuate; in a drill situation they never left their floor. There were 39 respondents (7%) who identified themselves as having a limitation that could prevent them from participating in a drill. Of these, half (19 people) had a mobility limitation such as requiring crutches, cane, or a wheelchair, 40% had a health limitation such as asthma, heart disease, or rheumatism, 5% had a temporary limitation such as an injury or pregnancy, one had a hearing limitation, and another had a visual limitation.

The building stairwell had been used by 75% of the respondents. There was no significant association between the floor on which an employee worked and the use of stairs. There were 52% of respondents who were aware that the stairwell doors would lock behind them if they used the stairwells, among them 6% added, that they thought or were told that in case of emergency the doors would either unlock automatically or would be unlocked by security officers. The other 48% were not aware that

Figure 3. *Photograph of the sign on all stairwell doors. (The color version of this figure is available online.)*

the door would lock behind them upon stairwell entry. There was, however, a sign on every stairwell door stating that the doors were locked, as shown in Figure 3, but the sign text may have led to different interpretations.

In an open-ended question, respondents were asked to describe what they believed to be the building's evacuation procedure in October 2003. Responses were broad, and were categorized into 18 categories. These frequencies of response should not be summed since the same respondent could mention one or several categories as presented in Table 1.

The official evacuation plan outlined in the '2003 Building/Tenant Fire Safety Plan' called for employees, under the direction of floor fire wardens, to await instruction from the building's P.A. system. Evacuation was only to take place on those floors directly threatened by the fire, which were defined as the fire floor, two floors directly above the fire, and five floors below the fire. These floors were to be announced, alarms on these floors were to sound, and the occupants were to relocate to another floor at least five floors below the fire level. Complete building evacuation was not mentioned in the fire plan; it did mention that additional floors could be evacuated at the discretion of the Fire Safety Director or the Fire Department. In the case of evacuation, an outside meeting place located at least 1.5 blocks from the building was identified, at which occupants were to assemble and be accounted for by fire wardens. The plan also included the designation of two 'searchers' per floor, one male and one female, who were to inspect restrooms, storage areas, and other 'areas isolated from the main areas of the office' to ensure that everyone had left the floor.

The evacuation plan implied that in an evacuation situation, most building occupants were expected to engage in 'protect-in-place' activities. The approach of protect-in-place as an alternative to evacuation was developed in response to numerous fire deaths in high-rise buildings that occurred in corridors and stairwells, far from the area of the origin of fire.

Table 1. Evacuation procedures as understood by respondents.

Behavior	Respondents who mentioned	Percent of respondents who mentioned (of 420) (%)
Use stairs	315	75.2
Move to ground level	161	38.4
Follow P.A. instruction	108	25.8
Follow warden or fire department instruction	84	20.0
Go down a few floors	81	19.3
Do not use elevator	56	13.3
Search floor	51	12.2
Other (wait for aid, help disabled, etc.)	43	10.3
Go up a few floors	35	8.4
Meet outside at a designated area	30	7.2
Mark empty office doors with a post-it note	29	6.9
Close doors	22	5.3
Don't know	20	4.7
Believe stairwell doors will unlock in an emergency	17	4.1
Protect-in-place	14	3.3
Use stairs to move to the 22nd (sky lobby) floor	6	1.4
Move to elevator lobby of their floor	3	0.7
Use elevator	2	0.5

In most cases, the victims would have remained safe had they stayed where they were instead of attempting to evacuate [3].

Overall, the official evacuation plan, which called for a phased evacuation of the adjacent eight floors and protect-in-place activities from all other occupants, seems to have been poorly understood by the respondents. Only 3.3% of the respondents mentioned some activities related to protect-in-place such as 'go down 2 floors if the fire is on your floor or else stay put.' The most frequently mentioned behaviors were to 'use stairs' (75%) and 'move to ground level' (38%), which might be a reflection of the training received rather than the official plan in place. Additionally, 26% of respondents indicated that they should 'follow P.A. instruction,' 20% that they should 'follow warden or fire department instruction,' and 19% that they should 'go down a few floors.' These behaviors were the primary focus of the evacuation plan, yet only a fifth to a quarter of respondents understood these to be a part of the proper procedure. A close analysis of the evacuation procedure described by the respondents reveals that only about 20% seem to understand the official evacuation plan.

Respondents on Location at the Time of the Fire

An analysis of the video recordings from the lobby security video cameras shows that a total of 223 occupants were seen leaving after 5:05 p.m. This is not an absolute number of evacuees since one back door was not covered by camera; one of the tapes had an interruption of 160 s and some of the recording was very grainy and it was difficult to distinguish between security officers, who exited and re-entered several times, and the evacuating occupants. Of the 223 evacuees seen on the tapes, 59 left from an elevator and 10 walked directly from the Day Care Center ground floor exit.

Among the surveys returned, 89 were from respondents who were in the building at the time of the fire, which represents 40% of the occupants who were seen leaving the building on videotapes. Among the 89 respondents, 68% were female and 32% were male. The mean age of the respondents was 42.3 years (SD = 10.7).

