Pre-evacuation Data Collected from a Mid-rise Evacuation Exercise

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ABSTRACT: This article describes the observation of an unannounced evacuation exercise from a mid-rise administrative building. The primary focus of this activity was to collect pre-evacuation data, although evacuation times were also recorded for completeness. The article includes a description of the structure, the population, the emergency procedure employed and the observations made during the evacuation (both numerical and descriptive). Data are presented in a number of formats including raw values, averages, ranges, and distributions, i.e., in as much detail as possible and in context with the evacuation scenario. This should increase/improve potential applications, and reduces the likelihood of misunderstanding. A simple graphical scheme was developed to connect the numerical and descriptive data collected and provide a comprehensive timeline of events. In addition, a detailed description of the data collection methods employed is presented, outlining their strengths and limitations. This article therefore presents a range of valuable data, a detailed description of the methods employed and a means to clearly present the data collected.

KEY WORDS: pre-evacuation time, notification, evacuation data, unannounced evacuation exercise.

INTRODUCTION

FOR MOST OF the 20th century it was widely assumed that during an evacuation from a fire, the public should be deprived of information, as it inevitably would have led to panic [1–3]. Hence, the full extent and seriousness of the situation usually would have been withheld. This was particularly the case in public spaces, where fear of a hysterical response led management to contain and control a crowd rather than managing the situation. This has now been replaced by the view that the population should be informed of the incident as early as possible in order to increase their acceptance of the emergency procedure and inform their

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decision-making process [2–5]. This is succinctly summarized in Annex A of the 2007 edition of NFPA 72:

> *Occupants rarely panic in fire situations... 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.* [5]

An emergency incident can be a rapidly developing situation in which information is an invaluable commodity. Amongst other things [2–4,6–9], it is imperative that evacuees respond in a timely fashion; this response is dependent upon the information available to them. Contrary to popular belief, the time to respond to an incident can often seriously prolong the overall time required to reach safety [2–4,6–11]. This time can be influenced by a number of variables:

- The notification system;
- staff;
- visual access;
- level of engagement;
- perception of the event;
- level of training/familiarity with procedure;
- frequency of evacuation exercises/false alarms;
- social roles;
- familiarity with surroundings, etc.

Given this, it is vital to understand and prioritize the methods available to inform a population of an incident and of the required response. In order to make this assessment, empirical data are required that relates to the pre-evacuation time of the resident population. Here, the term pre-evacuation time relates to the time between the alarm sounding and the time that an individual initiates a purposive attempt to evacuate.

The authors collected data as part of a project funded by the Fire Protection Research Foundation [12,13]. The project required a series of evacuation exercises to be conducted. These exercises employed a range of different notification systems and emergency procedures. During each exercise, the pre-evacuation time for the population (or a sample of it) was recorded. This article describes an evacuation exercise that was monitored in order to ascertain the pre-evacuation times of the resident population from a mid-rise office building. The evacuation exercise was unannounced and was part of the standard fire safety schedule of the building. The facility was selected as it provided an example of a well-trained, familiar, experienced population that was being informed of the 'incident' and the response required of them.

The data from the exercise are presented in a number of formats, ranging from its most basic form (i.e., as raw data) to detailed analysis allowing averages, ranges and frequency curves to be presented. In addition, overall evacuation times are presented. The variety of data formats provided should allow the data to be employed in a number of different applications. These applications include general research/theory development; egress model development; engineering calculations; improvement of the emergency procedure applied in the structure; and the modification of building codes. In addition, the techniques used to collect these data are described, outlining the limitations of the approach(es) adopted. This should aid future data collection activities.

The data set is presented in as much detail as possible and in context with the event conditions to clearly describe the evacuation as it transpired. To aid in this, a simple timeline schematic was developed to allow the numerical and descriptive information gathered to be presented in the same graphic (Appendix B). This article should provide the engineer/researcher with valuable data in context with prevailing conditions, guidance on data collection techniques and a method to represent the data collected in a simple and coherent manner. This information is provided in order to clarify the strengths and weaknesses of the data set. Omissions in the data set are identified, as are limitations in the data collection process. Once these issues are described, the results are presented in some detail.

BACKGROUND

In the next sections key factors are described that influenced the outcome of the evacuation exercise. The information provided relates to the building configuration, the resident population and the evacuation procedure employed.

Building Information

The building involved in this trial was part of an administrative[1] office complex located in North America. This complex consisted of a 14-story

[1]This would be primarily classified as Business Use (according to NFPA 101, Life Safety Code, 2006) or Group B (according to International Building Code, ICC, 2006).

tower (including a basement level) and an adjoining three-story low-rise structure. The top floor of each of these structures was used for building support systems, along with the basement area of the low-rise structure, and were therefore of no interest during this analysis. The data collection activity focused on the occupied floors of the tower.

Each floor of the tower occupied ~1940 m^2 (or, 21,000 ft^2, see Figure 1(a)). The tower had two stairs that ran throughout the evacuated floors. Each of the stairs was ~0.91 m (3 ft) in width, allowing a single lane of pedestrian traffic. This behavior was also observed during the evacuation exercise.

The two stairwells were available during the evacuation, both of which were accessible through the main foyer. The foyer was monitored by security and represented the normal route for entering the tower. This foyer connected the tower and the low-rise structure.

The internal layout differed from floor to floor, although each floor was used for office space. The tower was in the process of being refurbished to move from a closed to an open configuration. Several of the floors were empty due to refurbishment activities, while others had already been modified to an open-plan configuration. The floor configuration had a negligible impact on the results produced. This was established by comparing the results from different floors.

On the day of the exercise the weather conditions were moderate and did not adversely influence the performance of the exercise in anyway.

Occupant Population

At the time of the exercise (i.e., mid-morning), the complex was occupied by 825 people, as established by examining CCTV footage. Occupants were distributed throughout the structure, with 713 people (~90%) of the population in the tower, while the rest were in the low-rise structure. The population distribution within the tower is shown in Table 1. Floor populations were established in several ways: occupants were counted leaving the floor during the evacuation, either manually or via video camera; access to the tower was monitored as occupants passed through a set of security gates and their target floor recorded; or population sizes were derived from the numbers expected (i.e., previously counted) on the floor in question as indicated by building management. These methods are presented in descending order of reliability.

