

Behavioural responses to an audible fire alarm in high-rise buildings in Hong Kong

Fong, N. K., Wong, L. T. and Sui, W. H .

Department of Building Services Engineering
The Hong Kong Polytechnic University, Hong Kong, China.

Introduction

- Hong Kong
 - a developed city in South-East Asia
 - a population of ~ 6.8 million
 - a limited area of about ~ 1,100 km².
- The high population density,
 - ~ 43,000 persons per km² in the urban area
 - ~ 6,300 persons per km² overall
 - A great demand for high-rise buildings → can accommodate a large number of occupants.
- Fire safety in high-rise building is very important

Introduction

- One of the important features in Fire Safety in high-rise building
 - **Evacuation**
- **Human behaviour** is one of the important factors affecting the evacuation time in case of fire.
- Evacuees are dictated by their physical and psychological states at the time of fire awareness.

From previous study

- The reaction of people to the perception of a fire
 - depends on their perception of the seriousness of the fire.
- Before egress, many people tend to take some preservative actions
 - E.g. saving a computer or storing important things into a safety box.
- People in a group
 - would rather wait for orders from a leader/senior person than make decisions by themselves.



From previous study

- Occupants
 - choose 'their usual route' or 'a safe route' rather than 'a closer route'.
- use of elevators
 - mainly related to the floor on which the occupants were, but not the age of the occupants.

Time line approach

In estimating the evacuation time of the occupants, the following formula is proposed in BS7974, 2002,

$$\text{Safety margin} = t_{ASET} - t_{RSET}$$

$$t_{RSET} = \Delta t_{det} + \Delta t_{alarm} + (\Delta t_{pre} + \Delta t_{trav})$$

where t_{RSET} is the Required Safe Escape Time,
 Δt_{det} is the time from ignition to detection,
 Δt_{alarm} is the time from detection to a general alarm,
 Δt_{pre} is the pre-movement time for the building occupants and
 Δt_{trav} is their travel time.

Time line approach

- Large value of $\Delta t_{\text{pre}} \rightarrow$ delay in initiating evacuation
- Improper choice of escape route \rightarrow prolonged $\Delta t_{\text{trav}} \rightarrow$ prolonged t_{RSET}

From previous study

- Δt_{pre} would be affected by the perception of the fire incident
 - critical factors in the perception of a fire incident (Bryan)
 - Recognition → the individual identifies the ambiguous fire cues as a fire incident indicator
 - Validation → the individual attempting to validate an initial perception of fire cue
 - Definition → the individual attempts to relate the information concerning fire to the perceived variable
 - Evaluation → perceived time available, formulation of escape procedure
 - Commitment
 - Reassessment

Current study

- In this study
 - behavioural responses of 327 building occupants to audible fire alarm cues in high-rise buildings in Hong Kong were surveyed.
- A questionnaire was developed
 - concerning an occupant's responses and reactions to various fire cues in a fire emergency and his/her choice of an evacuation route.
- Behavioural responses to some probable fire scenarios were surveyed with respect to the occupant's experience of fire emergency.

Questionnaire survey

- multiple-choice basis
- covered issues:
 - personal details
 - experience of fire emergency
 - (Group1 : with fire experience, Group2: without fire experience)
 - perception of an audible fire alarm
 - probable reaction time
 - responses
 - familiarity with evacuation routes
 - choice of egress route
- conducted in 10 high-rise commercial and residential buildings in Hong Kong
- 350 randomly selected occupants were invited, 327 of them participated (approximately 93.4%)
- The survey was completed in one week.

Results

Occupants' Classification:

The respondents

Age Group	Gender		Row Total
	Female	Male	
20 or below	6 (1.8%)	11 (3.4%)	17 (5.2%)
21 to 30	77 (23.5%)	76 (23.2%)	153 (46.8%)
31 to 40	65 (19.9%)	38 (11.6%)	103 (31.5%)
41 to 50	9 (2.8%)	14 (4.3%)	23 (7.0%)
51 to 60	9 (2.8%)	10 (3.1%)	19 (5.8%)
61 or above	5 (1.5%)	7 (2.1%)	12 (3.7%)
Column Total	171 (52.3%)	156 (47.7%)	327 (100%)

Recognition of an audible fire alarm

(a) Source of alarm sound

First perception	With experience of fire emergency?		Row total
	Group 1 (Yes)	Group 2 (No)	
It was from a fire alarm bell	160	123	283
It was not from a fire alarm bell	25	19	44
Column total	185	142	327

