



A Post-fire Survey on the Pre-evacuation Human Behavior

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Abstract. A delay in the pre-evacuation reaction may be one of the reasons causing occupants to be 'trapped' in a dangerous zone. Under fire situations, people are found to behave differently in that some may start evacuation immediately, some may ignore the fire alarms and engage in their activities and some others may participate in fighting the fire. These behavioral reaction patterns are influenced by some factors, such as occupant characteristics, building characteristics and fire characteristics. The purpose of this study is to investigate the pre-evacuation behavior of occupants under fire and explore the associations between these factors and the human behavior. To obtain the human behavioral information in real fire, a post-fire survey for a multi-storey office building fire in a major city in Mainland China was carried out with the assistance of local fire professionals. Some of the possible factors that might influence the occupants' actions at recognitions and response stage were examined. It was reckoned that the behavioral reaction at recognition and response stage was mainly dependent on the human characteristics and building characteristics except the fire characteristics. The results also implied that pre-evacuation time was typically influenced by the occupant characteristics.

Keywords: pre-evacuation human behavior, post-fire survey, pre-evacuation time

1. Introduction

Compliance with the fire safety requirements in the prescriptive building and fire codes would no doubt reduce the fire risk by ensuring the standard of fire service installations and providing adequate means for safe evacuation in the building design. However, the success of these measures depends heavily on the behavior of building occupants in case of fire. When fire occurs, people are found to behave differently, for example, some may move to the exits immediately, some may ignore the alarms and keep working for a while, some may prefer to stay in a room and wait for the assistance from the fire brigade and others may attempt to fight the fire. In some fire situations, it has been found

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that people are unlikely to move immediately to the exit after they have noticed the cue, such as the fire alarm signal. This indicates that the evacuation process may be delayed due to the behavioral responses to fires. Therefore, how occupants will respond to a fire has aroused much more concerns for architects, building designers, building control officers, building managers, insurers, as well as the occupants themselves.

There are many false expectations regarding how occupants actually behave in case of fires. One assumption is the panic behavior, which assumes that people will panic and try to rush to an exit. In fact, such extreme behavior seldom occurs in a fire. Recent studies have demonstrated that panic is not the usual response of people, who will act rationally [1–4]. To understand the evacuation process under fire, it is necessary to investigate the behavioral responses pattern of people.

With regard to the analysis of pre-evacuation process, it is necessary to consider the time delay to initiate the movement action and behavior patterns of occupants when they have recognized the occurrence of fire. People's behavioral reactions may be influenced by their cognition and perception to the environment, which in turn may be influenced by the factors related to occupant characteristics, building characteristics and fire characteristics. The difficulty in explaining people's response in fire may be due to the lack of adequate data to identify the relative importance factors influencing the decision making process of people under various fire environments. By far, the studies on pre-evacuation human behavior have been conducted in four ways, that is, evacuation drill including announced [5] and unannounced [6, 7], post-fire survey [8, 9], laboratory investigation [10] and computer simulation [11]. Obviously, drill exercises can provide an opportunity for examining how people would response to certain type of scenarios under controlled situations. However, it is noted that human behavior in actual fire situations may be extremely different from that in normal situations or notional fire situations. It is mainly due to the mental stress when people respond to the real fire situations [12]. Without any cues of smoke or flame, people's behavioral responses may be considered as a representation of the situation where the fire was located in a remote area or on other floor of the building and the only sign of the fire would be the warning message from the fire alarm system. Of all the investigation approaches, post-fire survey may be regarded as the only possible approach to obtain the people's behavioral information in real fire situations.

This article reports a comprehensive post-fire survey for a high-rise building fire in a major city in Mainland China—Xi'an. This may be the first systematic post-fire survey in the region that can provide the information for fire researchers or fire professionals to understand the behavioral reaction of the local people. The information was collected using a questionnaire distributed to the occupants of each unit in the building with the help of local fire professionals. In order to acquire the first-hand information, the survey was conducted within two-week time after the fire. Based on the survey results, this study aims to identify the major factors that may influence on the local people's behavior in the pre-evacuation

stage and the reported delayed time prior to leaving the building has also been examined.

2. Background of the High-rise Building Fire

In the early afternoon of a day in 2002, a fire broke out in a high-rise office building, with shopping mall at the lower few floors, at Xi'an. The fire originated from the cooling tower placed externally on the podium level. Around the fire bed, plastic and rubber goods were piled and ignited causing dense smoke spread. Soon after fire broke out, the window next to the burning cooling tower was broken and the smoke and flame spread into the interior space. As sprinklers were installed next to the window, water spray retarded the further spread of smoke and flame into the interior of the building. Total evacuation of the building was initiated. Eventually, the fire was extinguished by the firemen and no casualty was reported.

3. Data Collection

The information was collected by face-to-face, with the assistance of local fire professionals, and interviewees were required to answer the structured questions in the form of a questionnaire. Since Chinese is the mother tongue of all the respondents, the questionnaire was set in Chinese (an English translation has been given in Appendix I for reference). A total of 650 interviews were performed and 595 valid replies were collected.

The structured questions aimed at collecting the following information related to human behavior:

Part I: Personal information including gender, education and evacuation training experience.

Part II: Initial situation when fire occurred, such as occupant location, pre-fire activities and cues of fire perception.