The population was made up of administrative and engineering staff. The population was 44% male and 56% female (Table 2). Information on the age distribution was also collected (Table 3). Only 1% of the population reported impairments and these were physical impairments, as opposed

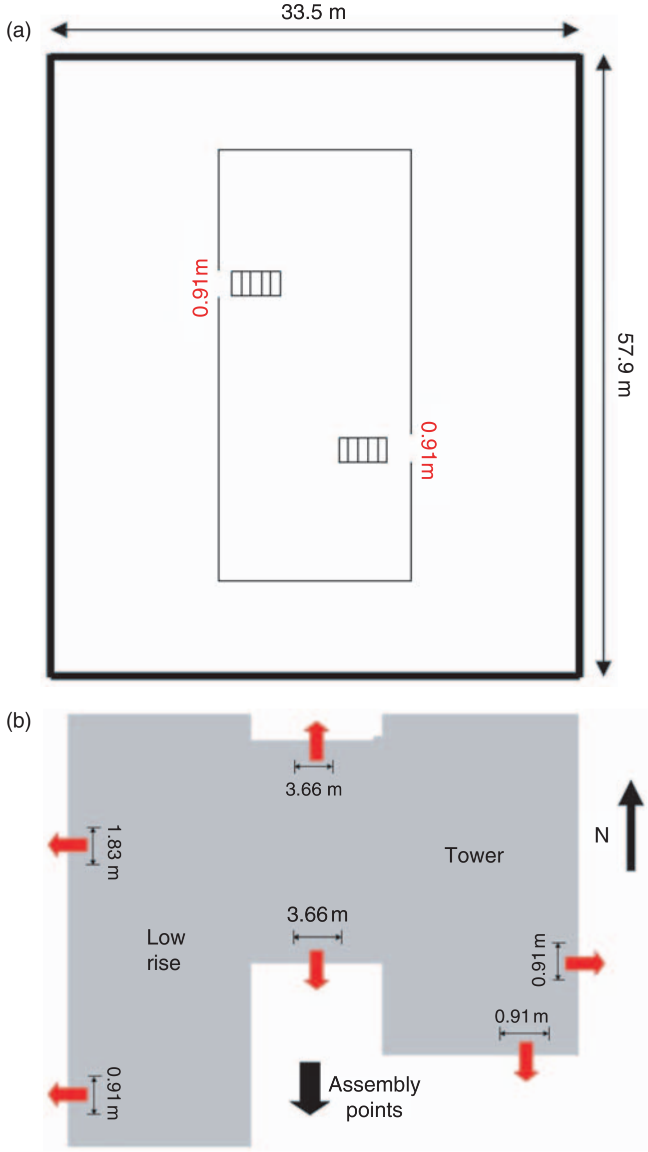


Figure 1. *(a) Footprint of tower; (b) Footprint of complex. The tower location is highlighted. (The color version of this figure is available online.)*

Table 1. Population distribution on each floor.

Floor no.	Population size	Method
12	54	Security count*
11	46	Security count
10	46	Derived from expected population on that floor
9	46	Derived from expected population on that floor
8	61	Manual observation
7	64	Security count
6	52	Direct observation
5	80	Direct observation
4	59	Security count/manual observation
3	47	Derived from expected population on that floor
2	47	Derived from expected population on that floor
1	63	Security count
Lower	48	Security count
Total	713	Camera covering exits during evacuation

*This value includes the population operating on floor 13 and a reduced population of 32 on floor 12 due to refurbishment. These are combined as it was not possible to clearly differentiate between them.

Table 2. Gender distribution.

Gender	Population (%)
Male	44
Female	56

Table 3. Age distribution.

Age range	Population (%)
18–24	0
25–34	10
35–44	22
45–60	35
60+	33

to visual or aural impairments. These demographics were collected from a post-incident survey.

Evacuation Procedure

The facility management conducted emergency fire and earthquake exercises several times a year. These exercises were unannounced.

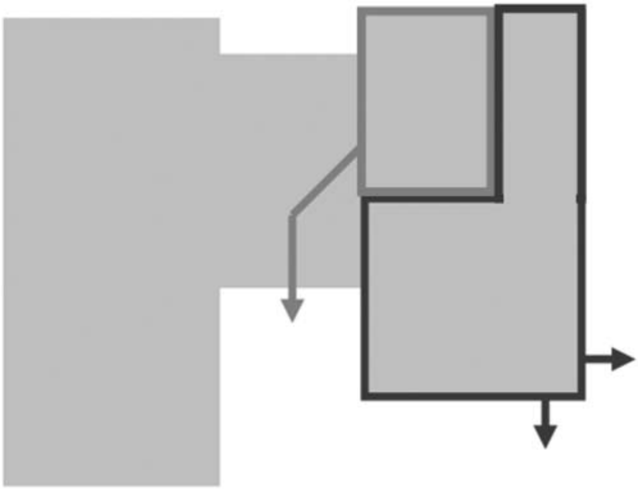


Figure 2. *Intended egress routes from the tower.*

The observed evacuation exercise required a full building evacuation. The procedure initially required the immediate evacuation of the three floors deemed to be most at risk from the incident followed by the rest of the building. During the exercise the fire floor was selected at random. Neither staff members nor occupants were aware of the exercise of the located of the simulated incident.

The complex employed a voice notification system. The announcement was preceded by three rounds of a slow whoop. The following announcement was then made on the fire floor, and floors above and below:

> "*May I have your attention, please; may I have your attention, please. An alarm has been activated in the building. Please proceed to the stairwells and exit the building. Do not use the elevators.*"

It is estimated that it took between 15 and 20 seconds for the combined whoop and message to be played. At a time of 3 minutes after the initial alarm, a general alarm was sounded throughout the structure. The delay between the local and general alarms served to reduce the congestion on the two stairs and increase access for the arriving fire department personnel.

The population within the tower was instructed to use both stairs (both by the notification message and by staff), which then emptied out to separate exits. Evacuees using the northern stair used the main southern exit point (Figure 2). Evacuees using the southern stair used the eastern and south-eastern exit points (Figure 2).

Just to the south of the complex was a set of pre-determined assembly points. These points were identified by markings on street lamps located in large parking areas. Each of the assembly points was associated with an area of the complex (e.g., a specific floor). These locations were familiar to the occupant population and formed part of the emergency procedure.

