A PRE-EVACUATION BEHAVIOURAL STUDY FOR THE PEOPLE IN HIGH-RISE RESIDENTIAL BUILDINGS UNDER FIRE SITUATIONS

S.M. Lo, K.C. Lam and K.K. Yuen
Department of Building and Construction, City University of Hong Kong, Hong Kong, China

Z. Fang
Faculty of Civil Engineering, Wuhan University, China

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ABSTRACT

Safe evacuation of occupants in a building in case of emergency is a major concern for architects, building designers, building control officers, building managers, insurers, as well as the occupants themselves. In the past, the physical environment was seen merely as a factor that constrained the movements of occupants which led to studies that concentrated on flow capacities and sizes of different elements. Recent studies have revealed that the pre-evacuation psychological reaction of the people may have great influence on the evacuation pattern. People's awareness and behavioural response will affect the fire protection strategy. In Hong Kong, over 90% of people are living in multi-storey multi-ownership residential buildings. Their awareness and response to a fire incident in any apartment in their building is an important issue affecting the evacuation process. This article discusses the pre-evacuation behaviour, and by means of two post-fire surveys, illustrates the Hong Kong people's responses.

1. INTRODUCTION

The general belief is that people will panic[1] under fire situations. Over the past twenty years many researchers [1-7] have examined the human responses to fires, and have found that panic is not the usual response especially at the initial stage when the occupants have just acquired the cue. It was found that people tend to behave in a controlled and rational way in fire incidents, so long as they sustain a hope of getting out and being saved. Marchant [1] has used the term "value-added" to describe the processes leading to panic. The process can be briefly outlined in the determinating conditions: i) structural conduciveness; ii) strain; iii) anxiety; iv) precipitating factor; v) hysteria; vi) mobilization and vii) panic. The aforesaid conditions should be "added" to constitute to panic state. If one of the conditions has been controlled, a panic state is unlikely to be induced. This explains the fact that in most fire incidents people do not panic. Today's buildings are in general equipped with active fire fighting facilities and members of the public, particular in highly developed cities, have a basic familiarity with this situation. This, as well as the avoidance behavior of people will lead to a stage where rational behavior, based on facts, and not panic behavior, based on false beliefs, can be expected in a fire [1].

In view of the fact that people will normally behave in a controlled manner, they are unlikely to move immediately to the exit after they have perceived a cue. This concept indicates that the evacuation process will involve pre-evacuation behavioral responses to fires in addition to the movement process.

In Hong Kong, over 90% of people are living in multi-storey multi-ownership residential buildings. Their awareness and response to fire incidents in other flats of the same building is an important issue affecting the evacuation process. This article discusses the pre-evacuation behaviour, and by means of two post-fire surveys introduces the Hong Kong people's responses.

2. APPROACHES OF THE STUDY

The fire cases are selected because the buildings are of similar form and layout as many other residential buildings in Hong Kong. The buildings are of similar age – both have been occupied for about 10 years. At each story of the buildings, the flats are accessed through internal concealed corridor, which is also the common protected lobby of the scissors staircases and firemen's lift. A schematic diagram showing the typical layout of this type of building is shown in Appendix I.

1 Marchant [1] mentioned: "*panic is generally a dynamic situation where too many people are trying to achieve an exit through too small a space too quickly*".

Although there are many fire incidents that happen every year, there are not many fire incidents that involve evacuating large amount of people, and in buildings with similar layout and age. The living pattern is typical in Hong Kong situation and both cases happened at the midnight. In view of similarities in many aspects, the two cases are selected for our study.

In order to collect accurate information and to assist the interviewees[2] in their recall of the fire situation, interviews were conducted in person[3] shortly after the fires, and they were required to answer structured questions. It may be argued that this technique relies on what people have said rather than what they have done (i.e. less reliable for results based on autobiographical memory). However, the reasons for using this method to obtain the behavioral information of people under real fire situations are as follows:

i) This is the only possible method to obtain the behavioral information about people in real fire situations. It is difficult to observe what people have done during a real fire because it is unlikely that any building has a full CCTV system to "record" the reactions of people in each and every part of the building.

ii) If information/data is based on the observations of firemen, the data concerning the situation in the period between ignition and the arrival of the firemen may not be collected.

iii) A fire drill exercise does not reflect the real world situation.

iv) It is impossible to set fire in a building to "test" the behavioral reaction of people as this may endanger the people concerned.