Part III: Human response to fire before the start of movement, including first action, feeling, estimated pre-evacuation time and so on.

Part IV: Evacuation situations such as estimated movement time, estimated waiting time at the exit and so forth.

4. The Survey Results

Pre-evacuation process was divided into *Recognition stage* and *Response stage* [5, 6]. Recognition stage begins at an alarm or cue and ends with the first response. During this period, occupants realize that there is a threat and begin to respond. Response stage begins at the first response and ends with the commencement of moving towards the exits. During this phase, occupants carry out a range of activities before they begin to move to an exit.

4.1. Behavioral Reactions at the Recognition Stage

The delay times at the recognition stage are taken by occupants to decide what is happening, investigate if there really is a fire or take some fire-fighting actions once the warning information is assessed. These actions can be categorized into five action classes. Their definitions are listed as follows:

Searching information by occupants themselves refers to occupants attempting to reassess the fire situation and location by him/her.

Discussion with other occupants involves the validation process of occupants by seeking verbal reassurance from other colleague(s) or nearby individuals.

Alerting other people includes informing the occurring fire incident to their colleagues, friends or neighbors.

Calling the fire brigade indicates to dial the emergency call number directly (Fire phone number is 119 in China) or contact the management office for emergency help.

Fighting the fire represents the occupants may collect a fire extinguisher or other things to fight the fire in some way (Table 1).

From the above table, it was found that about half of the occupants reported to alert other people when they noticed the warning information. The results indicated that these occupants were sure about the fire incident according to the fire cues perceived, such as heavy smoke and fire bell signal. Indeed, it was reported that the smoke generated by the fire was so dense that occupants could easily aware of the fire. Thus, most of the occupants did not proceed to gather more information for the validation of warning. There were relatively rare occupants to select *searching information by occupants themselves* and *discussion with other occupants* as their choice at the recognition stage. However, what they concerned at first was the safety of their colleagues, friends and neighbors. After they recognized the potential danger, they would like to inform the others about the dangerous situation as their first choice.

The second choice of action was to call the fire brigade for assistance. The fire aroused the people's anxiety and calling the fire brigade may be considered as a defensive action which can help to reduce the fear. In this case, about 22.5% of occupants sought help from the fire brigade.

Table 1
Summary of Actions at the Recognition Stage

Actions	Frequency	Percentage (%)
Searching information by occupants themselves	50	8.7
Discussion with other occupants	54	9.3
Alerting other people	291	50.3
Calling the fire brigade	130	22.5
Fighting the fire	53	9.2
Total	578	

Unspecified answers not included in the table

4.2. Behavioral Reactions at the Response Stage

After an individual recognized the seriousness of the situation, he/she will then evaluate the effect of the threat and determine the action respond to the threat. The response process has involved the following four possible actions:

Collecting personal belongings involves occupants collecting their valuable items or important documents before they start to evacuate.

Instructing others to leave refers to alerting their colleagues, friends or neighbors to evacuate immediately, helping the elder or handicapped persons escape with them.

Sheltering in place indicates to select a small interior room with no or few windows and take refuge there.

Carrying out immediate evacuation means that occupants start their movement once they recognize the fire.

With reference to the summarized actions at the response stage (Table 2 refers), approximate half of the occupants selected *carrying out immediate evacuation* as their choice when they realized that a real fire occurred. This indicated that many occupants tended to evacuate once they noted that there was a fire. The second choice was to alert other occupants and help the elder and handicapped persons escape from the fire. It indicated that people were helpful and obliging under fire situations, which was similar to the behavioral pattern at the recognition stage.

4.3. Pre-movement Time

In this study, the pre-evacuation time was taken to be the delay time starting from the perception of fire cues and ended when the people commenced to move to the exit. However, it was difficult to record the accurate pre-evacuation time of individuals in a real fire. Accordingly, the respondents were required to recall the pre-evacuation process and gave an estimation of the delay time. The estimated pre-evacuation time was categorized in four classes: 0~2, 2~5, 5~10 and >10 min. The results are summarized in the following figure (Figure 1).

It was noted that most of the occupants (about 80%) spent less than 5 min in preparing for the evacuation. The result implied that occupants would tend to escape in a short time if they perceived the cue suggesting the presence of a fire.

Table 2
Summary of Actions at the Response Stage

Actions	Frequency	Percentage (%)
Collecting personal belongings	28	4.9
Alerting others to leave	214	37.2
Sheltering in place	56	9.7
Carrying out immediate evacuation	278	48.3
Total	576	

Unspecified answers not included in the table

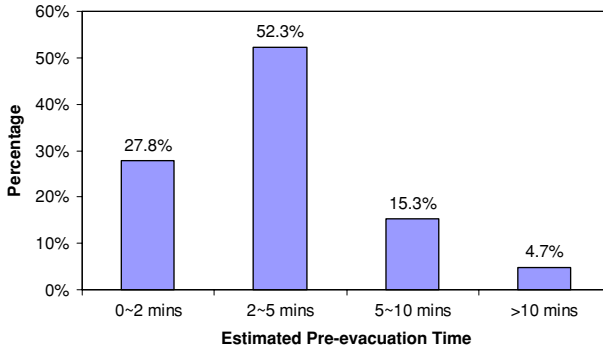


Figure 1. Summary of estimated pre-evacuation time.

