Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 52 (2013) 290 – 296

Procedia Engineering

www.elsevier.com/locate/procedia

Pre-evacuation Human Reactions in Fires: An Attribution Analysis Considering Psychological Process

Mu H L[a,b,c], Wang J H[a,b,c], Mao Z L[a], Sun J H[a,c,*], Lo S M[b,c,*], Wang Q S[a]

[a]State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei 230026, China
[b]Department of Civil and Architectural Engineering, City University of Hong Kong, Hong Kong, China
[c]USTC-CityU Joint Advanced Research Centre (Suzhou), Suzhou 215123, China

Abstract

Through reviewing a large quantity of relevant literature and investigating into a few representative fire cases, some typical pre-evacuation human behavior under fire situations are discussed and defined preliminary. Furthermore, interactional factors that influence human reactions before evacuation in fires are demonstrated systematically. On the basis of this theory, attribution analysis is also conducted on psychological process to fires of human in pre-evacuation time, which includes the first phase of risk perception and the second one of decision-making, while combining the effects from psychological deviation and culture background. Moreover, a probabilistic description method of pre-evacuation human behavior concerning psychological process in fires is proposed in this paper for an exploration. The results may assist in completing the theory of human psychological reactions and emergency behaviors in pre-evacuation time of fire situations, and also providing scientific reference for those coping with unconventional emergencies and developing the measures of intervention.

Selection and peer-review under responsibility of School of Engineering of Sun Yat-sen University

Keywords: human-fire interactions; attribution analysis; pre-evacuation human behavior; psychological process; probabilistic describing method

Nomenclature

T_s	start time of evacuation in fire process (s)
B	human behavior
P	psychological factor
E	environmental factor
P_x	probability of factor X (including conditional probability)
I	emergency incident (indicating fire incident in this paper)
S	certain specific surrounding involving emergency
H	human factor (including the sub-factors as inherent character and relevant experience)

1. Introduction

As one of unconventional emergencies, fire with its harmfulness, regularity and coping style is concerned by many scientists. Moreover, research on human evacuation in fires is a complicated, interdisciplinary and very significant problem. When fires occur, in order to guarantee safety of evacuees, RSET (required safe egress time) should be less than ASET (available safe egress time). In addition, the start time of evacuation T_S is an important part of RSET. Here, we know that during fires, evacuation start time T_S is determined by many kinds of factors. For this reason, the numerical value of T_S is uncertain. However, it can be found that T_S has a close relationship with human reactions including psychological process

* Corresponding author. Tel.: +86-551-360-6425, +852-3442-7683.
E-mail address: sunjh@ustc.edu.cn, bcsmli@cityu.edu.hk.

Selection and peer-review under responsibility of School of Engineering of Sun Yat-sen University
doi:10.1016/j.proeng.2013.02.142

before evacuation through investigation. When unconventional emergencies occur, human ability for risk perception and decision-making will deviate according to specific surrounding and pressure environment. As a result, the proper reaction of human, which is supposed to behave, is affected and change. Literature [1] indicated that emergent psychological and behavioral scientific task is one of the five key problems of unconventional public emergency management. Through focusing on human psychology and behaviors before evacuation in fires, the research on evacuation start time and the whole evacuation process will make great progress.

In the relevant research field, which is about human psychological reactions for risk event, some scientists have obtained several significant results. Langford [2] developed a psychological model for forecasting human risk perception and preference. Slovic [3] stated that three basic dimensionality of human risk perception: fear risk, unknown risk and the individual quantity of facing a particular risk. In addition, because of the crisis of SARS virus all over China, the research on human psychology and behaviors has been paid more attention by native scientists. Shi [4] established a predicted model of human risk perception against SARS incident. At the same time, he indicated that negative information would make people have higher risk perception than positive information. Xie [5] discovered that human psychological mode can be predicted to a certain degree by risk characteristics, relying on family, their knowledge of SARS, willingness, conformity and so on.