3. GENERAL BACKGROUND OF THE CASES

The general descriptions of the cases are as follows:

i) *Carado Garden in Shatin (Case S)*

The fire happened at the midnight of a day in September 1997, the day after the Chinese Mid-Autumn Festival. A family in a flat on 1/F of Block 1 of the Carado Garden, while celebrating the festival, lighted up candles in the lanterns near the windows. However, they forgot to put out the candles before they went to sleep. At about 2:30 am, the heat at the bottom of the lanterns caused the lanterns to burn, but the family was asleep at that time and did not realize the incident until the fire had developed. Some children near the building noted the cue. They informed the residents, the security guard in the building and called the police.

ii) *Tai Po Centre in Tai Po (Case T)*

The incident occurred in a flat on 11/F of Block 19, Tai Po Centre at about 12:00 am in a day of November 1997. In this incident, large amount of smoke rapidly spread through the internal corridors of the building to the staircase. At the time of the incident, most of the residents in the building were asleep, and the smoke awakened them. Because of the high intensity of smoke, some of the residents escaped through the staircases to the roof instead of going down to the ultimate place of safety.

The other information about the interviewees is listed in Appendix II for information.

4. THE AWARENESS

People will start to react to an incident when they have perceived a cue, such as the fire bell, the smoke smell, noise from other people, etc. In modern multi-ownership residential buildings, people are living in fire tight cells – residential units. They are unlikely to know the activities in other units of different ownership. In such circumstance, unless people have been "informed" by the cue, they will not have any response to the incident. Such high-rise multi-ownership residential buildings are commonly constructed in Hong Kong, and the awareness of the occupants would be one of the fire safety factors in these buildings.

2 The interviewees were in "family" basis because during the interview, the members within a family had participated in providing the information. In this circumstance, more accurate results would be provided through the discussion of the individual family members.

3 The advantages of using face-to-face interviews can be summarized as: i) it provides an opportunity to establish rapport with the subject and to stimulate the trust and cooperation; ii) it provides an opportunity to help the subject in their interpretation of the questions; and iii) it allows flexibility in determining the wording and subsequence of the questions by giving greater control over the situation [8].

Whether a person will recognize a cue will depend on his/her attention to the activity that he/she is performing at that time. The degree of attention is in turn a function of "signal factor" and "motivational factor". Fig. 1 shows the stages in a fire incident, and Fig. 2 shows the influence of recognition.

Table 1 shows the results of the post-fire surveys. From Table 1, it can be seen that people have largely noted the incident from other people. Only a small percentage of people have been "notified" by the fire bell. This indicates that the nature of the cue (the signal factor) may affect the awareness of the occupants.