All floors of the structure had a pair of Emergency Response Coordinators (ERCs), whose responsibility was to ensure the population evacuated in accordance with the emergency procedure. In addition, building management identified a pair of additional (replacement) ERCs for each floor, in case the original ERCs were injured or absent. On hearing the alarm, the ERCs swept their floor to alert the population and eventually ensured that it was clear. On leaving the floor an ERC picked up a register. The arrival of the evacuees at the assembly point was then recorded by ERCs.

DATA COLLECTION PROCESS

The primary objective of this research was to collect data relating to pre-evacuation times. However, in order to support this activity, a range of other information was required. This provides the context in which the exercise took place, background information, and the conditions that developed during the event. Data were, therefore, collected on the pre-evacuation and evacuation phases of the evacuation using a range of techniques (Table 4) to give not only a numerical estimate of the evacuation, but also some description of the conditions that arose. A description of the data-collection techniques employed is now provided.

Given the configuration of the floors, it would have been impossible to insert sufficient camera equipment into the office spaces to capture pre-evacuation times. Certainly, this would not have been possible without inadvertently informing the population of the upcoming exercise. Instead, camera equipment and observers were located inside the stairwells and monitored the arrival of evacuees at the stair door (Figure 3(a)). These observers/cameras were deliberately positioned so as not to interfere with the progress of the evacuating population. In no instance did the observers hinder or influence the evacuation. The observers were not visible from outside of the stairwells and so did not prompt an early response from the resident population.

It was important that the anonymity of the evacuees was maintained during the data collection process.[2] Video cameras were used, but were

[2]This was requested by the host organization.

Table 4. Data collection techniques employed.

	Pre-evacuation	Evacuation
Video cameras	X	X
Manual observations	X	
Survey	X	X

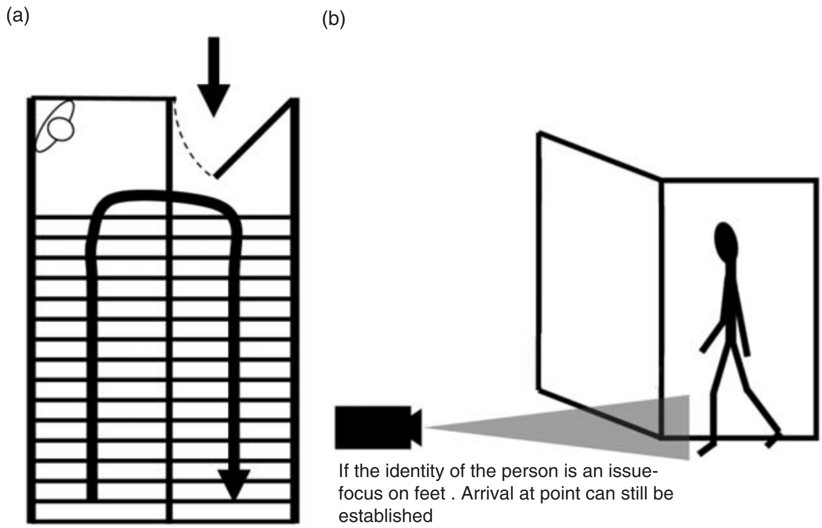


Figure 3. *(a) Location of video camera and observers; (b) Position preserved evacuee anonymity.*

deliberately positioned so as not to focus on the faces of those concerned. This was achieved by laying the video cameras on the floor and then focusing them on the feet of the evacuees (see camera position in Figure 3(b)). The cameras used were standard, relatively small, digital video cameras. They were synchronized in order to ensure that the timings could be compared.

Given the location of the cameras, a point had to be established that indicated when an individual had responded to the call to evacuate: the stair entrance was selected. The time to arrive at the stair entrance also included a small amount of time taken for the individual to move from their initial location to the stair door. The pre-evacuation times collected (i.e., the time between the alarm sounding and arrival at a stair entrance) should therefore be considered a *conservative* indicator of the actual pre-evacuation times. It is estimated that it would have taken between 10 and 15 seconds to travel from the most distant point on a floor to a stair door. In most instances, this time would have been negligible.

Congestion developed on the stairs during the evacuation. This had no impact on the measured pre-evacuation times of those evacuating from the fire floors, as the stairs were clear when these evacuees entered them. However, some care was required when examining the pre-evacuation times of those responding to the general alarm. From the video analysis (and from manual observation) the congestion on the stair did not generally delay arrival at the stair doors, unduly increasing the pre-evacuation times produced. Data-points were excluded if congestion were seen to have an impact on the arrival at the stair door.

In total four video cameras were located in the stairwells of Floors 5 and 6 of the tower. These floors (along with Floor 7) were evacuated during the first phase of the emergency procedure. In addition, four observers were positioned to conduct manual observations using stopwatches on Floors 4 and 8. These floors (along with Floors 1–3 and 9–13) were evacuated during the second (general) phase of the emergency procedure. Therefore, a sample of the movement in response to the initial alarm and to the general alarm was collected.

The authors established a simple set of guidelines in order to enable consistent and efficient manual data collection. It was apparent from the analysis of previous egress data [14–21] that it would be impossible to record data for each individual given the number of arrivals that might occur in a short period of time. However, people flow is not laminar, but is instead made up of groups of differing size that arrive periodically. Given this, a simple scheme was devised.

Each data collector was given this scheme and applied it during the trials. The collector recorded the time for the first and last person to arrive in the first group of evacuees (Figure 4). For subsequent groups, the observer

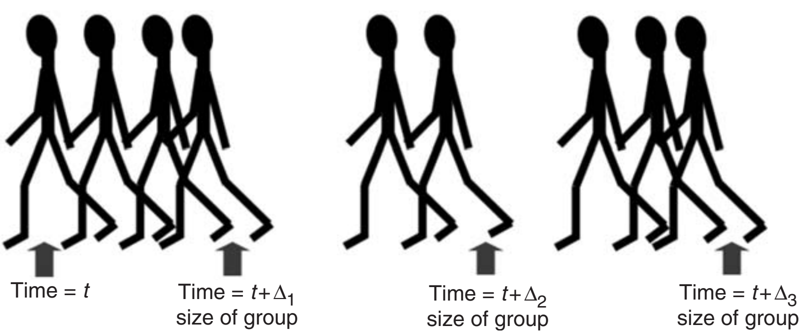


Figure 4. *Manual data collection, where* $\Delta_3 > \Delta_2 > \Delta_1$.

recorded the time of the last arrival along with the number of people in the group. This was the minimum information recorded; it was often possible for the data collectors to record more information than this. The pre-evacuation time of the last person in a group was taken as a conservative estimate of the pre-evacuation time of the group. This method provided a conservative estimate of the arrival/pre-evacuation times for each individual.