Through observing the scene of fires, analyzing the data of human behaviors from video record and carrying out investigation with questionnaires, research on human psychology and behaviors can be conducted. Qualitative analysis method is easy to operate and of significance when investigative results are reliable and sample size is sufficient. However, because fires are unconventional and sudden, it is difficult to obtain accurate data in time. Compared with the research for foreign countries and people, research for Chinese psychological reactions and behaviors is insufficient. Moreover, it is very necessary that appropriate quantitative method should be adopted for quantifying the influencing factors of psychology and behavior and improving the existing evacuation model. In this paper, through review of a large quantity of relevant literature and analysis of cases of fire accident, human behaviors in fires and the influencing factors, especially including psychological deviation, are researched. On the basis of this, a probabilistic describing method of human psychology and behaviors in fires is proposed.

2. Pre-evacuation human behaviors in fires

When fires occur, behavioral reactions of human are affected by many factors, which are very complex. In the research field of human behavior before evacuation in fires, after Maryland University investigated the survival of one fire accident first [6], more and more attentions have been paid into this research. In Wood's investigation [7], when people encountered the fire, 15% chose to extinguish the fire first, 13% raised the fire alarm, while only 9.5% immediately attempted to evacuate. Sime [8] claimed that people usually validate the danger in the first instance, instead of starting to evacuate immediately in fire emergencies. Pauls [9] observed that in a building fire, human behavior mainly consists of five aspects: not moving, putting out the fire, informing other people, finding more information and evacuating. On the basis of these references, when fires occur, human reactions before evacuation can be generally concluded as follows:

- Confirm information of fires (Pre-reaction: If the cue is ambiguous, people may search for more information to confirm. However, after this process, people may also behave other action.)
- Try to extinguish fires
- Inform other people or alert
- Dress or collect property
- Start to escape (evacuate or jump out)
- Maintain original status or ignore information
- Wait for rescuing and shelter

To be different with classical philosophical hypothesis, human behavioral reactions in fires tend to be improper. Consequently, the situation that people evacuate immediately in fires is just ideal. Though there are many uncertain factors in fire incidents, the tendency of human behavior can be inferred through investigating and analyzing. Proulx [10] found that people who are under five or above sixty-five years old need more time before starting to evacuate through investigating the survival in one fire. Sekizawa [11] carried out an investigation into the reason for starting to evacuate for sixty-eight survival in a high-rise building fire, which is shown in table 1 as the following.

Table 1. Reason for evacuation in one high-rise building during a fire [11]

Reason	Percentage

Smoke in the room	10%
Fire in the veranda	1%
Be persuaded by others	34%
No answer	9%
Others	46%

In order to obtain the data of Chinese situation, SM Lo conducted a series of fire investigation in an early period. The investigation into the fires in two high-rise residential buildings in Hong Kong in 1997 was conducted [12]. These high-rise buildings are Carado Garden in Shatin (S) and Tai Po Centre in Tai Po (T). Because of similar building structure and time when fire occurred (at midnight), these two cases are researched comprehensively. Table 2 illustrates the relationship between investigating and first action of human in these two cases of fires. There are twenty-three people (T1) who had carried out an investigation and twenty-two people (T2) who had not. Among T1, twelve people (52.2%) chose to inform others immediately, and only five people (21.7%) evacuated immediately. On the other hand, sixteen people from T2 (72.7%) chose to evacuate immediately. It could be seen that people who did not investigate the situation, in particular for the people in T case, they tended to leave the building at once. In literature [13], investigation into the relationship between initial feeling of five hundred and seventy people altogether and estimated pre-evacuation time during the fire that occurred in a high-rise building in Xi'an in 2002 is stated. Through X^2 test, the resulting value of 30.2669 indicate that initial feeling of occupants has significant influence on the estimated pre-evacuation time for a given significant level (α = 0.05), which demonstrates the people of calm initial feeling trended to start evacuating in a less time comparing with the people felt nervous initially.