In the initial moment of the incident, the 89 respondents were evenly located throughout the building on different floors: 34% of the respondents were located on Low Level floors, 33% were located on Mid Level floors, and 33% were located on Upper Level floors. This distribution of the respondents provides a very good overview of the condition throughout the building as perceived by the respondents.

Recognition and Response

The majority, 38% of the respondents first became aware that there was something unusual occurring by hearing a P.A. message, 28% became aware because they saw or heard others, 24% became aware because they smelled something, and 10% became aware because they saw something.

The respondents were asked the time at which they initially became aware that something unusual was happening. There was a marked tendency to round off the various reported times, therefore, the time analyses should be used with caution. Twenty-five percent said they became aware of the incident at 5:00 p.m. For those who became aware of the incident via a P.A. message, the time ranged from 4:50 p.m. to 5:15 p.m., with most responses being at 5:05 p.m.

The respondents were asked what they thought was happening in the initial moments. Of the 84 respondents to this question, 30% thought that there was a fire or emergency, 29% of the respondents thought that there was a minor problem, 29% did not know what was happening, and 12% thought that it was a false alarm or a drill.

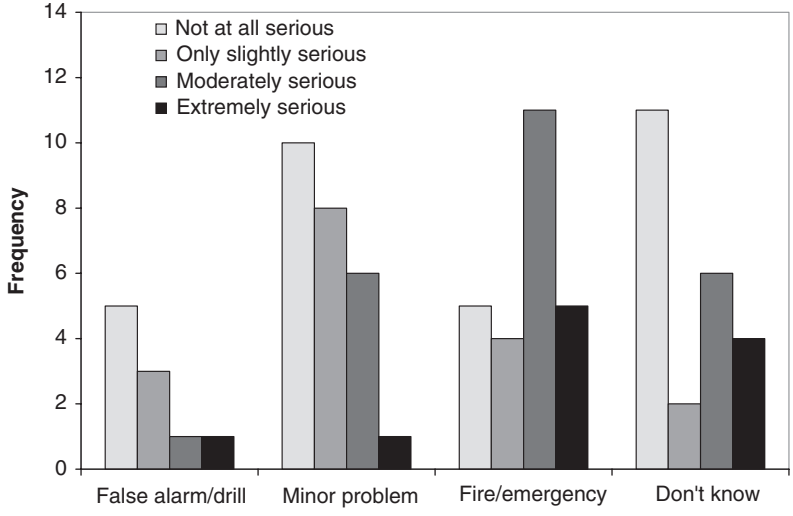

Figure 4. *Initial feelings about the situation.*

When asked 'How serious did you believe the situation to be at first?' respondents were provided with four categorized answers: 'Not at all serious', 'Only slightly serious', 'Moderately serious', and 'Extremely serious'. It appears that initially, 36% thought that the situation was 'Not at all serious', 28% thought that it was 'Moderately serious', 22% thought that it was 'Only slightly serious', and 14% thought that the situation was 'Extremely serious'. Analysis showed that the respondents' initial assessment of the situation significantly affected how serious they thought the situation was ($\chi^2 = 8.975$ df $= 3$, $p = 0.030$). This is shown in Figure 4, where frequency represents the number of respondents.

When they became aware that something unusual was happening, 44% of the respondents were working, 19% were on their way out of the building, 16% were preparing to leave for the weekend, 12% were on the phone, and 9% were in discussions with others. Most of the respondents, 73%, were with others when they became aware of the incident.

A few questions addressed the office conditions as experienced by the respondents from the time of their initial awareness of the incident to the time at which they left their floor. The smell of smoke or fire was reported by 71% of the respondents. Respondents located on the Mid Level floors were more likely to smell smoke ($\chi^2 = 14.144$, df $= 2$, $p = 0.001$). Among the respondents, 79% of the Lower Level (22 of 28), 89% (24 of 27) on the Mid Level, and 44% (12 of 27) on the Upper Level floors smelled smoke. The smell of smoke seemed to have been much more prevalent on the

floors right above and below the fire floor compared to the floors above the 22nd floor. Some respondents (36% or 28) saw smoke on their floor. No relationship was found between seeing smoke and floor level ($\chi^2 = 4.210$, $df = 2$, $p = 0.122$). However, there were many occurrences of seeing smoke by those who were located on the Lower and Mid Levels.

The building's fire alarm system could only be activated from either the fire alarm panel at the security desk in the lobby or in the maintenance area on the 3rd floor; there was no pull-station or automatic activation of the system. The building fire alarm was not activated, however, four respondents heard a local fire alarm on floors 10, 14, and 16.

Two-thirds or 66% of the respondents heard one or several P.A. messages; whereas 34% did not hear any message. No relationship was found between floor level and the likelihood of hearing a P.A. message ($\chi^2 = 4.933$, $df = 2$, $p = 0.085$). However, more respondents on the Mid Level and Upper Level floors heard a P.A. message(s) than those on the Lower Level floors.

Although the procedure called for the first message to be transmitted only to the occupants on the affected floor, the first message advising of a fire on the 12th floor was apparently transmitted throughout the building. On the 12th floor, where the fire started, none of the respondents heard a P.A. message; all occupants on that floor had possibly left by the time the message was issued.