5. Data Analysis

Due to the categorical nature of collected data, non-parametric measures of correlation and statistical tests have been adopted to test their association. Contingency table analysis is a popular non-parametric estimation measure used to determine whether dependence exists between the two qualitative variables for a given significant level [13, 14]. To perform the contingency table analysis, the SAS System Software (Ver 8.0) has been utilized.

5.1. Factors Influencing Human Behavior at the Recognition Stage

5.1.1. Gender. See Table 3. The results of χ^2 test indicates that there exists a significant relationship between *Gender* and *Actions* at the recognition stage for a given significant level ($\alpha = 0.05$). It implied that the response of male to the fire incident would be different from that of female. Both male and female would select *alerting other people* as their most frequently reported action when they firstly perceived the cue of the dangerous situation. However, the second most reported action of male was *calling the fire brigade*, which had very small difference with the third and fourth reported actions. The least reported action of male was *discussion with other occupants*. Nevertheless, the second most reported action of female differed significantly with the other three actions. The least reported action of female was *searching information by them*. The difference between male

**Table 3
Gender vs. Actions at the Recognition Stage**

Gender	Actions at the recognition stage				
	Searching information by occupants themselves	Discussion with other occupants	Alerting other people	Calling the fire brigade	Fighting the fire
Male	16	8	56	18	14
Female	33	46	229	110	39

$$\chi^2 = 10.1008; p\text{-value} = 0.0388; \text{Cramer's } V = 0.1332$$

and female may be due to the discrepancy of gender in that, in Chinese society, male may be more self-confident than female. In the circumstance, male would prefer to investigate the fire incident by themselves rather than discuss with other occupants. Comparatively, female would like to be told about the situation rather than search the information by themselves (Table 4).

5.1.2. *Education Level.* The χ^2 test *p*-value indicates that *Education Level* has significant association with people’s reactions at the recognition stage (Table 5 refers). The difference between *searching information by occupant themselves* and *fighting the fire* is obvious. It was found that people of lower education level would have more preference to select fighting the fire by them than that of higher education level. The occupants with higher education level would firstly identify the fire information such as fire size, fire location, severity and so on, then decide what they should respond to the fire (Table 6).

5.1.3. *Emergency Training.* See Table 7. The χ^2 test results indicate that the relationship between *Emergency Training* and *Actions* at the recognition stage is significant for a given significant value ($\alpha = 0.05$). The first reported action of respondents with different emergency training level was about the same—alerting other people when they perceive the fire cues. However, the ranking of the other actions is significantly different, which is list as follows (Table 8).

Table 4
Summary of Sequence of Actions

Actions	Male	Female
Searching information by occupants themselves	3	5
Discussion with other occupants	5	3
Alerting other people	1	1
Calling the fire brigade	2	2
Fighting the fire	4	4

Table 5
Education Level vs. Actions at the Recognition Stage

Education Level	Actions at the recognition stage				
	Searching information by occupants themselves	Discussion with other occupants	Alerting other people	Calling the fire brigade	Fighting the fire
Secondary level or below	29	41	217	96	46
Post-secondary diploma or above	20	13	69	33	6

$\chi^2 = 11.7897$; *p*-value = 0.0190; Cramer’s *V* = 0.1438

Table 6
Choice Ranking of Actions of Respondents with Different Education Level at the Recognition Stage

Actions	Secondary level or below	High diploma or above
Searching information by occupants themselves	5	3
Discussion with other occupants	4	4
Alerting other people	1	1
Calling the fire brigade	2	2
Fighting the fire	3	5

Table 7
Emergency Training vs. Actions at the Recognition Stage

Emergency Training	Actions at the recognition stage				
	Searching information by occupants themselves	Discussion with other occupants	Alerting other people	Calling the fire brigade	Fighting the fire
No training	4	1	8	3	0
Know a little from the experiences in daily life	19	12	71	49	20
Participant in professional fire training	26	40	203	76	33

$$\chi^2 = 19.3199; p\text{-value} = 0.0132; \text{Cramer's } V = 0.1308$$

Table 8
Choice Ranking of Actions of Respondents with Different Emergency Training at the Recognition Stage

Actions	No training	Know a little from the experiences in daily life	Participant in professional fire training
Searching information by occupants themselves	2	4	5
Discussion with other occupants	4	5	3
Alerting other people	1	1	1
Calling the fire brigade	3	2	2
Fighting the fire	5	3	4

5.1.4. *Initial Feeling.* The χ^2 test p -value illustrates that there exists a significant relationship between *initial feeling* and *human response at the recognition stage* for a given significant level ($\alpha = 0.05$) (Table 9 refers). It was noted that if the occupants were extremely nervous, none of them would fight the fire. When decision

Table 9
Initial Feeling vs. Actions at the Recognition Stage

Initial Feeling	Actions at the recognition stage				
	Searching information by occupants themselves	Discussion with other occupants	Alerting other people	Calling the fire brigade	Fighting the fire
Extremely fear and act in a fluster	3	3	7	6	0
Very nervous	4	0	17	12	0
Nervous	14	18	98	39	12
Calm	16	17	92	27	17
Calm and make appropriate decision	12	13	76	45	24

$\chi^2 = 28.5037$; p -value = 0.0275; Cramer's $V = 0.1116$

Table 10
Choice Ranking of Actions of Respondents with Different Anxiety Feeling at the Recognition Stage

Actions	Extremely fear and act in a fluster	Very nervous	Nervous	Calm	Calm and make appropriate decision
Searching information by occupants themselves	3	3	4	5	5
Discussion with other occupants	3	4	3	3	4
Alerting other people	1	1	1	1	1
Calling the fire brigade	2	2	2	2	2
Fighting the fire	5	4	5	3	3

made under calm condition, one of their major choices would be to fight the fire by themselves. The action sequence of respondents with different anxiety feeling is summarized in the following table (Table 10).