Table 2. The relationship between investigating and first action of human in fires of case S&T [12]

First action	Investigation (T1=23)						Not investigation (T2=22)					
	S	T	A(S+T)	S/T1	T/T1	A/T1(%)	S	T	B(S+T)	S/T1	T/T1	B/T1(%)
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**
Evacuate	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**

In most cases, human behavior can be assumed as a function of psychology and physiology. Furthermore, the developing process of fires and the essential safety of system can be mappinged by these factors respectively. During fires, before behaving, there are two important processes, which are risk perception and decision-making. Subsequently, the mechanisms of behavior performed and adjusted according to feedback are initiated. As a matter of fact, evacuating behavior is just one of many behaviors that may be chosen by people. In addition, the judgment and decision of human can not avoid deviation in emergency conditions. For this reason, human behaviors in fires possess uncertainty. Hence, the key problem of evidence, approach and deviation avoiding for human deciding requires further research.

3. Attribution analysis of human psychological process in Fires

3.1. Influencing factors of human behavior in fires

As mentioned, human behavior under fire situations can be assumed as the function of physiology and psychology. Meanwhile, as subfunction, these two variables are also mappinged by many factors, such as heat, smoke, noise and toxicity with the developing of fires, and the characteristic of system, which is illustrated in the Fig 1. In fires, people who have impairment need more time in the process of reacting and evacuating than unimpaired people. The temporal status includes disease, sleep, alcohol or drug. At the same time, the high temperature, dense smoke, noise and toxic gas from fires will influence and aggravate physiology and psychology of human. To the psychological factor, there are many research and investigation, which concern the gender, educational level, profession and relevant experience of interviewees. Through further analysis, it can be discovered that character and relevant experience of human mainly affect the risk perception and

decision-making. Moreover, the character here is a variable, which is not only determined by individual will and cultural background, but also changing with individual emotion and psychological deviation.

In this paper, the physiological conditions are assumed as accordant and sound. Attributing means analyzing and concluding the reason of human behavior. Experimental social psychologist Heider [14] claimed that human reaction to environment is determined by his understanding of environmental stimulus. Furthermore, human behavior can be attributed to personal stress and/or environment stress. To the object of attributing research, Kelly [15] proposed cube theory (three-dimensional attribution theory) from cognitive mechanism, which consists of three aspects:

- The person who behave the action.
- External stimulus or other factors.
- The environment.

With respect to this type of research mode, Malle [16] adopted the mode from the process of attributing human behaviors as following:

- Behavior observing.
- Intention inferring.
- Reason for this intention.
- Historical background.

On the basis of these theories, combining psychological deviation and cultural background, analysis on attribution of human reactions in fires concerning psychological process is conducted in this paper.

3.2. Risk perception and decision-making

When one incident occurs, the first psychological reaction of human before behavior is a cognitive process. Hayes [17] indicated that this cognitive process included perceiving, recalling and thinking. To the emergencies such as fires, the cognitive process before behavior is exactly the perception of the risk. Risk incident is defined as a kind of signal in the theory of Slovic [18]. Its feature, propagation condition and process will influence the receiving and explaining of human. Moreover, there are processing, outputting and feedback after risk perception in the effect of the signal in the whole system. Feedback means summarizing, evaluating and then dynamically regulating reaction. Outputting means the reaction that human behave in fires. Processing means the inferring and decision-making of human before behaving. Accordingly, the influencing factors in fires for risk perception and decision-making are individual character and the surrounding. Consequently, human behavior is determined by the interaction among these factors. Furthermore, as three key aspects, familiarity for the fire incident, threatening by the fire and human character are observed. Two extreme situations in fires are assumed in Table 3, which are used for illustrating the influence by three factors.

Table 3. Extreme situations of influencing risk perception and decision-making in fires

Situation	(A)	(B)
Surrounding	There is a distance between human and fire. The harm from fire has not hurt human.	Fire or other incidental harm will or have hurt human.
Incident feature	The cue, information and development tendency of fire is unambiguous.	The cue of fire occurring is ambiguous. The information and development tendency are difficult to understand.
Human character	Have utility experience. Received relevant training. Can keep clam.	Have not any experience. Did not receive relevant training. Ignore the fire or do not reaction. Feel nervous.
Possible result	Risk perception, decision-making and behavior are proper.	Risk perception, decision-making and behavior are improper.