Of the 54 respondents who heard a P.A. message, 58% heard one message, 28% heard two messages, 11% heard three messages, and one individual heard five messages. Among the respondents who heard a message, 66% said that the first message they heard was to the effect of 'evacuate the 12th floor'. Another 17% stated that the message was unclear, 15% said that the first message they heard was 'evacuate the entire building', and 2% said that the message was 'evacuate using only the stairs'.

For respondents who heard the message 'evacuate the 12th floor', 22% (8 of 36) started their evacuation although they were not on the 12th floor. Their motivation to evacuate was the P.A. message in addition to the perception of fire cues. The other 78% who heard the message to 'evacuate the 12th floor' started discussing the situation with co-workers or were getting ready to leave. Those who heard a first message to the effect of 'evacuate the entire building', quickly put away work related papers, grabbed personal belongings, and started to evacuate.

After hearing a first message, respondents noticed that 29% of the other people around them were evacuating, 24% were determining if they needed to evacuate, and 21% were preparing to evacuate, 14% didn't know or didn't notice what others were doing, and 12% of the other people were doing nothing.

Of those 22 respondents who heard a second message, 65% reported that it was 'evacuate the entire building', 17% heard 'evacuate the 12th floor', two heard 'evacuate using only the stairs' and two stated that the message was unclear. After hearing a second message all occupants started to evacuate except two respondents who continued working since they heard 'evacuate the 12th floor', which they felt did not pertain to them since they were on other floors. One of these respondents left after hearing a third message, which said 'evacuate the building' and the other one left because co-workers urged him to leave.

Before starting to evacuate, 39% or 32 respondents attempted to obtain information from one or several sources. For instance, 14 contacted their co-workers to obtain information and 13 called family or friends. Eight respondents called or attempted to call their department switchboard/receptionist and six called building security. Of these six respondents, one was informed that there was a fire, one was given direction to evacuate and three were given direction to evacuate by the stairs; one used the Northwest stairwell, one used the Southeast stairwell, and one used the elevator. Before starting to evacuate, two respondents called or attempted to call 911.

When asked what factors motivated their decision to evacuate their floor, 88% of respondents provided one or more motivations for starting their evacuation. The motivations were coded under five factors as presented in Table 2. The respondents could mention one or several motivating factors, and in fact one third of the respondents mentioned more than one factor. Overall, most of them mentioned that the motivating factor was the perception of 'fire cues,' i.e., the smell or sight of smoke or flames. In second place was hearing a message(s) from the P.A. system, followed by being motivated to evacuate by other people. Another motivating factor was that it was time to leave for the day anyway. Finally, a small number were motivated to evacuate because of a concern for their safety or the potential danger.

Table 2. Motivation to start evacuation.

Motivation to evacuate	Respondents who mentioned	Percent of respondents who mentioned (of 78) (%)
Perceived fire cues	37	47.4
Heard P.A. message	24	30.8
Interaction or behavior of other occupants	21	26.9
Was leaving for the day	19	24.4
Concerned for own safety or danger	8	10.3

Most of the respondents on the Lower and Mid Levels were motivated to evacuate by fire cues, the P.A. message, and other people's behavior (see Figure 5). On the Upper Level floors, however, the primary motivations were that they were leaving for the day and because they heard a P.A. message. Only three Upper Level respondents mentioned fire cues as a motivation to evacuate. For the building as a whole, it should be noted that only eight respondents mentioned their own safety or the imminent danger to be a motivating factor to evacuate.

The time to start evacuation, also called pre-movement time, is the time elapsed between the moment a person becomes aware that something unusual is happening and the moment that person starts evacuation movement. The time to start their evacuation was estimated by 81% of the respondents. Once aware of the incident, the mean pre-movement time reported was 5.0 min (SD = 4.7). The shortest reported time to start was immediately, and the longest reported time was 30 min. Most respondents, over 80%, are totally sure or fairly sure of their estimated pre-movement time because they looked at their watch or a clock. Three respondents took more than 15 min before deciding to leave. One of these three, who became aware that something unusual was happening because a co-worker heard a P.A. message, kept on working for 15 min before deciding to leave. The second respondent, who also took 15 min to begin evacuation, became aware that something unusual was happening at 5:05 p.m. but stated that