5.1.5. *Occupant Location.* See Table 11. The χ^2 test results indicate that occupant location has significant association with the actions at the recognition stage. It was found that occupants on the fire floor would select fighting the fire and alerting other people as their most frequently reported response to the fire. However, the occupants at the non-fire floors would regard the fire fighting choice as their least preference. The results demonstrated that the occupants would engage in controlling the fire rather than evacuated immediately when they were near the fire origin. The difference of choice of actions between occupants on fire floor and non-fire floor is summarized as follows (Table 12).

Table 11
Occupants' Location vs. Actions at the Recognition Stage

Occupant location	Actions at the recognition stage				
	Searching information by occupants themselves	Discussion with other occupants	Alerting other people	Calling the fire brigade	Fighting the fire
Non-fire floor	46	47	270	121	39
Fire floor	3	2	14	7	14

$\chi^2 = 35.6561$; p -value < 0.0001; Cramer's $V = 0.1780$

Table 12
Choice Ranking of Actions Between Different Occupants' Locations at the Recognition Stage

Actions	Non-fire floor	Fire floor
Searching information by occupants themselves	4	4
Discussion with other occupants	3	5
Alerting other people	1	1
Calling the fire brigade	2	3
Fighting the fire	5	1

5.1.6. *Pre-fire Activities*. See Table 13. The χ^2 test p -value shows that there exists a significant relationship between *pre-fire activities* and *actions* at the recognition stage. It was found that occupants taking a nap would select fighting the fire as their most frequently reported choice. The results may be due to the fact that they were not engaged in any activity when they noticed the alarm signal. The pre-fire activities of the occupants, in particular the office activities, may cause them to choose *alerting other people* as the most frequently reported action. The details of choice of actions are summarized in the following table (Table 14).

Table 13
Pre-fire Activities vs. Actions at the Recognition Stage

Pre-fire activities	Actions at the recognition stage				
	Searching information by occupants themselves	Discussion with other occupants	Alerting other people	Calling the fire brigade	Fighting the fire
Snooze	1	0	3	2	5
Watching TV	3	4	12	10	3
Working	39	44	263	101	39
Others	6	5	9	8	3

$\chi^2 = 32.1164$; p -value = 0.0013; Cramer's $V = 0.1383$

Table 14
Choice Ranking of Actions of Occupants Engaged in Different Pre-fire Activities when they Perceived the Fire Cues

Actions	Snooze	Watching TV	Working	Others
Searching information by occupants themselves	4	3	4	3
Discussion with other occupants	5	5	3	4
Alerting other people	2	1	1	1
Calling the fire brigade	3	2	2	2
Fighting the fire	1	3	4	5

5.1.7. *Cues of Fire Perception.* See Table 15. The results of χ^2 test indicate that the relationship between *cues of fire perception* and *actions* at the recognition stage is significant for a given significance level ($\alpha = 0.05$). It was noted that the largest share of respondents reported to carry out the fire fighting action when they were choked by the smoke. This implied that the situation was urgent to the occupants and their first response was to prevent the fire developing to an uncontrollable condition. If the fire was relatively remote to the occupants, they would have more time to response to the fire. Their choice when they perceive the fire cues would be very different. The choice of actions of occupants when they perceive different fire cues is summarized as follows (Table 16).

5.2. Factors Influencing Human Behavior at the Response Stage

5.2.1. *Gender.* The p -value of χ^2 test at a significance value ($\alpha = 0.05$) indicates that there is no significant relationship between gender and actions at the response stage (Table 17).

Table 15
Cues of Fire Perception vs. Actions at the Recognition Stage

Cues of Fire Perception	Actions at the recognition stage				
	Searching information by occupants themselves	Discussion with other occupants	Alerting other people	Calling the fire brigade	Fighting the fire
Choked by smoke	0	1	2	3	5
Smell something burning	2	1	11	22	7
Interrupt by the outside noise	15	12	52	26	4
Informed by others	25	34	183	61	30
Informed by the warning system	7	3	19	6	5
See the smoke	1	2	23	8	2

$\chi^2 = 66.7826; p\text{-value} < 0.0001; \text{Cramer's } V = 0.1708$

Table 16
Choice Ranking of Actions of Occupants at the Recognitions Stage
when they Perceive Different Fire Cues

Actions	Actions at the recognition stage					
	Choked by smoke	Smell something burning	Interrupt by the outside noise	Informed by others	Informed by the warning system	See the smoke
Searching information by occupants themselves	5	4	3	5	2	5
Discussion with other occupants	4	5	4	3	5	3
Alerting other people	3	2	1	1	1	1
Calling the fire brigade	2	1	2	2	3	2
Fighting the fire	1	3	5	4	4	3