In the two situations, human physiological conditions are assumed to be ideal. However, the scale of fire is not considered, because even in a small fire, the surrounding that may cause hurt can also appear.Through comparing and analyzing the hypothetical factors in the situation (A) from Table 3, conclusions can be drawn as following:

- When one ideal factor completely fails, human can still behave properly in all probability.
- However, when two or three ideal factors completely fail, it is difficult for human to behave properly.

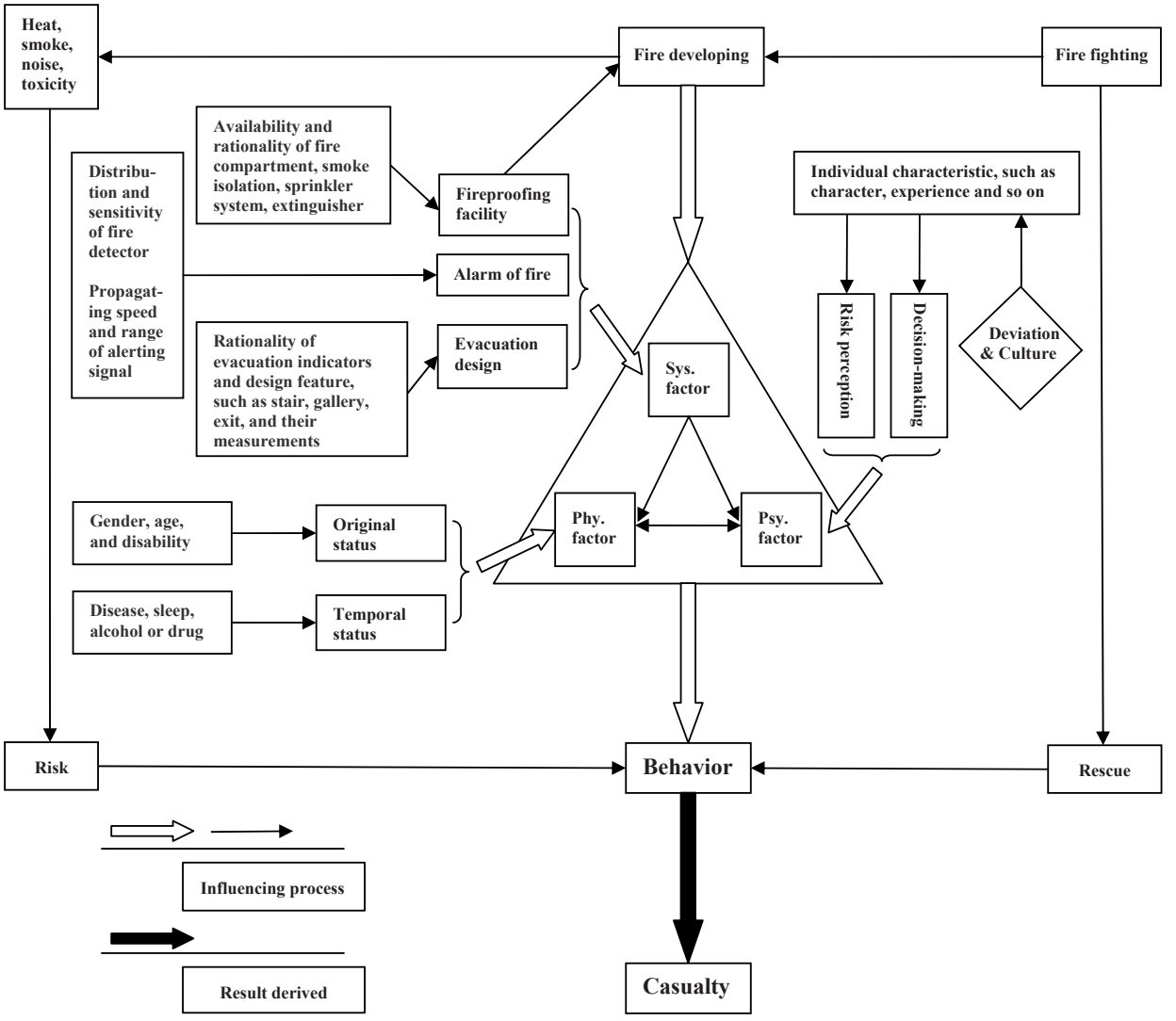

Fig. 1. Illustration of Attribution of human behavior and the influencing factors in fires (Sys. = systemic; Phy. = physiological; Psy. = psychological)

3.3. Psychological deviation and cultural background

Risk incident is commonly a series of discordant signal. Kahnemen [19] claimed in his prospect theory that the decision of human in uncertain condition might refer to the familiar mode in mind, instead of deciding rationally as the hypothesis of rational man asserts. Especially in a pressured environment, human are more likely to cope with crisis by the past similar experience and ignore other new feasible methods.

However, if people can not handle the problem with past coping style in fires, they will lose balance in psychology, which includes confused, anxious, depressed, radical and panic. In view of cognitive psychology and behavioral science, in this situation, risk perception and decision-making of human will deviate seriously, so as to result in improper behaviors. For this, in order to keep as safe as possible in fires, human should try their best to break through the limit of inherent coping style in mind and avoid all kinds of deviation. On the basis of theories of psychology, there are several types of deviation, such as representative, availability, anchoring in judgment process and framing effect [20]. All the deviations have negative impact for human risk perception and decision-making.

- Firstly, though fire incident has small probability, if a person does not have relevant experience about fires, it is difficult to have understanding. For these reasons, he may be optimistic excessively and not know exactly what to do or overreact.
- On the contrary, people who had relevant experience about fires are possible to have an exaggerated risk perception because of availability and its deviation.
- People commonly dislike ambiguity, so when fires occur, the phenomenon that wasting time to verify the information of fires is very frequent.