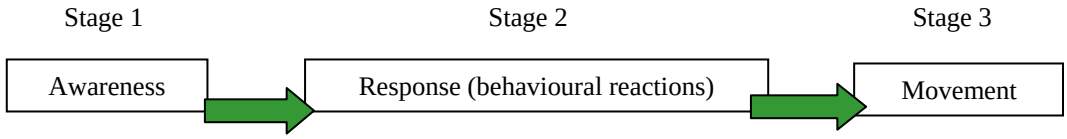

Fig. 1: Reaction stages in a fire incident

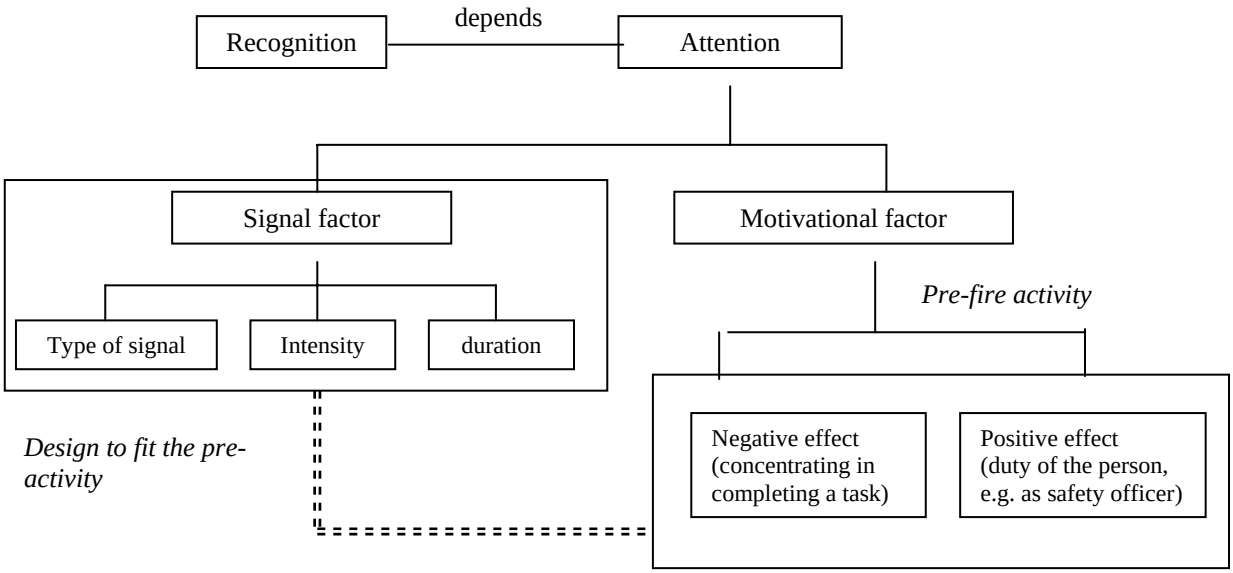

Fig. 2: Influence of recognition

Table 1: Question asked: How did you realize the fire?

	Case S		*Case T*		**Total**	
		%		*%*		**%**
(a) Informed by neighbor	7	*38.9*	7	*25.9*	**14**	***31.1***
(b) Informed by other family members	4	*22.2*	8	*29.6*	**12**	***26.7***
(c) Noise outside	7	*38.9*	1	*3.7*	**8**	***17.8***
(d) Fire alarm	0	*0.0*	5	*18.5*	**5**	***11.1***
(e) Burning smells	0	*0.0*	4	*14.8*	**4**	***8.9***
(f) Smoke	0	*0.0*	1	*3.7*	**1**	***2.2***
(g) Flame	0	*0.0*	0	*0.0*	**0**	***0.0***
(h) Heat / radiation	0	*0.0*	0	*0.0*	**0**	***0.0***
(i) Others	0	*0.0*	1	*3.7*	**1**	***2.2***

(S = Shatin case; T = Tai Po case)

It was observed that most of the residents asleep had largely been awaken by other residents e.g. neighbours and family members (Table 2 and 3 refers). Whereas, for people who were not sleeping at the time of incident, the cues received were more directly from abnormal noise, burning smell, smoke, alarm etc. It implied that such people would react faster to abnormal situations. In accordance with the results shown in Table 4, the cues and the activities people performing while the incident occurred were dependent. The Cramer's V[4] values further indicate the high degree of dependence of the two variables.

The fire bell signal appeared to have little effect on the people asleep. Perhaps, the intensity of the signal might be inadequate. In Hong Kong's multi-storey apartment buildings, people live in fire tight cells, which means that the entrance doors are fire rated doors and the enclosing walls are solid reinforced concrete structure. The properties of these elements of construction reduce the passage of sound. Accordingly, the sound level of fire bells should be observed not only at design stage, but also at post-occupation stage (i.e. maintain at adequate level).

5. BEHAVIOURAL RESPONSE

Having recognized the cue, people will go through a series of decision-making process [6-7] before deciding their action. The decision process after recognition can be shown in Fig. 3.

Table 2: Question asked: What were you doing before you had noted the fire?