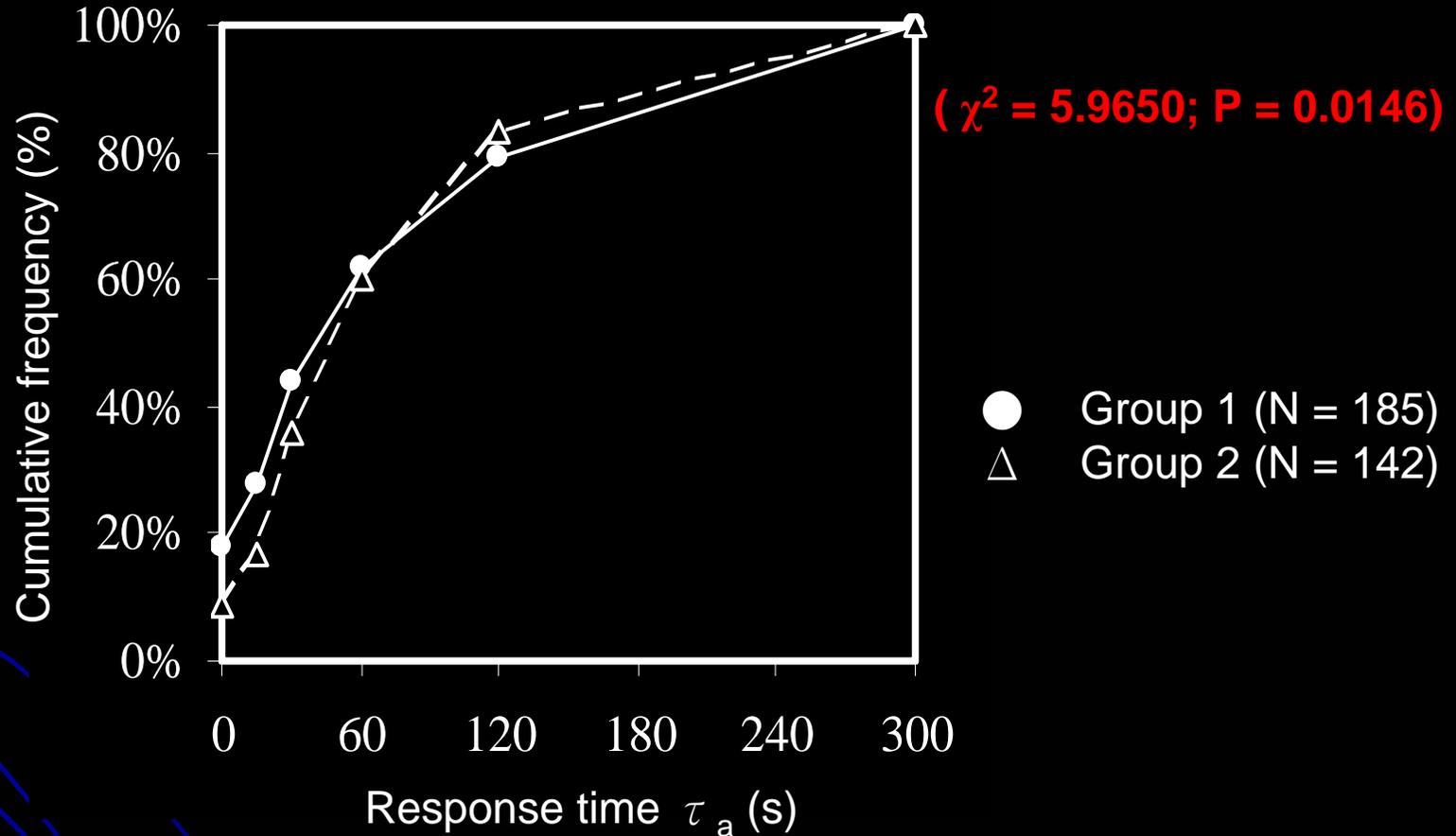
$(\chi^2 = 0.0010; P = 0.9721)$

(b) Interpretation of alarm sound

First perception	With experience of fire emergency?		Row total
	Group 1 (Yes)	Group 2 (No)	
There was a fire	75	33	108
There was not a fire	110	109	219
Column total	185	142	327

$(\chi^2 = 10.87; P < 0.001)$

Occupants' first perception of an audible fire alarm:



Response time to an audible fire alarm

Occupants' perception of fire spreading and response time:

Occupant's response time τ_a (s)	Would the fire spread to your unit?		Row total
	Probably or Very Likely	Very Unlikely or Not Sure	
0	12	21	33
≥ 300	10	29	39
Column total	22	50	72

response time related to the occupants' perception of the likelihood of the fire spreading to their location
($\chi^2 = 20.67$; $P < 0.0000$)

Occupations' response to a continuous audible alarm:

Occupant's response	With experience of fire emergency?		Row total
	Group 1 (Yes)	Group 2 (No)	
Investigate the situation	64	56	120
Ask someone what to do	18	13	31
Ask someone what has happened	58	46	104
Call the firemen	7	1	8
Wait for further information	11	12	23
Evacuate	27	13	40
Others	0	1	1
Column total	185	142	327

insufficient evidence to show a significant difference between the responding patterns of the two groups ($P = 0.27$)

Occupants' choice of an escape route in case of fire emergency:

(a) Choice of escape route in case of fire

Choice	With experience of fire emergency?		Row total
	Group 1 (Yes)	Group 2 (No)	
Staircase	172	136	308
Both staircase and elevator	11	5	16
Others	2	1	3
Column total	185	142	327

(P = 0.31)

(b) Usage frequency of staircase

Usage	With experience of fire emergency?		Row total
	Group 1 (Yes)	Group 2 (No)	
Everyday	28	15	43
Sometimes	48	31	79
Rarely	86	71	157
Never	23	25	48
Column total	185	142	327

(P = 0.32)

(c) Reason of choosing staircase

Choice	With experience of fire emergency?		Row total
	Group 1 (Yes)	Group 2 (No)	
Familiar	10	5	15
Designated for emergency purposes	103	89	192
Closer	10	6	16
Safer	59	41	100
Others	3	1	4
Column total	185	142	327

(P = 0.62)

(d) Reason of choosing the selected staircase from a number of staircases

Choice	With experience of fire emergency?		Row total
	Group 1 (Yes)	Group 2 (No)	
Familiar	38	26	64
Closer	112	80	192
Follow others	8	12	20
Predetermined (e.g. fire drill)	24	24	48
Others	3	0	3
Column total	185	142	327

(P = 0.32)

Age-group response to a continuous audible fire alarm:

Response of three age groups to a continuous audible fire alarm

Age group	Start evacuation	First action to be taken except evacuation				Row total
		Call firemen	Notify neighbors	Collect valuables	Extinguish the fire; and others	
<30	34	58	32	33	13	170
31-50	29	58	12	19	8	126
>50	3	15	6	7	0	31
Column total	66	131	50	59	21	327

insufficient evidence to indicate that 'immediate' evacuation was age-dependent ($P = 0.25$)

Conclusion

- In general, the following behavioural responses were observed from the survey results:
 1. The majority of respondents treated an audible fire alarm as a 'warning signal' rather than 'a cue for evacuation'.
 2. An occupant might not respond to an audible fire alarm immediately.
 1. The response time to the alarm might be related to the occupant's level of anxiety and his/her experience of fire emergency.
 2. Besides evacuation, the **'first'** actions of an occupant to the alarm were **'investigate the alarm'**, **'seek more information'**, **'alert others'**, **'collect valuables'**, and **'attempt to extinguish the fire'** if there was any.

Conclusion

3. Occupants tended to select a staircase for emergency evacuation.
 - i) The choice of route did not depend on the floor on which the evacuation of an occupant started.
 - ii) Apart from the closest staircase, a familiar one would be selected by some occupants.

Conclusion

4. Experience of fire emergency might have influences on the perception of a fire alarm cue.
 - i) The results indicated that the first perception of the occupants, who had not experienced any fire emergency before, would be **a false alarm** or **a fire alarm test**.
 - ii) They would investigate the situation if only the fire alarm sustained for a few minutes.
5. For those occupants who had previous experience of fire emergency, more of them would recognize the fire alarm and evacuate immediately.
 - i) However, for all those who did not evacuate immediately, there was insufficient evidence to show a significant difference of response time between the two groups.

Conclusion

6. In the calculation of t_{RSET} , both Δt_{pre} and Δt_{trav} play an important role.

- i) Based on the above survey, Δt_{pre} was over five minutes for the majority of occupants.
- ii) This value had not included the concerns of sleeping risk and environmental unfamiliarity.

The End
Thank you