Using this approach, a reasonable estimate of the average pre-evacuation time for each group could be achieved given the following: there were relatively few people in each group; the groups were small such that the difference between the time of the last person in the group and the first was also relatively small; the number of people in the overall flow was much greater than the number in any group; there were more groups in the flow of people than there were people in any single group; the pre-evacuation time was sufficiently extended such that the overall pre-evacuation time was significantly larger than the difference between the last person in any group and the average time of the group; and that the individuals in a group were closer together than individuals from different groups. These conditions were satisfied allowing this method to be a useful indicator of the pre-evacuation times produced for any of the groups. Typically, the groups had 2–5 members. The accuracy of this approach has been examined elsewhere [12], where it was found to produce reasonable and reliable results.

The four video cameras captured 132 pre-evacuation times (representing 16% of the evacuating population). Observers collected approximately 150 pre-evacuation times, not captured on camera, representing 18% of the evacuating population. In combination they represented 34% of the overall population. Only this sample could be collected given the constraints placed on the data collection process; e.g., the level of access, preservation of anonymity, etc. All pre-evacuation times were calculated from the beginning of the alarm message.

The analysis presented here focuses on the data extracted from the video footage, as this is considered to be more reliable. The data collected manually is used primarily to support these data and demonstrate that data are representative of the building and the procedure.

Cameras were also located outside of the structure. These were already in position to perform security monitoring, but were redirected as part of the data collection process; i.e., focused specifically on exit locations. All exits from the structure were monitored during the trial. These cameras collected all 825 evacuation times.

The authors also conducted a post-incident survey. The population was able to respond via e-mail or on hardcopy. These responses were collected within 24 hours of the evacuation-taking place to ensure that the events were still fresh in the minds of the evacuees. A total of 103 responses were received (representing 12% of the evacuating population). The questionnaire used is shown in Appendix A.

RESULTS

The data collected from the exercise are presented in the following sections. The data are separated according to the phase of the evacuation (e.g., pre-evacuation and evacuation phases) and whether the data are numerical or descriptive in nature. In each case, the source of the data is outlined.

Numerical Results: Pre-Evacuation Times

The data presented here primarily relate to the observations captured on video (Table 5). These were the most reliable observations made and provided a sufficiently large sample to be of value. These data are segregated according to the floor from which the evacuees came and the stair that was used.

On average, the population responded after 74 seconds, with pre-evacuation times ranging from 23 to 152 seconds. This represents a very quick response to the call to evacuate (compare with data presented elsewhere [12,21]). The pre-evacuation times produced do not differ significantly between floors. The pre-evacuation times for those entering the south stair were significantly shorter than those for the northern stair ($p < 0.05$). It is speculated that this may be due to the southern stair being closer to the elevators, which were used to enter the building.

The distribution of the pre-evacuation times collected is shown in Figure 5. It is apparent that a large proportion of the population had started to evacuate by 60 seconds. These evacuees responded to the alarm signal. A second group of evacuees responded between 90 and 150 seconds, either responding to the arrival of ERCs and/or performing pre-evacuation activities (e.g., shutting down PCs) prior to their response.

Table 5. Pre-evacuation times captured on video given stair and floor being used.

	North stair		South stair		Overall	
	Avg. pre-evac. times (seconds)	No. data points	Avg. pre-evac. times (seconds)	No. data points	Avg. pre-evac. times (seconds)	No. data points
Floor 5	81.3 [24–150]	51	59.1 [31–88]	29	73.3 [24–150]	80
Floor 6	77.5 [46–152]	19	73.8 [23–144]	33	75.2 [23–152]	52
Total	80.3 [24–152]	70	66.9 [23–144]	62	74.0 [23–152]	132

This is perhaps more evident in Figure 6 where the pre-evacuation time of each individual is shown. It is apparent that the curve flattens after the 75th percentile, as the response of evacuees becomes more distributed.

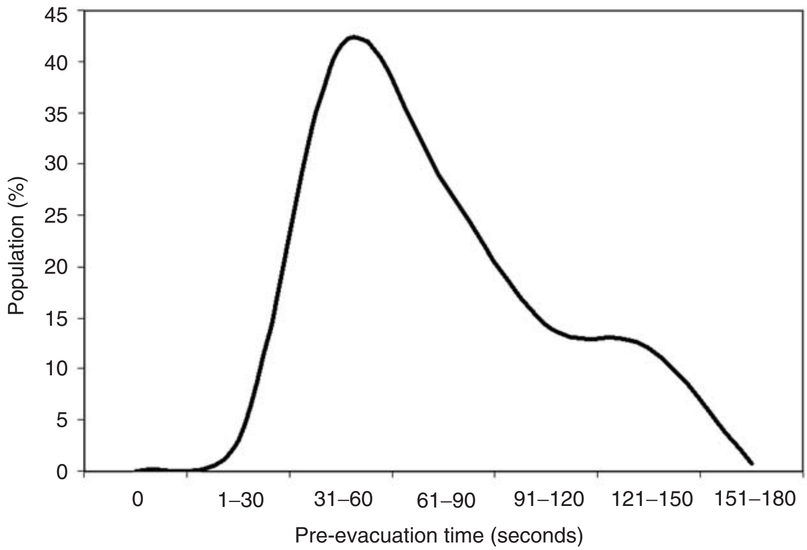


Figure 5. *Pre-evacuation time distribution for Floors 5 and 6. Derived from video footage.*

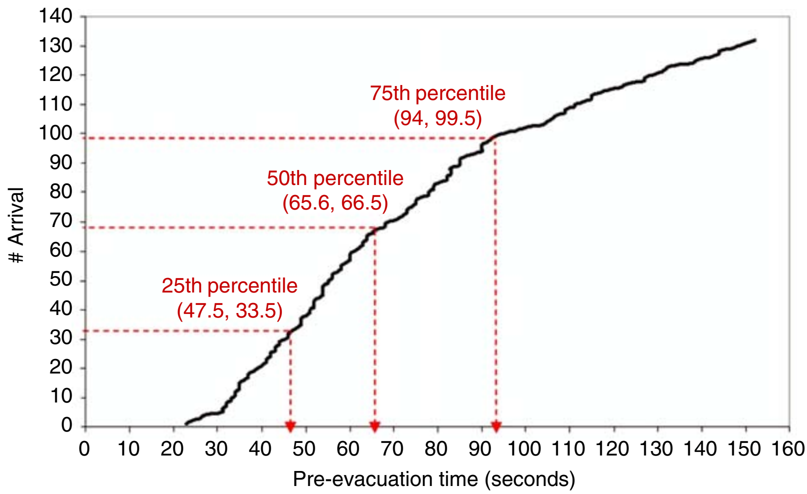


Figure 6. *Pre-evacuation time curve derived from video footage. (The color version of this figure is available online.)*

Table 6. Raw pre-evacuation time data (seconds) derived from video footage.