	Case S		*Case T*		**Total**	
		%		*%*		**%**
(a) Sleeping	16	*88.8*	20	*74.1*	**36**	***80.0***
(b) Carrying out housework	0	*0.0*	0	*0.0*	**0**	***0.0***
(c) Others	2	*11.1*	7	*25.9*	**9**	***20.0***

Table 3: Cues Vs Pre-activities

	Sleeping						Others (e.g. Watching TV)					
	Total (T1) =			36			Total (T2) =			9		
	S	T	A = S+T	S/T1 (%)	T/T1 (%)	A/T1 (%)	S	T	B = S+T	S/T2 (%)	T/T2 (%)	B/T2 (%)
Neighbor	6	7	**13**	16.7	19.4	**36.1**	0	0	**0**	0.0	0.0	**0.0**
Family Member	5	7	**12**	13.9	19.4	**33.3**	0	1	**1**	0.0	11.1	**11.1**
Noise	5	0	**5**	13.9	0.0	**13.9**	2	1	**3**	22.2	11.1	**33.3**
Fire Alarm	0	4	**4**	0.0	11.1	**11.1**	0	1	**1**	0.0	11.1	**11.1**
Burning Smell	0	2	**2**	0.0	5.6	**5.6**	0	2	**2**	0.0	22.2	**22.2**
Smoke	0	0	**0**	0.0	0.0	**0.0**	0	1	**1**	0.0	11.1	**11.1**
Others	0	0	**0**	0.0	0.0	**0.0**	0	1	**1**	0.0	11.1	**11.1**
				44.4	55.6	**100.0**				22.2	77.8	**100.0**

Table 4: Relationship between cue and pre-activities

Statistical Analysis						
Case	**χ^2 value**	***df***	**p**	**H_o**	**Chi-sq. conclusion**	**Cramer's V**
S	3.536	2	0.20	Accepted	Independent	0.443
T	13.071	6	0.025	Rejected	Dependent	0.696
Total	16.262	6	0.01	Rejected	Dependent	0.601

4 As the sample size could not provide a conclusive indicator by using Chi-square test, Cramer's V has also been determined to provide an additional indicator.

When a person has noted the cue, he/she will attempt to validate the seriousness of the cue. In many occasions, the cue may not be clearly indicative of the seriousness of the situation or may be ambiguous. People are then required to validate the reality of the cue. They tend to assess the cues in accordance with past experience and in the form of an optimistic expectance. The optimistic expectance aspect of the response may be a direct result of the individual's concept of his/her personal invulnerability [8-10]. It is obvious that evacuation may be delayed if occupants do not perceive the cue as indicative of a dangerous situation. If the cue can itself be validated, an individual will proceed to the next step and define its seriousness. From Tables 5-7, it could be seen that the possibility of carrying out investigation would depend on the nature of the cue. If the cue were "fire alarm", "burning smell" or "smoke" (Table 6), which would be ambiguous, a person would tend to search for more information [9]. Whereas, if the threat was "told" by other persons, then the information would be clear and there would not be necessary for the person to carry out further investigation.

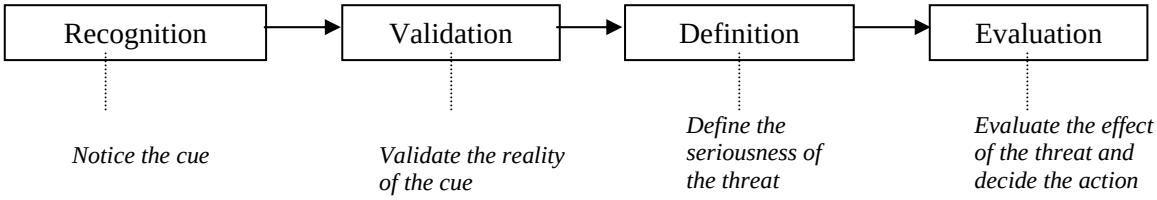

Fig. 3: Four phases of behavioural reaction [6-7]

Table 5: Question asked: Have you carried out investigation to validate the incident?

	Case S		*Case T*		**Total**	
		%		*%*		**%**
(a) Yes	13	*72.2*	10	*37.0*	**23**	***51.1***
(b) No	5	*27.8*	17	*63.0*	**22**	***48.9***