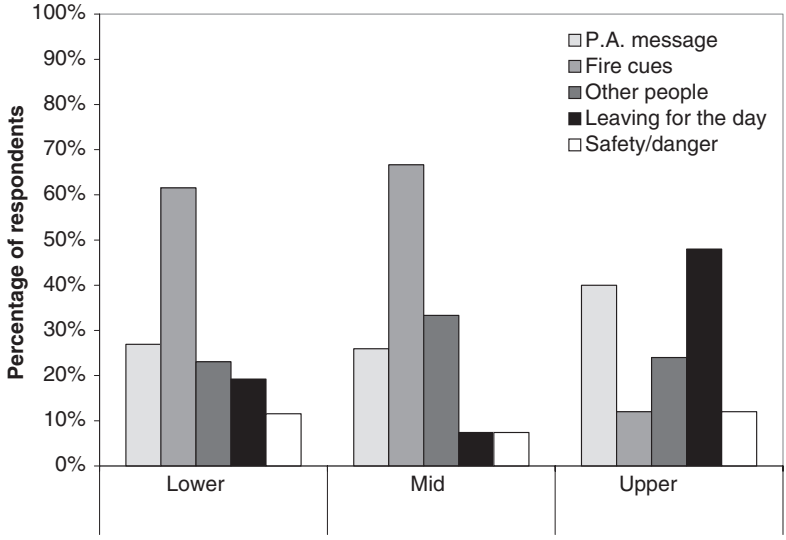

Figure 5. *Motivation to evacuate by floor level.*

they 'were not aware that something was wrong.' These two respondents did not at first feel that the situation was serious at all. The other respondent, who took 30 min to begin evacuation, became aware that something unusual and moderately serious was happening at 5:00 p.m. A co-worker mentioned that they smelled smoke, however, the respondent continued to talk with someone in an office. The respondent finally decided to leave the 7th floor office because of smoke.

When asked if they left because someone told them to leave, 45% of the respondents gave a positive response. When asked who told them to leave, the survey provided six categories. Thirty-eight percent reported that they were told to leave by a 'Co-worker'; 24% by a 'Supervisor'; 22% by the 'Message'; 16% were told to leave by multiple persons (a combination of the above mentioned choices); and no one reported being told to leave by a 'Fire warden' or 'Fire fighter'. When they started to evacuate, 77% of the respondents were in a group of two or more. Half of the respondents waited for others before they left.

Respondents were asked if they took anything with them when they left. Three categories were provided: 'Personal effects', 'Job related material', and 'Emergency equipment'. Majority of the respondents, 71%, took personal effects, 7% took both personal effects and job related material, 4% took job related material, and 4% took emergency equipment when they left; 14% specified they took nothing. For respondents who took personal or job related items, they took what they regularly took home for the weekend. Further, it can be seen from the security videos that most people exiting the building were wearing jackets. The approximate outside temperature at the time of the fire was 55°F (13°C). In addition, respondents from the Day Care Center located in the Bustle building, mentioned taking phone lists of the families of the children.

Evacuation Movement

The respondents were asked to explain their evacuation movement, the means they used to leave, the conditions they encountered during evacuation, and the travel time to exit the building.

In total, 51% of the respondents attempted to use an elevator to evacuate. Such a high percentage of respondents attempting to use the elevator was rather unexpected considering that the building evacuation procedure and training recommended the use of stairwells and prohibited the use of elevators during a fire emergency. Further, as shown in Figure 6, signs located directly above the elevator call button, on every floor, indicated that 'In Case Of Fire Elevators Are Out of Service.' It should be noted that this information was not entirely correct, since the elevators did not

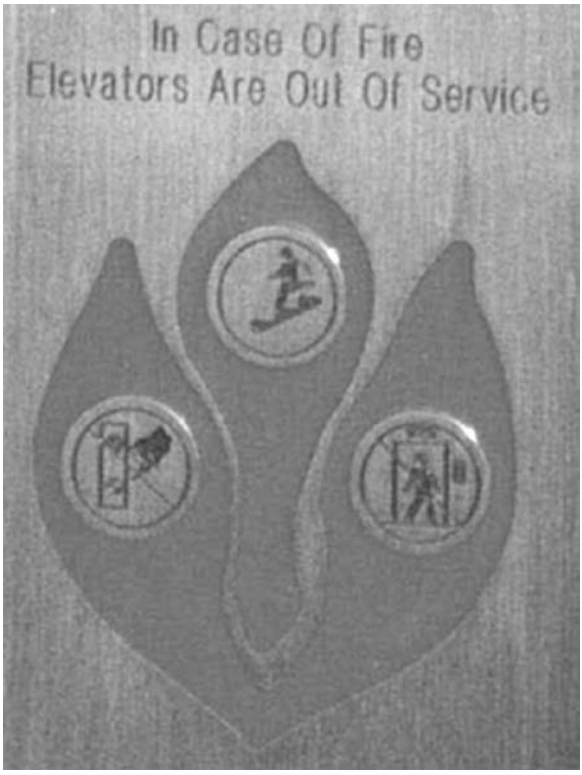

Figure 6. *Photograph of the elevator sign.*

have an automatic recall function and would continue to operate in a fire situation until manually or electronically recalled.

The high use of elevators to evacuate the building appears to be related to the time of the day – many people were leaving for the day and the weekend. Of those who mentioned that their motivation to evacuate was because they were leaving for the day, 95% (18 of 19 respondents) attempted to use the elevator. Of these 18 persons, most were aware that something unusual was happening; 11 heard a P.A. message, 7 smelled smoke, 2 saw smoke, and 1 respondent heard a fire alarm on their floor prior to evacuating by elevator.