- As a result of that people dislike loss, the feeling of losing is more intense than obtaining. Therefore, people trend to risk their life to save property and extinguish fire.
- Due to the framing effect, the different pattern of expression by alerts or other people may cause deviation for judging and decision-making of human.
- Influenced by anchoring in judgment process from films and television programs, jumping from a high building for avoiding the harm of fires is possible.

Additionally, referred to cultural background, there are familism and moralism, which are very common for Chinese people. On one hand, more people can be rescued in some situation. However, on the other hand, the evacuation start time may be delayed, more people may go back to the fires, and the evacuating speed of group may become slower. Moreover, Chinese people are not good at conducting counterfactual thinking [21], which means can not imagine a nonexistent situation. For this reason, adequate attention may not be obtained from fire training for Chinese people.

4. Probabilistic describing method of pre-evacuation human behavior in fires

In view of the complexity and lack of systematic analysis of attribution, the research on uncertainty of human behavior in fires is still a kind of description. Literature [22] summarized five input variables, such as age, experience, initial action, the way of obtains information and initial position. The conclusion from adaptive neural network demonstrated that the result were close to the real value. Literature [23] cited the equation as following, which indicated that human behavior was determined by the internal psychological factor and the environmental factor exteriorly.

$$B = f(P \times E) \tag{1}$$

In fires, human psychology and behavior is a stochastic process. Consequently, it can be defined as a series of probability algorithm. Through it can not be completely corresponding with Bayes' formula; it may also indicate essential Probability among stochastic variables [24]. On the basis of it, a probabilistic describing method of human psychology and behaviors before evacuation in fires is proposed as following:

$$P_B = P_{(I,S,H)} \tag{2}$$

In Equation (2), P_B stands for the probability of one human behavior appearing. Furthermore, H includes the factors of character c and experience e. As a result of c and e are independent event, the relationship is presented in Equation (3).