23	34	41	48	54	59	66	76	85	95	113	132
24	35	42	49	54	60	68	78	85	98	115	133
26	35	42	49	54	60	68	78	85	100	115	138
27	35	43	49	54	60	69	79	86	104	117	139
31	36	43	50	55	61	71	79	88	105	119	142
31	37	44	51	55	62	72	80	90	106	122	144
32	37	44	51	56	63	73	82	90	107	123	144
32	38	45	52	56	63	73	82	90	109	127	147
33	39	46	52	57	64	74	83	91	109	127	148
33	40	46	52	58	64	75	83	92	111	129	150
34	41	47	53	58	65	75	83	93	111	131	152

Table 7. Manual observations made on floors 4 and 8.

Floor – stair	Pre-evacuation range (seconds)
8 – North	11–135
8 – South	30–150
4 – North	5–173
4 – South	12–134

The raw pre-evacuation times collected by the four video cameras are provided in Table 6. In addition to the previous data derived from video footage, manual observations were made. These observations, conducted on Floors 4 and 8, had two objectives: to establish that the sample provided by the video footage was representative of the building as a whole and to examine the difference in the response of the population to the local and general alarms. Only the ranges are provided here, given the manual method employed (Table 7). These times represent the time from the general alarm. Therefore, the 3 minute delay between the general alarm and the alarm on the fire floors has been taken into account.

It is apparent that the response to the general alarm was similar to the response to the local alarm. This is more evident in Figure 7 where the pre-evacuation time ranges of all of the floors are shown. The first arrivals on Floors 4 and 8 are slightly lower than those on Floors 5 and 6. This may have been due to a small section of the population on Floors 4 and 8 overhearing the initial alarm on the adjacent floors and preparing to evacuate prior to the second general alarm sounding. It is also apparent that the response on each floor is reasonably similar throughout. It therefore appears that the sample collected from video is representative of the structure and of the procedure.

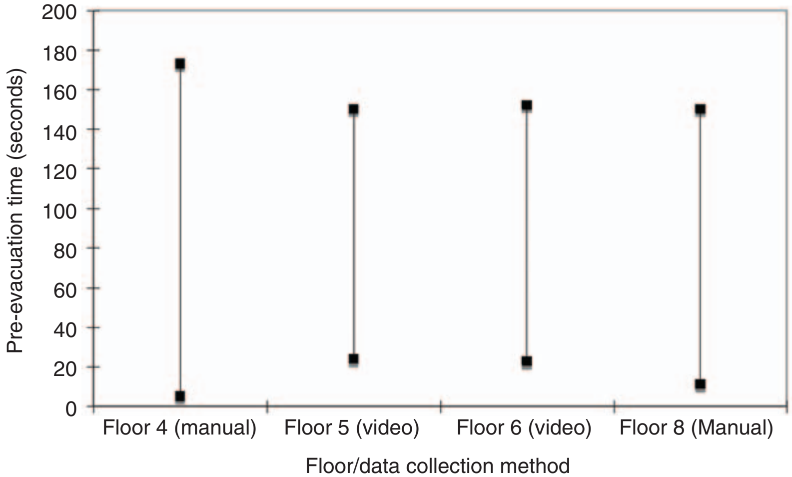


Figure 7. *Range of data collected according to floor and method used.*

Numerical Results: Overall Evacuation Times

The external camera positions allowed a complete evacuation time data-set to be collected. The evacuation times produced, categorized according to exit, are shown in Figure 8. The overall average evacuation time was 362.0 seconds, with the results ranging from 11 to 816 seconds.

The evacuation times produced varied according to the number of people using each exit with the two western exits leading from the low-rise structure producing significantly shorter evacuation times (ranging from 11 to 465 seconds, see Figure 8). This was due primarily to the congestion that developed on the stairs in the tower and the fact that some evacuees had to travel longer, congested expanses of stair.

As part of the emergency procedure the southern three exit points out of the tower should have been used; however, only two of these exits were eventually used. This was due to the building sections allotted to use the south-eastern exit being empty at the time of the exercise rather than any failing of the procedure itself. The evacuation of the tower continued between 14 and 816 seconds with the average occupant evacuating after 402 seconds.

The evacuees arrived at over one person per second for the first 75% of the population. This approximately linear arrival curve was dictated largely by the congestion produced on the stairs. Once people entered a stairwell, they queued for some time prior to reaching an exit. After 75% of the population had evacuated only the main exit was being used (i.e., the other exits had stopped being used) producing a lower arrival rate (see Figure 9).

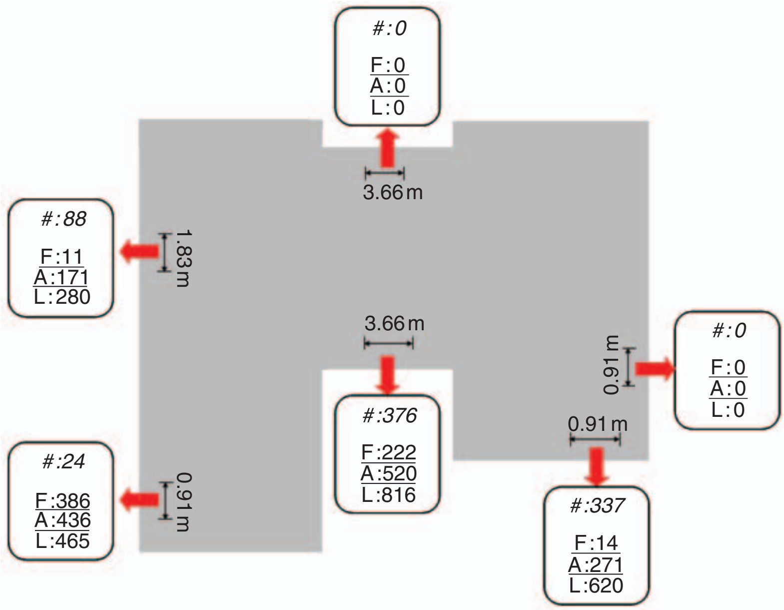


Figure 8. *Evacuation times produced according to the exit used. (# – number using exit; F – time of first arrival (seconds); A – average time of arrival (seconds); L – time of last arrival (seconds)). (The color version of this figure is available online.)*