Table 17
Gender vs. Actions at the Response Stage

Gender	Actions at the response stage			
	Collecting personal belongings	Instructing others to leave	Sheltering in place	Carrying out immediate evacuation
Male	7	46	14	44
Female	21	164	42	229

$\chi^2 = 4.3674$; p -value = 0.2244; Cramer's $V = 0.0878$

5.2.2. *Education Level.* For a given significance level ($\alpha = 0.05$), the χ^2 test p -value describes that there is no significant association between *Education Level* and *Actions* at the response stage. This indicated that no matter which education level the occupants had, their selected actions at the response stage would be similar (Table 18).

Table 18
Education Level vs. Actions at the Response Stage

Education level	Actions at the response stage			
	Collecting personal belongings	Instructing others to leave	Sheltering in place	Carrying out immediate evacuation
Secondary level or below	18	172	43	195
High diploma or above	9	41	13	77

$\chi^2 = 6.4645$; p -value = 0.0911; Cramer's $V = 0.1067$

Table 19
Emergency Training vs. Actions at the Response Stage

Emergency training	Actions at the response stage			
	Collecting personal belongings	Instructing others to leave	Sheltering in place	Carrying out immediate evacuation
No training	0	3	1	12
Know a little from the experiences in daily life	12	42	28	85
Participant in professional fire training	13	166	25	176

$\chi^2 = 32.2434$; p -value < 0.0001 ; Cramer's $V = 0.1692$

5.2.3. *Emergency Training.* The results of χ^2 test indicate that *Emergency Training* may cause significant influence on the response stage behavioral reactions. It was noted that the frequency of selecting the action of instructing others to leave and carrying out immediate evacuation increased with the emergency training level. However, the frequency of other two actions varied largely between occupants with no training and occupants with a little fire experience, while the frequency varied small between occupants with a little fire experience and with professional fire training (Table 19).

5.2.4. *Initial Feeling.* See Table 20. The χ^2 test p -value means that there exists significant relationship between *initial feeling* and the actions at the response stage. This implied that occupants with different level of nervous feelings would have different actions when they noticed the fire. The difference in choice of actions of occupants at the response stage is summarized as follows (Table 21).

Table 20
Initial Feeling vs. Actions at the Response Stage

Initial Feeling	Actions at the response stage			
	Collecting personal belongings	Instructing others to leave	Sheltering in place	Carrying out immediate evacuation
Extremely fear and act in a fluster	4	4	3	9
Very nervous	3	8	4	19
Nervous	8	63	18	88
Calm	7	54	17	91
Calm and make appropriate decision	4	83	13	70

$\chi^2 = 29.4282$; p -value = 0.0038; Cramer's $V = 0.1312$

Table 21
Choice Ranking of Actions of Occupants with Different Initial Feeling at the Response Stage

Actions	Extremely fear and act in a fluster				Calm and make appropriate decision
	Very nervous	Nervous	Calm		
Collecting personal belongings	2	4	4	4	4
Instructing others to leave	2	2	2	2	1
Sheltering in place	4	3	3	3	3
Carrying out immediate evacuation	1	1	1	1	2

5.2.5. *Occupant Location.* The results of χ^2 test indicate that *occupants' location* would have no significant influence on actions at the response stage. When they noticed the fire, the priority of action of occupants on every floor in the building is similar (Table 22).

5.2.6. *Pre-fire Activities.* See Table 23. The χ^2 test *p*-value describes that there exists significant association between *Pre-fire activities* and *Actions* at the response stage. If occupants were *taking a nap (snooze)* while they perceived the fire cues,

Table 22
Occupants' Location vs. Actions at the Response Stage

Occupant location	Actions at the response stage			
	Collecting personal belongings	Instructing others to leave	Sheltering in place	Carrying out immediate evacuation
Non-fire floor	27	198	66	266
Fire floor	12	123	24	175

$\chi^2 = 6.25$; *p*-value = 0.1097; Cramer's *V* = 0.0763

Table 23
Pre-fire Activities vs. Actions at the Response Stage

Pre-fire activities	Actions at the response stage			
	Collecting personal belongings	Instructing others to leave	Sheltering in place	Carrying out immediate evacuation
Snooze	1	0	5	5
Watching TV	0	11	9	11
Working	21	193	35	240
Others	6	6	4	13

$\chi^2 = 55.6572$; *p*-value < 0.0001; Cramer's *V* = 0.1820

they would prefer to carry out immediate evacuation or take refuge in place. When they were watching TV or committing in office works at the start of fire, the occupants would choose the action of *instructing others to leave or evacuate* as their preference. As a result, occupants engaged in different pre-fire activities would perform different actions when they recognized the fire. The difference in action choice of occupants in various pre-fire activities is summarized as follows (Table 24).

5.2.7. *Cues of Fire Perception.* The χ^2 test results indicate that *cues of fire perception* has no significant relation with *actions* at the response stage. Even if they perceived the fire cues by different means, the possibility of choosing an action may be similar (Table 25).