Table 6: Nature of cue and investigation

Cue	Investigation						Not Investigation					
	Total (T1) =			23			Total (T2) =			22		
	S	T	A = S+T	S/T1 (%)	T/T1 (%)	A/T1 (%)	S	T	B = S+T	S/T2 (%)	T/T2 (%)	B/T2 (%)
Neighbor	5	0	**5**	21.7	0.0	**21.7**	2	7	**9**	9.1	31.8	**40.9**
Family Member	1	2	**3**	4.3	8.7	**13.0**	3	6	**9**	13.6	27.3	**40.9**
Noise	7	0	**7**	30.4	0.0	**30.4**	0	1	**1**	0.0	4.5	**4.5**
Fire Alarm	0	4	**4**	0.0	17.4	**17.4**	0	1	**1**	0.0	4.5	**4.5**
Burning Smell	0	3	**3**	0.0	13.0	**13.0**	0	1	**1**	0.0	4.5	**4.5**
Smoke	0	1	**1**	0.0	4.3	**4.3**	0	0	**0**	0.0	0.0	**0.0**
Others	0	0	**0**	0.0	0.0	**0.0**	0	1	**1**	0.0	4.5	**4.5**
				56.5	43.5	**100.0**				22.7	77.3	**100.0**

Table 7: Relationship between nature of cue and possibility of carrying out investigation

Statistical Results						
Case	**χ^2 value**	***df***	**p**	**H_o**	**Chi-sq. conclusion**	**Cramer's V**
S	7.141	2	0.025	Rejected	Dependent	0.630
T	13.275	6	0.025	Rejected	Dependent	0.701
Total	13.427	6	0.025	Rejected	Dependent	0.546

If a person can definitely confirm the threat, he/she will proceed to define the nature and the effect of the threat. The definition process primarily consists of an attempt by the person to relate the information arising from the threat to some factors such as the qualitative nature of the threat which is usually a function of some other physical variables, such as "intensity of smoke", "intensity of flames", "thermal intensity", etc. and these variables may be related to the location of the person and the time context. Therefore, the decision making process is a dynamic process.

Normally, if the threat is ambiguous, a person will tend to assume that the threat is of mild nature. The concept of avoidance [11-12] assumes that an individual tends to ignore or deny an unexpected and unpleasant event that has happened. Some may even continue their work and ignore the cue [6,7,11]. From Table 8, it could be seen that 3 interviewees had ignored the threat after investigation in Shatin's case. If the person could define the seriousness of the threat, it is expected that he/she would take a more rational action.

With reference to Tables 9 and 10, it could be seen that people who had been carrying out "investigation" tended to alert others. Whereas, people who did not investigate the situation, in particular for the people in Tai Po's case, they tended to leave the building at once. This implied that in Shatin's case, people had defined the seriousness and many of them tended to alert others. In Tai Po's case, they noted the dense smoke, which indicated an immediate danger to the people, they had selected to leave the building immediately. The Cramer's V values, especially for the Tai Po case, indicated that the type of action of a person is affected by the investigation result, in particular seriousness could be defined.

Table 8: Question asked: What was your first action after you had noted the fire incident?

	Case S		*Case T*		**Total**	
		%		*%*		**%**
(a) Informed others	6	*33.3*	8	*29.6*	**14**	***31.1***
(b) Telephoned other people	0	*0.0*	0	*0.0*	**0**	***0.0***
(c) Dialed 999	0	*0.0*	1	*3.7*	**1**	***2.2***
(d) Attempted to extinguish the fire	0	*0.0*	0	*0.0*	**0**	***0.0***
(e) Evacuated	8	*44.4*	13	*48.1*	**21**	***46.7***
(f) Ignored	3	*16.7*	0	*0.0*	**3**	***6.7***
(g) Others	1	*5.6*	5	*18.5*	**6**	***13.3***

Table 9: The first action and investigation

First Action	Investigation						Not Investigation					
	Total (T1) = 23						Total (T2) = 22					
	S	T	A = S+T	S/T1 (%)	T/T1 (%)	A/T1 (%)	S	T	B= S+T	S/T2 (%)	T/T2 (%)	B/T2 (%)
Inform Others	5	7	**12**	21.7	30.4	**52.2**	1	1	**2**	4.5	4.5	**9.1**
Dial 999	0	1	**1**	0.0	4.3	**4.3**	0	0	**0**	0.0	0.0	**0.0**
Escape	5	0	**5**	21.7	0.0	**21.7**	3	13	**16**	13.6	59.1	**72.7**
Ignore	2	0	**2**	8.7	0.0	**8.7**	1	0	**1**	4.5	0.0	**4.5**
Get Wet Towel	1	1	**2**	4.3	4.3	**8.7**	0	1	**1**	0.0	4.5	**4.5**
Get I.D.	0	1	**1**	0.0	4.3	**4.3**	0	0	**0**	0.0	0.0	**0.0**
Close Window / Door	0	0	**0**	0.0	0.0	**0.0**	0	2	**2**	0.0	9.1	**9.1**
				56.5	43.5	**100.0**				22.7	77.3	**100.0**