Among the respondents who mentioned using the stairs as the appropriate evacuation procedure, 54% attempted to use the elevator to evacuate. Four individuals who reported the procedure as using the stairs also mentioned 'you should not use the elevator during an evacuation,' but did attempt to use the elevator to evacuate. No statistical relationship was

found between those attempting to use elevators and their floor level ($\chi^2 = 3.339$, df $= 2$, $p = 0.188$). A greater percentage, however, of those located on higher floors attempted to use the elevator; 62% of those located on upper floors versus 38% of those located on the lower floors attempted to use the elevator. Of those who used the elevator, all but one came out of the elevator on the ground level floor.

There were seven respondents present in the building at the time of the fire who indicated that they had a limitation, which would prevent them from participating in an evacuation. Five of these respondents described their evacuation from the building; three used the elevators and two used the stairwells. One of the respondents using the elevator was in a wheelchair, and was accompanied to the ground by an aide. The second had asthma and the third, arthritis. Both respondents who used the stairwell had arthritis.

Of the 34 respondents who used one of the two stairwells to evacuate, 65% used the Northwest stairwell whereas 26% used the Southeast stairwell; the Southeast stairwell was the one where fatalities were found. Sixty-one percent of the respondents chose their stairwell because it was the closest, 25% because it was the one they used during training, and 14% because they felt that it was the safest evacuation route.

There were three respondents who evacuated from the Bustle section of the building. They were Day Care workers, and were in charge of approximately 30 children at the time of the fire. This group was on the first (ground level) and second floors, and they evacuated through the Day Care center directly to the street.

The respondents were asked to describe the conditions in the stairwell as they entered, using check boxes for the presence or absence of 'Full lighting,' 'Emergency lighting,' 'Smoke,' 'Smell,' and 'Water.' All of the respondents stated that there was full or emergency lighting. Smoke was noticed in both stairwells upon entry. In the Southeast stairwell, 78% noticed smoke whereas 64% stated that there was smoke in the Northwest stairwell. The smoke was described as 'light' by all of the respondents in entering either stairwell, except for one respondent who described the smoke as 'dark/black,' but this respondent was not clear about which stairwell he/she used. An unusual smell was noticed in both stairwells. In the Southeast stairwell, 87% of respondents noticed an unusual smell versus 70% in the Northwest stairwell. All respondents described the smell as 'smoke/burn/fumes,' except for two who indicated smelling 'plastic.' When the respondents first entered either of the stairwells, no one noticed water.

When asked, 'How crowded were the stairs when you entered the stairwell?,' the survey provided four categorized answers: 'I was alone,'

'A few others around,' 'A crowd but moving well,' and 'Very crowded and slow.' In the Southeast stairwell, 89% responded that there were 'A few others around,' and 11% responded that there was 'A crowd but moving well.' In the Northwest stairwell, 48% responded that there were 'A few others around'; 39% responded that there was 'A crowd, but moving well'; and 13% responded 'I was alone'. No one responded 'Very crowded and slow'. The security video recordings show that approximately 154 occupants used the stairwell to evacuate; this would represent a light density considering the stairwell layout and the different times at which respondents entered the stairwells.

The respondents were asked to describe the conditions in the stairwell while they were walking down. Again, they had to check boxes for the presence or absence of 'Smoke', 'Flames', 'Water', and 'Unusual noise'. Smoke was noticed in both stairwells. While they moved in the Southeast stairwell, 78% responded that they saw smoke. Smoke was generally noticed from the 32nd floor down to the 10th. In the Northwest stairwell, 70% of the respondents noticed smoke. Generally, the smoke was seen from the 26th floor to the ground level lobby floor; however, most responses indicated the 12th and 14th floors. In both stairwells, 66% stated that the smoke was light whereas 33% stated that the smoke was dark and black. No respondent reported seeing flames in the stairs. The three respondents who noticed water used the Northwest stairwell. While walking down the stairs, the respondents who used the Southeast stairwell noticed 'unusual noises' such as 'footsteps' or 'voices'. Two respondents who used the Northwest stairwell also noticed 'unusual noises'; one heard 'an alarm' and the other 'a fire fighter'.

While walking down the stairs, 17% attempted to re-enter the building on a floor. Three of the respondents were in the Southeast stairwell and three were in the Northwest stairwell. When asked, 'Why they attempted to re-enter?', the reason provided by respondents who used the Southeast stairwell was, 'because of smoke'. For the respondents in the Northwest stairwell, the reasons were 'crowding', 'blockage', and 'searching for other people'.

In the Southeast stairwell, three respondents, who started on the 31st and 32nd floors, turned back. These three respondents seem to have descended to around the 15th floor. Two people turned back because of smoke and the other because of an open door. These three respondents were successful in climbing back up and re-entering on the 27th floor to use the Northwest stairwell. None of the respondents in the Northwest stairwell reported turning back. However, those who tried to re-enter on another floor were unsuccessful.

Three of the respondents made phone calls during the time they were in the stairwell; two called friends and one called a relative. The respondent who called a friend from the 15th floor, obtained information that the building was on fire.

In the Southeast stairwell, 33% of the respondents did not meet anybody during their descent while 67% encountered 1–10 people in the stairs. Four of these respondents met people going up the stairwell. In the Northwest stairwell, 95% of the respondents encountered people in the stairs; some met one person, whereas others encountered more than 30 individuals. From these accounts, it appears that neither stairwell was very crowded and the counter flow in the Southeast stairwell did not impede the overall evacuation process. Five people, who used either stairwell, mentioned that they were injured. Four of them experienced smoke inhalation and exhaustion.