5.2.8. *Actions at the Recognition Stage.* See Table 26. The χ^2 test *p*-value indicates that actions taken by the occupants at the recognition stage will have significant influence on what actions they will do at the response stage. It was noted that most of the occupants would carry out immediate evacuation as their first choice when they noticed the fire except those engaged in fighting the fire. The difference in action selection at the response stage is summarized in the following table (Table 27).

Table 24
Choice Ranking of Actions of Occupants Engaged in Different Pre-fire Activities when they Recognized the Fire Cues

Actions	Taking a rest	Watching TV	Working	Others
Collecting personal belongings	3	–	–	2
Instructing others to leave	–	1	2	2
Sheltering in place	1	3	3	4
Carrying out immediate evacuation	1	1	1	1

Table 25
Cues of Fire Perception vs. Actions at the Response Stage

Cues of fire perception	Actions at the response stage			
	Collecting personal belongings	Instructing others to leave	Sheltering in place	Carrying out immediate evacuation
Choked by smoke	1	0	4	6
Smell something burning	2	12	8	21
Interrupt by the outside noise	6	44	11	48
Informed by others	17	124	27	167
Informed by the warning system	1	19	4	15
See the fire ignition	1	13	3	20

$\chi^2 = 22.1788$; *p*-value = 0.1032; Cramer's *V* = 0.1135

Table 26
Actions at the Recognition Stage vs. Actions at the Response Stage

Actions at the recognition stage	Actions at the response stage			
	Collecting personal belongings	Alerting others to leave	Sheltering in place	Carrying out immediate evacuation
Searching information by occupants themselves	5	11	3	30
Discussion with other occupants	6	15	5	27
Alerting other people	9	121	14	140
Calling the fire brigade	4	42	22	60
Fighting the fire	3	23	12	14

$\chi^2 = 48.3265$; p -value < 0.0001; Cramer's $V = 0.1687$

Table 27
Choice Ranking of Actions of Occupants with Different Human Behavior at the Recognition Stage when they Recognized the Fire

Actions	Searching information by occupants themselves	Discussion with other occupants	Alerting other people	Calling the fire brigade	Fighting the fire
Collecting personal belongings	3	3	4	4	4
Instructing others to leave	2	2	2	2	1
Sheltering in place	4	4	3	3	3
Carrying out immediate evacuation	1	1	1	1	2

5.3. Factors Influencing Estimated Pre-evacuation Time

5.3.1. *Gender.* See Table 28. The results of χ^2 test describe that gender would have significant influence on the pre-evacuation time. It was found that the estimated pre-evacuation time of female was much shorter than that of male. This implied that ladies might be more likely to evacuate immediately than men. The

Table 28
Gender vs. Estimated Pre-evacuation Time

Gender	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
Male	20	55	24	10
Female	139	240	62	17

$\chi^2 = 14.2783$; p -value = 0.0025; Cramer's $V = 0.1587$

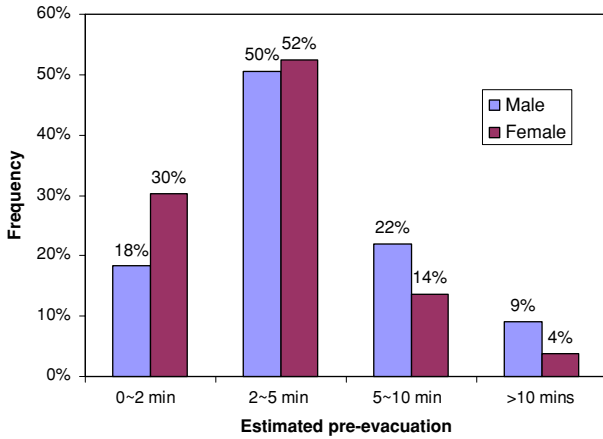


Figure 2. comparison of pre-evacuation time of male and female.

comparison of pre-evacuation time of male and female is illustrated as follows (Figure 2).

5.3.2. *Education Level.* The χ^2 results show that there exist no significant association between *education level* and *pre-evacuation time*. It was found that most of the occupants would spend less than 5 min in preparing for the movement (Table 29).

5.3.3. *Emergency Training.* The χ^2 test *p*-value indicates that *emergency training* has significant influence on the *estimated pre-evacuation time*. It was found that people with substantial emergency training might have a shorter pre-evacuation time. This implied that emergency training might help the occupants to make the decision for evacuation (Table 30).

5.3.4. *Initial Feeling.* The results of χ^2 test indicate that *initial feeling of occupants* has significant influence on the *estimated pre-evacuation time* for a given significant level ($\alpha = 0.05$). A slightly larger share of respondents at ‘calm’ condition had a shorter pre-evacuation time (Table 31).