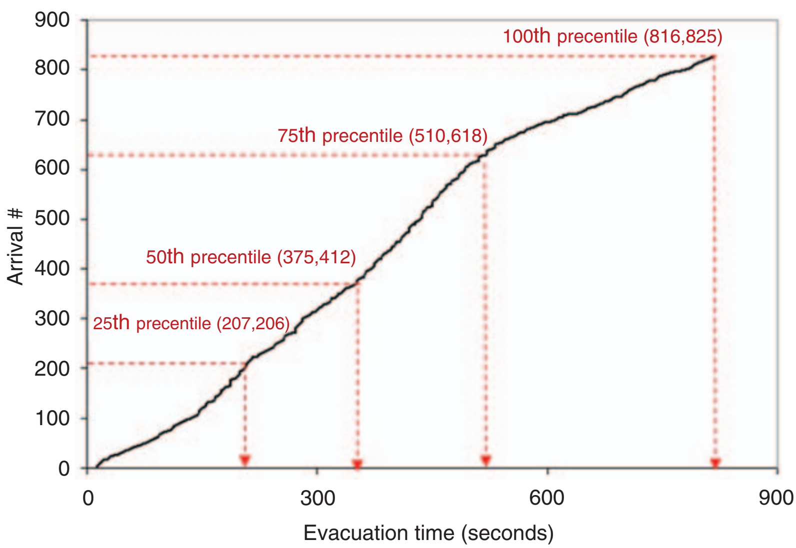


Figure 9. *Evacuation time curve. (The color version of this figure is available online.)*

The frequency distribution of evacuation times is shown in Figure 10. A class size of 120 seconds is used here. It is apparent that although the curve is approximately normal, it has distinctive shoulders. These are produced by the differences in the evacuation of the low-rise structure and the tower, along with the gradual evaporation of the populations using each of the exits.

Numerical Results: Survey Responses

The survey produced 103 responses. Respondents were asked to estimate the time that it took for them to respond to the alarm. It is apparent that the estimated distribution is based on shorter pre-evacuation times than those that were captured on video (Figure 11). These differences are due to several factors: people tended to over-estimate their performance; reported results fell at the upper end of the class sizes used rather than the average as would normally be assumed; and that these times do not include the potential 10–15 seconds travel time to the stairs.

Qualitative Results

All three methods used to collect data enabled qualitative information to be collected; i.e., information on the conditions produced during

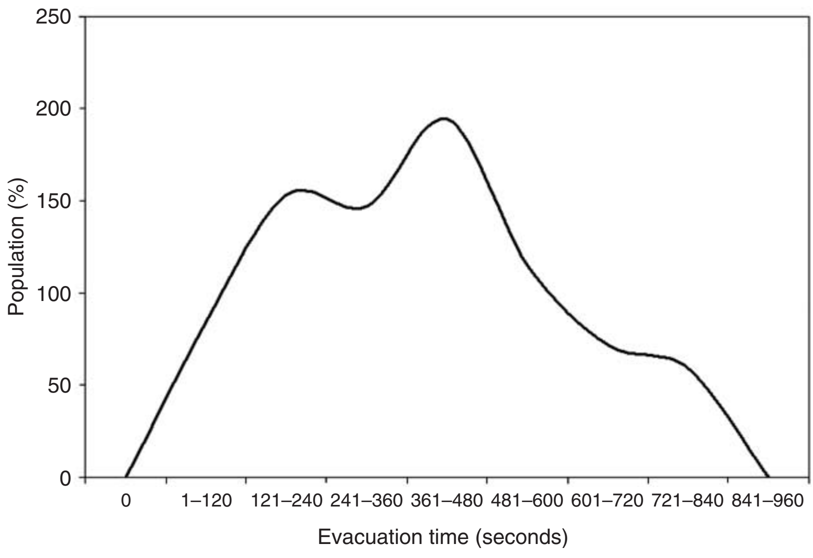


Figure 10. *Frequency distribution of the evacuation times.*

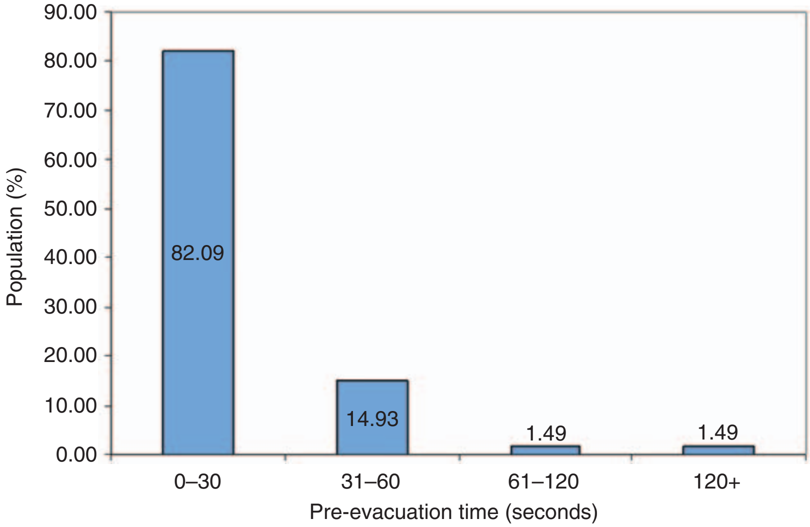


Figure 11. *Pre-evacuation estimates produced by survey respondents. (The color version of this figure is available online.)*

the exercise. The following discussion will focus upon the conditions evident in the tower evacuation.

The emergency procedure was successfully implemented. Floors 5–7 evacuated when the initial local alarm sounded and the rest of the building evacuated after the general alarm. There were isolated examples of people on Floor 8 overhearing the alarm sounding on the floors below and then investigating; however, these individuals did not evacuate. None of the population attempted to use the elevators during the evacuation, in accordance with the procedure. It is apparent that the population evacuating from the tower split relatively evenly between their allotted exits (e.g., 376 and 337 using each of the exit points used) as indicated by the procedure and the ERC advice provided. The evacuees used the stairs in a similarly balanced manner. This adherence to the procedure was due to the actions of the ERCs, the information provided by the notification system and the population's familiarity with the procedure.