The respondents reported the time they took to travel to safety once they had decided to leave their floor. It took the respondents an average of 5.9 min (SD = 6.3) to travel to safety. The shortest reported time to travel was 0 min as this respondent was located on the ground level floor and the longest reported time was 25 min from respondents who started from the 33rd floor. All the respondents who took under 1 min to travel used the elevator, with the exception of the one respondent on the 1st floor. The wide range of travel times can be partially attributed to the fact that some respondents used the elevator and others used the stairwell to evacuate.

The mean travel time to the ground estimated by respondents who used the elevator was 1.3 min (SD = 0.7). For respondents from the Lower Level floors the estimated mean travel time was 1.2 min (SD = 0.4), 1.7 min for the Mid Level floors (SD = 1.0), and 1.2 min for those from the Upper Level floors (SD = 0.5). It should be noted that elevators serving the Upper Level floors could run without stop from the 22nd floor down to the lobby.

Of the respondents who evacuated using the stairs, the majority (43%) took between 2 and 5 min to travel to safety; however the mean time to reach the exit at ground level was 8.9 min (SD = 6.6). The mean is high due to four respondents (located on floors 7, 27, and 33), who took more than 15 min to descend the stairwell. The longest time using the stairwell was 25 min by respondents from the 33rd floor. Three of these four respondents who took the longest time used the Northwest stairwell. The other respondent, on the 7th floor, did not specify which stairwell was used, but mentioned that it was less smoky than the other one. The mean time to reach the exit at ground level was 5.8 min (SD = 5.5) for those on the Lower Level, 8.1 min (SD = 3.8) for those on the Mid Level, and 15.0 min (SD = 7.5) for those on

the Upper Level. As could be expected, it appears that the longer the distance to travel down the stairwell to the ground floor lobby, the longer was the time required to reach the exit at ground level.

The respondents were asked if they were assisted to leave the building. Most respondents, 79%, left the building 'unassisted'; 17% were 'assisted by co-worker(s)'; two respondents were 'assisted by other', and one respondent was 'assisted by fire fighter(s)'. Three respondents were physically helped to evacuate. Seventeen percent of the respondents stated that they physically helped others to evacuate. The reasons for helping included 'handicapped persons', 'children', 'fear', 'it was their job to assist', as well as 'smoky conditions'. Respondents helped by: 'pushing wheelchairs', 'walking with others', 'holding the door', 'carrying others' belongings', and 'checking for people'.

At some point during their evacuation, 44% of the respondents moved through smoke. When asked how far they moved through the smoke, three people reported that they moved 30 ft (9.1 m), two people moved 20 ft (6.1 m), one moved 12 ft (3.7 m), while another moved 200 ft (61 m). In terms of floors, some respondents mentioned moving through 1 floor of smoke while others mentioned moving through 27 floors of smoke. Some respondents also mentioned not being able to see at all while others mentioned being able to see clearly.

Total Evacuation Time

An analysis of the evacuation times was conducted to determine the mean evacuation times for respondents irrespective of whether they used the stairs or the elevator.

The total evacuation time for each respondent was calculated by adding the pre-movement time to the travel time [4,5]. The total evacuation times ranged from 2 to 37 min. Overall, the average total evacuation time was 11.5 min (SD = 8.8). When using the elevator, the average total evacuation time was 5.8 min (SD = 3.1). When using the stairwell, the average total evacuation time was 15.1 min (SD = 9.3). Please note that these times are as estimated by the evacuees themselves.

Video cameras positioned on the ground floor lobby captured 223 occupants exiting the building from 5:00 p.m. till 5:35 p.m. These exiting occupants are shown as a continuous line in Figure 7. The frequency, or the number of occupants observed, is shown on the right axis.

Also represented in Figure 7 is the exiting times of the survey respondents which is calculated by adding the respondent-estimated pre-movement time to the travel time from the time of initial awareness that something unusual was happening. The respondents exiting times range