Table 29
Education Level vs. Estimated Pre-evacuation Time

Education Level	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
Secondary level or below	119	234	60	16
High diploma or above	36	66	27	10

$\chi^2 = 5.9022$; *p*-value = 0.1165; Cramer’s *V* = 0.1019

Table 30
Emergency Training vs. Estimated Pre-evacuation Time

Emergency training	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
No training	3	6	3	3
Know a little from the experiences in daily life	29	96	31	12
Participant in professional fire training	122	196	52	11

$$\chi^2 = 25.2905; p\text{-value} = 0.0003; \text{Cramer's } V = 0.1497$$

Table 31
Initial Feeling vs. Estimated Pre-evacuation Time

Reported initial feeling	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
Extremely fear and act in a fluster	3	14	2	1
Very nervous	9	16	9	1
Nervous	54	78	30	14
Calm	58	81	23	7
Calm and make appropriate decision	34	110	24	2

$$\chi^2 = 30.2669; p\text{-value} = 0.0025; \text{Cramer's } V = 0.1330$$

5.3.5. *Occupant Location.* The χ^2 test results indicate that *occupants' location* would have significant influence on the *estimated pre-evacuation time* (Table 32).

5.3.6. *Pre-fire Activities.* The p -value of χ^2 test describes that there exists no significant association between *pre-fire activities* and *estimated pre-evacuation time*. The delay time distribution was nearly the same even if the occupants engaged in different pre-fire activities. However, the uneven distribution of pre-fire activities might have some effect on the analysis (Table 33).

Table 32
Occupants' Location vs. Estimated Pre-evacuation Time

Occupant location	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
Non-fire floor	157	278	83	48
Fire floor	4	28	5	2

$$\chi^2 = 8.48; p\text{-value} = 0.1554; \text{Cramer's } V = 0.0879$$

Table 33
Pre-fire Activities vs. Estimated Pre-evacuation Time

Pre-fire activities	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
Snooze	0	10	1	0
Watching TV	8	17	6	0
Working	141	251	73	25
Other Activities	8	12	8	1

$\chi^2 = 12.8401$; p -value = 0.1700; Cramer's $V = 0.0873$

Table 34
Cues of Fire Perception vs. Estimated Pre-evacuation Time

Cues of fire perception	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
Choked by smoke	2	6	3	0
Smell something burning	12	24	6	1
Interrupt by the outside noise	23	61	20	4
Informed by others	102	173	44	17
Informed by the warning system	9	21	8	2
See the fire ignition	10	19	7	2

$\chi^2 = 8.8778$; p -value = 0.8838; Cramer's $V = 0.0717$

5.3.7. *Cues of Fire Perception.* The χ^2 test results indicate that *cues of fire perception* would have no significant influence on the *estimated pre-evacuation time*. The pre-evacuation time of occupants perceived different fire cues had similar distribution (Table 34).

5.3.8. *Actions at the Recognition Stage.* The p -value of χ^2 test shows that there is no significant association between the *actions taken by the occupants at the recognition stage* and *estimated pre-evacuation time*. It was noted that the variance in actions at the recognition stage would have no influence on the delay time to start the evacuation (Table 35).

5.3.9. *Actions at the Response Stage.* The χ^2 results indicate that the *actions taken by the occupants at the response stage* would have significant influence on the *estimated pre-evacuation time*. This implied that different reactions at the response stage would cause the time required for occupants to make the decision to evacuate differently (Table 36).

Table 35
Actions at the Recognition Stage vs. Estimated Pre-evacuation Time

Actions at the recognition stage	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
Searching information by occupants themselves	15	19	12	3
Discussion with other occupants	12	30	7	4
Alerting other people	87	142	40	13
Calling the fire brigade	32	67	21	6
Fighting the fire	10	35	6	1

$$\chi^2 = 13.2532; p\text{-value} = 0.3509; \text{Cramer's } V = 0.0887$$

Table 36
Actions at the Response Stage vs. Estimated Pre-evacuation Time

Actions at the response stage	Estimated pre-evacuation time			
	0~2 min	2~5 min	5~10 min	> 10 min
Collecting personal belongings	4	13	9	2
Instructing others to leave	73	107	20	7
Sheltering in place	14	28	11	3
Carrying out immediate evacuation	66	147	44	15

$$\chi^2 = 19.8008; p\text{-value} = 0.0192; \text{Cramer's } V = 0.1083$$

6. Conclusions

Base on the post-fire survey results of a high-rise commercial building fire at a major city in Mainland China, we have examined the interrelationship of the categorized factors and people's behavioral reactions at the recognition stage and the response stage, and identify the factors influencing the delay time in the pre-evacuation process. It was found that

- People's behavioral reactions at the recognition stage may be dependent on numerous factors including human characteristics such as education level, building characteristics (e.g. pre-fire activities—the usage of the building) and fire characteristics (flame, smoke spread, etc.).
- People may determine their actions on the basis of their individual experience and psychological status when they recognize the fire incident. Moreover, their actions at the recognition stage may also influence their actions at the response stage (i.e. before the start of evacuation).
- The time lapse between the actuation of fire warning system and the start of movement towards the exit is typically influence by the occupants' characteristics. It may be attributed to the fact that the pre-evacuation time varies with different individual.

Table 37
Summary of the Factors Related to the Human Behavior and
Pre-evacuation Time in the Pre-evacuation Process

Factors		Actions at the recognition stage	Actions at the response stage	Pre-evacuation time
Occupant Characteristics	Gender	√		√
	Education level	√		
	Emergency training	√	√	√
	Initial feeling	√	√	√
	Occupant location	√		√
Building Characteristics	Pre-fire activities	√	√	
Fire Characteristics	Cues of fire perception	√		
Human Behavior	Human action at the recognition stage	N/A	√	
	Human action at the response stage		N/A	√

Note: √ indicates that the row variable has significant influence on the column variable

- The results also illustrate that the actions taken by occupants at the response stage will influence the delay time in the pre-evacuation process.