Table 10: The relationship between first action and possibility of carrying out investigation

Statistical Results						
Case	**χ^2 value**	***df***	**p**	**H_o**	**Chi-sq. conclusion**	**Cramer's V**
Shatin	1.177	3	0.75	Accepted	Independent	0.256
Tai Po	21.104	5	0.001	Rejected	Dependent	0.884
Total	17.558	6	0.01	Rejected	Dependent	0.625

After an individual has defined the seriousness of the situation, he will then evaluate the effect of the threat and decide on his action (to evacuate, to fight the fire, to collect personal belongings, to inform others, to ignore the cue etc.). The process of evaluation may be described as the cognitive and psychological activities required for the individual to respond to the threat. It is the decision making stage.

When the people noted the fire incident, in the two cases, about 46% of people would evacuate (Table 8). This implies that in a high-rise apartment building in Hong Kong, many occupants may tend to evacuate once they note that there is a fire incident. Today, many ultra high-rise residential buildings (some are over 70 storeys) are constructed in Hong Kong. If most of the people in these buildings evacuate at more or less the same time, then serious congestion may happen inside the two staircases[5]. As the crowd flow inside the staircases is density dependent, the congestion may substantially reduce the crowd flow rate, and thus may affect the overall evacuation time. Accordingly, we may need to consider a suitable strategy to control the evacuation process in these buildings in order to facilitate smooth evacuation.

6. CONCLUDING REMARKS

The article discusses how the behavioural reaction of people affects their reactions under fire situations. The Hong Kong's surveys indicated that the people's reaction could be explained by the established behavioural reaction principles. Although the magnitude of the reaction rate might be differed from the rates obtained in other countries, the general reaction pattern could be similar.

It also indicated that people were largely aware of the incident through other people in the building. Not many people indicated that they were alerted by the alarm system. This may imply that the function of some existing fire alarm systems for alerting people may not be good enough for multi-storey apartment buildings.

From the survey, many people may tend to evacuate after they have noted the fire incident. People evacuating at more or less the same time may overload the staircases, especially for ultra high-rise buildings. Controlled evacuation under a suitable strategy may need to be considered for the ultra high-rise buildings, and controlled evacuation should be supported by "controlled awareness" of the occupants.

ACKNOWLEDGEMENT

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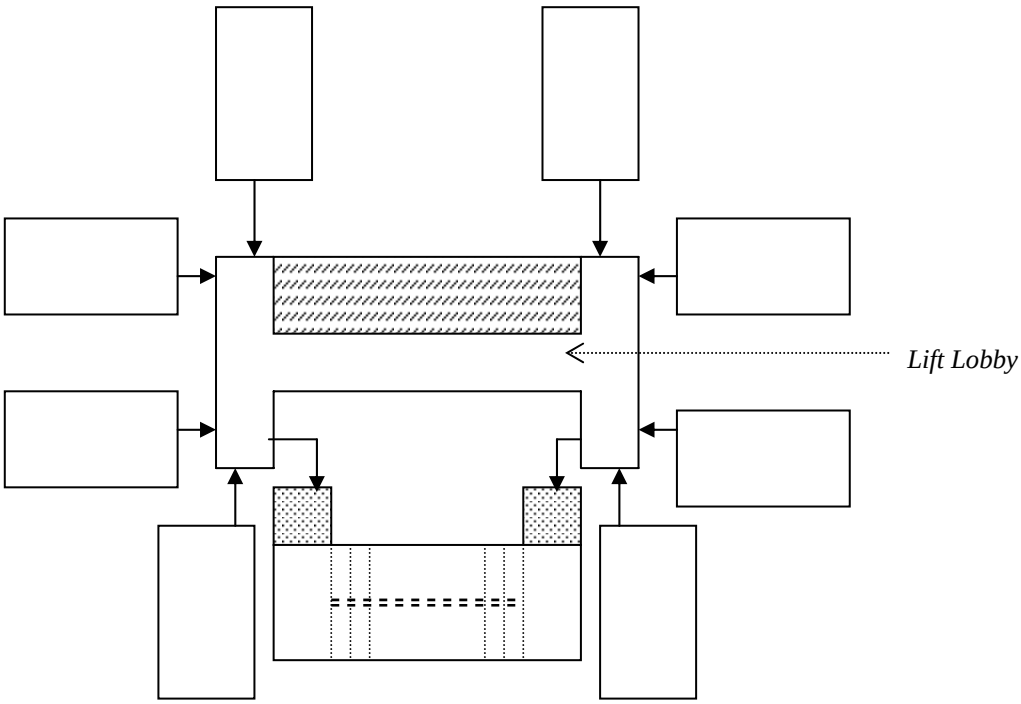
5 Many residential buildings are designed to the minimum requirement (2 staircases for building over 6-storey) prescribed in the Code of Practice on Means of Escape, Hong Kong.