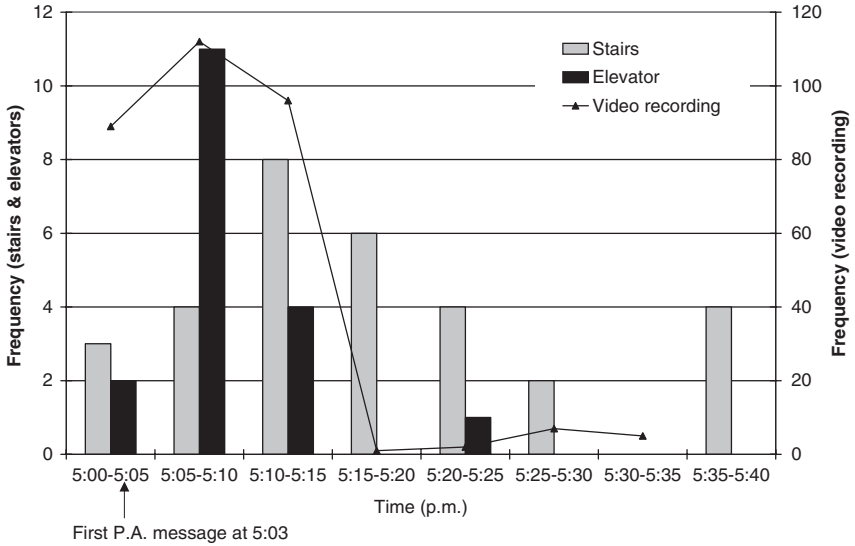

Figure 7. *Number of occupants exiting the building between 5:00 and 5:40 p.m.*

from 5:00 p.m. to 5:40 p.m., in 5-min intervals. Exiting times are represented with bars for respondents that used the elevator or the stairs. The frequency, or the number of respondents, is shown on the left axis.

The two sets of data presented in Figure 7, the video recordings and the respondent-estimated times, show a similar pattern. It can be seen that a large proportion of the building occupants evacuated within 5 to 10 min of the first P.A. message issued. Initially, more occupants evacuated using the elevators while evacuees who used the stairs spread over a longer period of time.

DISCUSSION AND CONCLUSIONS

The results of this human behavior study of the Cook County Administration Building fire show that although 85% of the overall respondents to the survey had received fire safety training, through drills or other means, they were ill-prepared to face an actual fire. During drills, most had moved down the stairwell to another floor or down to the ground floor, and several had heard the building fire alarm and knew their floor fire warden, but essentially what respondents had learned during training was that in case of a fire they would receive instructions. Only approximately 20% of the respondents understood that a phased-evacuation plan was the official procedure for this building. The official procedure

was that occupants two floors above and five floors below the fire floor were expected to move up or down to a safe floor. This phased-evacuation implied that only occupants on eight floors would evacuate while occupants on other floors would protect-in-place.

During drills, the occupants were told to move down to a specific floor where someone would be standing in the stairwell to ensure re-entry on that floor. During these drills, it was reported that a security officer would be holding open the door on a lower floor, allowing them to re-enter the building. The building's security manual instructed the security officers to report to the stairwell during an evacuation and unlock the doors. However, a number of officers were not aware of this procedure and only the security supervisor had a key that would unlock the stairwell door. At the time of the fire, there was no supervisor on duty and the key was located in the security office on the third floor. These factors made the emergency procedure virtually impossible to follow.

To have 85% of building occupants who have received fire safety training is good. It is difficult to achieve a higher percentage because there will always be new employees or people who are absent when the training takes place. The information learned on the procedure to follow during an emergency is of more concern here as, despite the training received, most occupants and staff did not understand the evacuation procedure. Every building should develop a Building Emergency Action Plan (BEAP). This plan should identify the different means of egress for the building, the fire safety features, the procedure to follow in case of different types of emergencies, and the procedure for occupants with different capabilities. The BEAP should not only describe the evacuation procedure since, in some cases, evacuation is not the best course of action; there are some situations when using the elevator is appropriate and other situations that call for moving to an area or floor of refuge. The BEAP should provide a variety of scenarios as well as the different alternative actions that occupants can consider. This plan should be made available to all the occupants and should be used during training. Some key elements should be posted in the building as a reminder.

Overall, 75% of the respondents had experience using the stairwell in the building and half the respondents knew that the stairwell doors would lock, although a few thought the doors would unlock during an emergency. Forty eight percent of the respondents were not aware that stairwell doors would lock behind them upon entering the stairwell. This finding is of great concern. It implies that despite signage and training, respondents did not have the vital knowledge required for effective decision-making during an emergency in that building.

Findings from the respondents who were in the building at the time of the fire show that 38% of them learned of the event by hearing a P.A. message. Among the respondents who heard the message 'evacuate the 12th floor', 22% decided to evacuate immediately, although they were not on the 12th floor. For others, the message to evacuate the 12th floor, was the onset of a 'milling process', as they started moving around their office to discuss with co-workers the content and meaning of the message and what they should be doing. For over a quarter of the respondents, seeing others milling and commenting on the P.A. message or the smell of smoke was the initial means by which they became aware of the event. Unfortunately, the P.A. system was not used at its fullest during that fire: the same limited message to 'evacuate the building using the stairs' was repeated over and over. There was no Incident Management System in place which would have provided clear lines of responsibility, authority, and accountability and means to ensure liaison with the responding emergency personnel. During an emergency, it is essential that as new information comes through, messages with precise instructions be delivered to the building occupants.

In the initial moments, the respondents were divided on the nature of the problem being a minor problem or a fire emergency. The respondents who were closer to the fire floor were, however, more likely to judge the situation as 'extremely serious' since they could perceive fire cues.

For several respondents, the first P.A. message was the trigger to leave for the day since it was the right time anyway. Less than 2 min later, when a second P.A. message was issued, respondents who were still on their floor milling with others, preparing to leave, or still working, started their evacuation movement. The time respondents took to start their evacuation movement after their initial awareness was judged by evacuees to be approximately 5 min.