Table 37 summarizes the associations of certain human factors and people's reactions in fire. This study serves as an initial attempt to acquire people's behavioral reactions under fire in China. Previous studies [15–17] have indicated that safe evacuation in buildings is a significant attribute of fire safety in buildings. Pre-evacuation behavior of people is a major component of evacuation process. It is worth initiating more works to examine the reactions of the occupants in different types of buildings, such as domestic, industrial and etc., under fire.

Moreover, a study on people's behavior under fire should not be applied to other populations unless the study has been designed and implemented as a multi-cultural study. Such a study should include selected matched identical populations relative to age, gender, primary groups and occupations. Also, only similar fire situations relative to the occupancies involved and the characteristics of the fire situation imposed threat to the occupants may have different effect on people's reactions.

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Appendix

Questionnaire of Human Behavior and Evacuation Analysis in a Building Fire (English Translation)

Name		Gender		Address		Tel.	
Part I - Personal information							
Index	Question	Options					
1	Age	☞ A. 6~12					
		☞ B. 13~17					
		☞ C. 18~45					
		☞ D. 46~60					
		☞ E. Above 60					
2	Gender	☞ A. Male					
		☞ B. Female					
3	Education Level	☞ A. Primary or below					
		☞ B. Secondary					
		☞ C. High diploma, undergraduate or above					
4	Do you have any emergency evacuation training or education?	☞ A. Never					
		☞ B. Know a little from the experiences in daily life					
		☞ C. Participant in professional fire and escape training					
Part II – Initial situation at the start of the fire (Recognition Stage)							
Index	Question	Options					
5	What was your location when fire occurred?	☞ A. Non-fire floor					
		☞ B. Fire floor					
		☞ C. Compartment of fire origin					
		☞ D. Staircases					
		☞ E. Corridors					
		☞ F. Rooms					
		☞ G. Others(please specify)					
6	What were you doing when fire occurred?	☞ A. Sleeping					
		☞ B. Housework or watching TV					
		☞ C. Working					
		☞ D. Others(please specify)					
7	How about your health and mobility?	☞ A. Be drunk and lost of awareness					
		☞ B. Feel illness and can walk without assistance					
		☞ C. Cannot walk without assistance					
		☞ D. Healthy					
8	How did you recognize the fire?	☞ A. Choked by smoke					
		☞ B. Smell something burning					
		☞ C. Interrupted by the outside noise					
		☞ D. Informed by others					
		☞ E. Informed by the warning system					
		☞ F. See the fire ignition					
		☞ G. Others (Please specify)					

**Appendix
continued**

Name		Gender		Address		Tel.	
Part III - Human response to fire before the start of movement							
Index	Question	Options					
9	What was your feeling when you recognized the fire?	☐ A. Extremely fear and act in a fluster					
		☐ B. Very stressful					
		☐ C. Mild stress					
		☐ D. Calm					
		☐ E. Calm and make appropriate decision					
10	Which action did you take when you recognized the fire?	☐ A. Searching information by occupants themselves					
		☐ B. Discussion with other occupants					
		☐ C. Alerting other people					
		☐ D. Calling the fire bridge					
		☐ E. Fighting the fire					
11	What did you think when you recognized the fire?	☐ A. My life is in danger					
		☐ B. My property will be lost					
		☐ C. My life is not in danger					
		☐ D. I can reach the safe place					
12	Which action did you take when you identified the fire?	☐ A. Collect the belongings					
		☐ B. Help others to evacuate					
		☐ C. Hold position and take refuge					
		☐ D. Evacuate immediately					
13	How long did you take from fire recognition to evacuation	☐ A. less than 2 mins					
		☐ B. 2~5 mins					
		☐ C. 5~10 mins					
		☐ D. More than 10 mins					
14	How did you select the evacuation route?	☐ A. Follow the crowd					
		☐ B. Use the commonly used lift					
		☐ C. Use the staircases					
		☐ D. Others (please specify)					
Part III – Detailed information during the evacuation process (Response Stage)							
Index	Question	Options					
15	What did you think in the evacuation process?	☐ A. It is hopeless to remain alive					
		☐ B. Be calm and try to escape from the building					
		☐ C. Keep moving and I am sure to reach the safe place.					
16	How was the congestion condition?	☐ A. Crowded (More than 1 persons per square)					
		☐ B. Moderate					
		☐ C. Few persons					
17	How long will you wait at the exit?	☐ A. less than 2 mins					
		☐ B. 2~5 mins					
		☐ C. more than 5 mins					

Appendix continued

Name		Gender		Address		Tel.		
18	How was the condition of evacuation route?							☐ A. It is clear
								☐ B. It is obscure
								☐ C. It is too dark to move
19	How long did you take to find the exit?							☐ A. less than 2 mins
								☐ B. 2~5 mins
								☐ C. more than 5 mins
20	Were you familiar with the evacuation route?							☐ A. Yes
								☐ B. No
21	How long did you take to escape from the building?							☐ A. less than 5 mins
								☐ B. 5~10 mins
								☐ C. More than 10 mins

Remark: the survey was conducted in Chinese

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