From the survey, 88% of the population had taken part in an evacuation exercise in the previous year; many had taken part in multiple exercises.[3] Around 100% of the population heard the alarm, indicating that the alarm system had sufficient coverage. Over 90% immediately recognized the alarm

[3]This is expected, given that the exercises were performed three times per year.

as indicating a potential fire. Over 95% indicated that the alarm alone was sufficient to encourage them to evacuate, indicating that the population associated the alarm (signal and/or message) with a potential fire incident. Therefore, the population received the notification signal, understood its meaning, was familiar with the required response, and then responded. This produced relatively short pre-evacuation times and a relatively even use of the different stairs and the exit points used. It would have been difficult to improve upon the efficiency of the response, given the procedure applied.[4]

From the quantitative data collected it is estimated that an evacuee spent an average of 20% of their evacuation time responding to call to evacuate, while spending 80% of their time moving to the final exit from the building. The majority of this time (i.e., 80%) would have been spent in congestion on the stair. A 50% of the population reported experiencing congestion on the stairs, supporting this assertion. The stair congestion was also apparent in the video footage, and from manual observations. The impact of stair congestion is further supported by the lack of congestion apparent at the final exit points throughout the evacuation process. These results (observed from camera footage and manual observations) suggest that procedural modifications (especially given the adherence of the population to the procedure employed) may reduce the overall evacuation results produced still further. Such modifications could be tested by conducting further exercises and/or employing computational egress models to test a range of procedures prior to implementation.[5]

A behavioral timeline was devised to link the numerical and descriptive aspects of the exercise into a single graphic (Appendix B). This method, influenced by the work of Lerup [22] among others, links the evacuation procedure with the performance of the evacuees and the data collection activities. The timeline performs a number of functions: it summarizes the key events of the exercise; it places these events in context with one another; and it explains the data collection method employed.[6]

CONCLUSIONS

The primary purpose of this article was to present the data collected during an evacuation exercise in as much detail as possible. This included

[4]That is not to say that the procedure itself could not be improved.
[5]Suggestions for the improvement of this procedure is beyond the scope of this article.
[6]This graphical notation is currently being developed as part of a NIST-funded project.

the background conditions present during the evacuation and a data set that included numerical and descriptive elements. The data set represented a relatively short pre-evacuation phase. This was due to the procedural factors in place: the preparation performed prior to the event; the presence of a voice notification system and numerous, assertive members of staff.

The authors used a number of techniques to collect this material. Techniques included video, manual, and survey techniques. These are described in some detail to provide guidance for future data collection activities. It was also critical to present the data in as detailed and complete a manner as possible. The article presents the pre-evacuation data in a number of different formats, including the raw values. This reduces ambiguity and will allow the data to be used appropriately and in a wide range of applications. In addition, a graphical timeline was developed that ties behavioral, procedure, and data collection events together. This provides a means to concisely summarize the event and reduces the likelihood of the data being misunderstood and misapplied in the future. Therefore, the data are described in detail and in context with the event conditions.

APPENDIX A. SURVEY QUESTIONNAIRE

[redacted] and Hughes Associates, Inc. would like to thank you for completing this survey. The results will be used as part of a National Fire Protection Association (NFPA) funded project examining the effectiveness of alarm systems. It will also increase our understanding of evacuation procedures and have a direct impact on the future safety of buildings in which we spend much of our time. The survey should only take you five minutes to complete. Your responses will remain completely anonymous. Please answer as many of the questions as possible.

Q(1) What is your age?
- ☐ Less than 18 years
- ☐ 18 to 24 years
- ☐ 25 to 34 years
- ☐ 35 to 44 years
- ☐ 45 to 60 years
- ☐ 60 and older

Q(2) What is your gender?
- ☐ Male
- ☐ Female

Q(3) Please indicate if you have any of the following impairments:
- ☐ Limited vision (such that it might prevent you seeing a flashing light)
- ☐ Limited hearing / deafness (such that it might prevent you hearing an alarm)
- ☐ Physical Impairment (such that evacuating via a staircase would be problematic)
- ☐ None of the above
- ☐ Other, please indicate below

....

Q(4) Have you ever experienced a fire alarm in this building/site before?
- ☐ Yes
If Yes, how many times in the last year?
....
- ☐ No

Q(5) Have you participated in a fire drill during the last year?
- ☐ Yes
If Yes, how many times in the last year?
....
- ☐ No

Q(6) Describe what you should do in response to a fire alarm at your site?

....

....

Q(7) During this current fire drill did you hear or see the alarm signal?
- ☐ Yes
If Yes...
- ☐ Did you hear the alarm sound
- ☐ Did you see lights from the alarm
- ☐ No
If No, how did you find out that the alarm had been raised?
....
....
Go to Q(9)

Q(8) Did you recognize the alarm signal as indicating a fire alarm?
- ☐ Yes
- ☐ No
If No, what did you think it was?
....
....

Q(9) Where were you when you first became aware of the fire drill (e.g. what floor, location, etc.)?

....

....

Q(10) What were you doing when you first became aware of the fire drill (e.g. when you heard the alarm, was informed by staff,etc.)?

....

....

Q(11) When you first became aware of the drill, were you
- ☐ Alone
- ☐ In a group of friends/colleagues
- ☐ In the presence of strangers

Q(12) What caused you to respond to the fire drill?
- ☐ The alarm signal
- ☐ A fire warden (i.e. ERC)
- ☐ A colleague / friend
- ☐ Something else. Please describe

....

....

(*continued*)

APPENDIX A. CONTINUED

Q(13) What did you do first in response to the fire drill?
- ☐ Collect your possessions
- ☐ Discuss event with neighbor
- ☐ Seek further information
- ☐ Await further instruction
- ☐ Start to evacuate
- ☐ Nothing / Continued with previous activity
- ☐ Other. Please describe

....

....

Q(14) How long did it take you to respond to the fire drill? For instance, from the time that you became aware that the alarm had been raised, how long did it take you to start to leave the building?
- ☐ 0-30 seconds
- ☐ 31-60 seconds
- ☐ 60-120 seconds
- ☐ Longer than 120 seconds

Q(15) Did you receive information that influenced your behavior during the evacuation (for instance, the route that you adopted, actions you performed)?