Respondents who were already in the 'leaving for the weekend' mode seemed committed to this task; they continued leaving as they normally would, using the elevator to leave the building after hearing a P.A. message or perceiving some fire cues. Some of these elevator users heard the P.A. message to the effect of 'use the stairs, not the elevators' and some specified in their description of the evacuation procedure that 'you should not use the elevator'. Despite that information, and the fact that there was a sign at the elevator call button on every floor stating 'In Case Of Fire Elevators Are Out Of Service', half the respondents admitted using the elevator to evacuate on that day. It should be noted that the elevators did not have an automatic recall function. More respondents from the Upper floors used the elevator to evacuate. The movement time for respondents using the elevator to egress was less than 1 min to reach the ground floor lobby. Contrary to common knowledge in fire safety, the use of elevators to egress

during this fire may have saved the lives of these people. This finding shows that occupants are prepared to use elevators during an emergency; particularly if by pushing the call button the elevator arrives and the doors open: the elevator works which seems to be an indication that it is 'OK' to use it.

Respondents with disabilities had received some training and instructions, and were to wait with a designated assistant on their floor. At the time of the fire, the assistant was not necessarily on location but other co-workers took on this task. This demonstrates, as in many other fires, the altruistic behavior of people during emergencies. Occupants with disabilities evacuated rapidly with co-workers using the elevator, while some mobile disabled people were helped down the stairs. It is fortunate that mobility impaired occupants did not enter the stairwell to wait for rescuers, as they would have been unable to exit the stairwell and could have been exposed to lethal conditions.

Half the respondents followed the instructions received through the P.A. messages to evacuate via the stairwell. Following the P.A. instruction was exactly in accordance with the evacuation procedure on which they had been trained. Upon entering the Southeast or Northwest stairwells, conditions appeared acceptable: the stairwells were well lit, and while some mentioned smell of smoke or the presence of light smoke, these conditions did not appear immediately threatening. The later fire cues acted as a confirmation that there was indeed a fire and were an incentive to rapidly enter the stairwell and evacuate, as directed.

The travel time in the stairwells could be roughly estimated at 15 s per floor for occupants in good shape when neither crowding nor adverse conditions are present in the stairwell [6]. For a person traveling 36 storeys, 15 s per floor would translate to 9 min of travel time. The estimated mean time to travel in the stairwell was approximately 9 min; some people located on the Lower floors took less than 1 min while some took up to 25 min to travel to the ground floor. From the respondents' movement descriptions, it seems that crowding inside the stairwell or counterflow was never an issue during this evacuation. This is explained by the low density of occupants still in the building at the time of the fire and the limited number who actually used the stairwells to egress.

The overall estimated evacuation time, which is the addition of the pre-movement time and the travel time, was 11.5 min. The mean evacuation time for respondents who used the elevator was 5.8 min, while the mean time to evacuate was 15.1 min for respondents who used the stairwell, which was more than twice as long as compared to the mean time taken by respondents who used elevators. These times are faster than times found in previous studies [7]. Typically, 5 min of pre-movement time is the mean reported by

occupants who evacuated high-rise structures during drills. During actual fires, the pre-movement times usually stretches depending on information available to the occupants.

Overall, the evacuation proceeded rapidly during this fire. This was due to many factors, most importantly the use of the P.A. messages to prompt evacuation and the fact that it was the end of the day and occupants were thus willing to leave, that several took the elevator, and that low density allowed occupants to move freely in the stairwells.

Fire Safety Management Lessons

A number of lessons can be learned from the occupant behavior and evacuation during this fire. It appears essential that a Building Emergency Action Plan and Incident Management System be developed to provide the framework for a coordinated response to emergencies. These documents should include an accountability mechanism and address the roles and responsibilities of occupants, security officers and fire department personnel. Consideration should be given to the needs of all occupants including the ones with limitations and disabilities. A procedure should be developed for after hours when there is a limited number of people in the building and account for occupants who might work on evening or night shifts such as cleaners or maintenance personnel.

Training is also an essential component. Although the number of hours spent on life safety training and the frequency of drills and practices is important, the quality of this training should be considered with care: the best of plans will fail if the participants do not understand it and do not know their role. Regular realistic emergency scenarios should be run to evaluate the competency of the different groups of building occupants. Signage to remind occupants of the basic procedures during an incident is also recommended.

On the technological front, the installation of a sprinkler system or unlocking of the stairwell doors could have changed the outcome of this fire. During this fire, the P.A. system was used, which proved to be an excellent means to warn occupants. However, there was no procedure in place for precise up-to-date information to be delivered to occupants.

Stairwell doors should be left unlocked or should allow re-entry to at least every 5th floor from the stairwell at all times. Signage must be provided inside the stairwell to identify the doors that are locked and on which floor re-entry is possible. Signage must also be provided advising whether there is, or is not, access to the roof.

The elevators were used successfully during this fire for occupants' evacuation. Guidelines should be developed to detail situations when

elevators could be safely used. Elevators should be recalled if they are not safe to use. Fire safety management procedures have a vital role to play in fire prevention and mitigation; these procedures should be developed with care to ensure the safety of all occupants.

ACKNOWLEDGMENTS

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