APPENDIX I

Typical layout of building studied in this paper



Remarks:

- 8 flats per story
- buildings over 20 stories
- two scissors staircases sharing a common core
- lift lobby is a protected lobby, and the doors between each flat and the lift lobby are fire rated doors

Legend:

Lifts

Protected Lobby

Scissors staircases

Residential Flats

Opening/ connection

APPENDIX II

Background information about the interviewees for information

Table B1: Question asked: Were you present in the building when the incident broke out?

	Case S	*%*	*Case T*	*%*	**Total**	**%**
(a) Yes	18	*100.0*	27	*100.0*	**45**	***100.0***
(b) No	0	*0.0*	0	*0.0*	**0**	***0.0***

Personal information

Table B2(a): Age

	Case S	*%*	*Case T*	*%*	**Total**	**%**
(a) 0-20	2	*11.1*	4	*14.8*	**6**	***13.3***
(b) 21-50	13	*7.2*	17	*63.0*	**30**	***66.7***
(c) Above 50	3	*16.7*	6	*22.2*	**9**	***20.0***

Table B2(b): Gender

	Case S	*%*	*Case T*	*%*	**Total**	**%**
(a) Male	8	*44.4*	9	*33.3*	**17**	***37.8***
(b) Female	10	*55.5*	18	*66.7*	**28**	***62.2***

Table B2(c): Education background

	Case S	*%*	*Case T*	*%*	**Total**	**%**
(a) Primary education or below	5	*27.8*	9	*33.3*	**14**	***31.1***
(b) Secondary education	10	*55.5*	16	*59.3*	**26**	***57.8***
(c) Post-secondary education or above	3	*16.7*	2	*7.4*	**5**	***11.1***

Table B3: Question asked: Have you any previous experience on fire incidents?

	Case S	*%*	*Case T*	*%*	**Total**	**%**
(a) Yes	3	*16.7*	3	*11.1*	**6**	***13.3***
(b) No	15	*83.3*	24	*88.9*	**39**	***86.7***

Table B4: Question asked: Have you received any training on evacuation?

	Case S	*%*	*Case T*	*%*	**Total**	**%**
(a) Yes	4	*22.2*	10	*37.0*	**14**	***31.1***
(b) No	14	*77.8*	17	*63.0*	**31**	***68.9***

Table B6: Question asked: How many years have you lived in this building?

	Case S	*%*	*Case T*	*%*	**Total**	**%**
(a) Less than 2 years	0	*0.0*	4	*14.8*	**4**	***8.9***
(b) 2 to 5 years	3	*16.7*	9	*33.3*	**12**	***26.7***
(c) More than 5 years	15	*83.3*	14	*51.9*	**29**	***64.4***

Table B7: Do you think the fire-fighting equipment and fire-protection facilities in this building are adequate?

	Case S		*Case T*		**Total**	
		%		*%*		**%**
(a) Enough	13	*72.2*	25	*92.6*	**38**	***84.4***
(b) Not enough	5	*27.8*	2	*7.4*	**7**	***15.6***

Table B8: Question asked: Do fire incidents always happen in the building that you are living?

	Case S		*Case T*		**Total**	
		%		*%*		**%**
(a) Yes	0	*0.0*	0	*0.0*	**0**	***0.0***
(b) No	10	*55.6*	27	*100.0*	**37**	***82.2***
(c) Sometimes	8	*44.4*	0	*0.0*	**8**	***17.8***