☐Yes ☐No

If Yes, where did it come from (mark all that apply)
- ☐ From the alarm
- ☐ From a member of staff
- ☐ From another evacuee
- ☐ From another source

....

....

If Yes, what was this information?

....

....

Q(16) How did you leave the building? For instance, what route did you take and what exit did you use?

....

....

Q(17) Did you experience any of these conditions when descending the staircases to the ground floor? You may tick more than one box.
- ☐ Occasional congestion due to large numbers of people moving along the stair
- ☐ Continual congestion due to large numbers of people moving along the stair
- ☐ Delays due to slow moving evacuees moving along the stair
- ☐ Staff moving in the opposite direction
- ☐ Delays due to people joining the stairs from other floors
- ☐ None of the above
- ☐ Other. Please describe

....

....

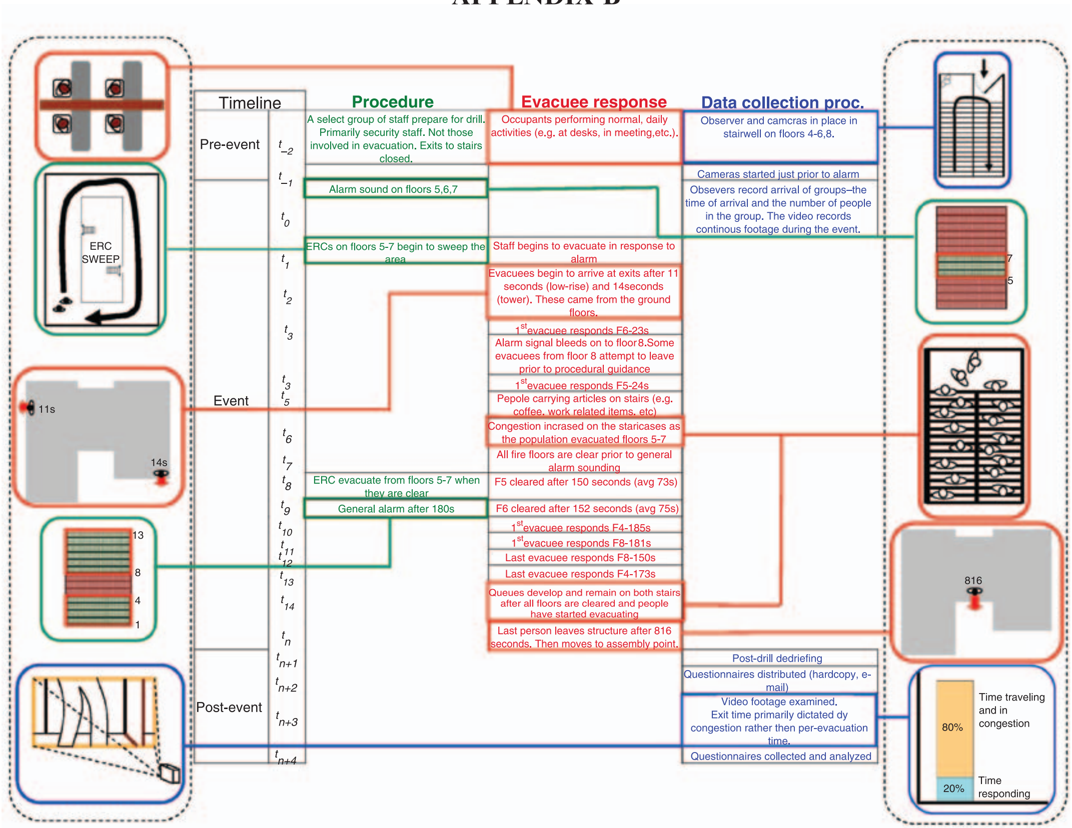
Q(18) Did you experience any of these conditions when you reached the assembly point? You may tick more than one box.
- ☐ People were prevented from re-entering the building
- ☐ Designated staff were on hand to provide information
- ☐ People were trying to find out what was going on
- ☐ People were leaving the assembly point
- ☐ Other. Please describe

....

....

Thank you for your time.

APPENDIX B


Timeline
Procedure
Evacuee response
Data collection proc.
Pre-event
t_{-2}
A select group of staff prepare for drill. Primarily security staff. Not those involved in evacuation. Exits to stairs closed.
Occupants performing normal, daily activities (e.g. at desks, in meeting,etc.).
Observer and camcras in place in stairwell on floors 4-6,8.
t_{-1}
Alarm sound on floors 5,6,7
Cameras started just prior to alarm
Observers record arrival of groups–the time of arrival and the number of people in the group. The video records continous footage during the event.
Event
t_0
t_1
ERCs on floors 5-7 begin to sweep the area
Staff begins to evacuate in response to alarm
t_2
Evacuees begin to arrive at exits after 11 seconds (low-rise) and 14seconds (tower). These came from the ground floors.
t_3
1st evacuee responds F6-23s
Alarm signal bleeds on to floor8.Some evacuees from floor 8 attempt to leave prior to procedural guidance
t_3
t_5
1st evacuee responds F5-24s
Pepole carrying articles on stairs (e.g. coffee, work related items, etc)
t_6
Congestion incrased on the staricases as the population evacuated floors 5-7
t_7
All fire floors are clear prior to general alarm sounding
t_8
ERC evacuate from floors 5-7 when they are clear
F5 cleared after 150 seconds (avg 73s)
t_9
General alarm after 180s
F6 cleared after 152 seconds (avg 75s)
t_{10}
1st evacuee responds F4-185s
t_{11}
1st evacuee responds F8-181s
t_{12}
Last evacuee responds F8-150s
t_{13}
Last evacuee responds F4-173s
t_{14}
Queues develop and remain on both stairs after all floors are cleared and people have started evacuating
t_n
Last person leaves structure after 816 seconds. Then moves to assembly point.
Post-event
t_{n+1}
Post-drill dedriefing
t_{n+2}
Questionnaires distributed (hardcopy, e-mail)
t_{n+3}
Video footage examined. Exit time primarily dictated dy congestion rather then per-evacuation time.
t_{n+4}
Questionnaires collected and analyzed
ERC SWEEP
11s
14s
13
8
4
1
7
5
816
80%
20%
Time traveling and in congestion
Time responding

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