$$P_{(H)} = P_{(c|H)} \times P_{(e|H)} \tag{3}$$

Through the feature of emergency incident, individual factor and the specific situation of surrounding, human behavior can be reflected effectively. As I、S、H are pairwise independence and not independent event, after analyzing Equation (2) and Equation (3), Equation (4) can be obtained:

$$P_B = P_I \times \frac{P_{(S|I)}}{P_{(S,I)}} \times \frac{P_{(H|S,I)}}{P_{(H,I)}} = P_I \times \frac{P_{(S|I)}}{P_{(S,I)}} \times \frac{P_{(c|H,S,I)} \times P_{(e|H,S,I)}}{P_{(H,I)}} \tag{4}$$

In Equation (4), P_I is the probability of one fire incident occurring, which can be obtained from the danger identified research and risk evaluating of one building. $P_{(S|I)}/P_{(S,I)}$ is the probability of the specific surrounding appearing from all of the surroundings in this fire. It can be calculated through the statistic of fire load and fire spreading research. $P_{(H|S,I)}/P_{(H,I)}$

stands for the probability of people who are familiar with the fire incident and the close-by surrounding at a certain extent from all the people involved. At the same time, there are $P_{(c|H,S,I)}$ and $P_{(e|H,S,I)}$, which contained in the $P_{(H|S,I)}$. It has a meaning that in these parts of people, the probability of the specific kinds of people appearing who have some character and who have some degree of experience about the fire incident. To researching and solving practical issues, in order to conduct quantitative analysis, a series of sequential weight of $P_{(c|H,S,I)}$ and $P_{(e|H,S,I)}$ can be setting from the most advantageous to the most disadvantageous. As an exploration for human behavior before evacuation in fires, the probabilistic describing method takes three aspects of factor into account. However, it still needs to be improved in future research.

5. Concluding remarks

In this paper, through discussing about human behavior before evacuation in fires, research is conducted into attribution analysis of human reactions considering psychological process to fires, which include risk perception and decision-making, combining with psychological deviation and cultural background. Moreover, a probabilistic describing method of pre-evacuation human behavior concerning psychological process in fires is proposed. In the future research, establishing a model from this probabilistic method will make the descriptive and semi-quantitative theory more accurate. When fires and other unconventional emergencies occur, the result can provide theoretical and scientific reference for those coping with unconventional emergencies and developing the measures of intervention.

Acknowledgements

The study is supported by National Natural Science Foundation of China (Grant No. 91024025), the Research Grant Council of Government of the Hong Kong Administrative Region, China (No. CityU118708), the Key Technologies R&D Program of China During the 12th Five-year Plan Period (Grant No. 2012BAK13B01) and the Fundamental Research Funds for the Central Universities (Grant No. WK2320000014).

References

[1] Fan, W. C., 2007. Advisement and Suggestion to Scientific Problems of Emergency Management for Public Incidents, Bulletin of National Natural Science Foundation of China 21, p. 71.
[2] Langford, I. H., Rosemary, J. D., Georgiou, S., Bateman, I. J., 2000. A Cognitive Social Psychological Model for Predicting Individual Risk Perceptions and Preferences, CSERGE Working Paper.
[3] Slovic, P., 1987. Perception of Risk, Science 236, p. 280.
[4] Shi, K., et al., 2003. Rational Characteristic and a Prediction Model for Psychological Behavior of People in seventeen cities in the Crisis of SARS, Chinese Science Bulletin 7, p.1378.
[5] Xie, X. F., Zheng, R., Xie, D. M., and Wang, H., 2005. Analysis on Psychological Panic Phenomenon of SARS, Acta Scicentiarum Naturalum Universitis Pekinesis 41, p. 628.
[6] Bryan, J. L., 1957. A Study of the Survivors Reports on the Panic in the Fire at the Arundel Park in Brooklyn, Maryland, 1/29/56, Fire Protection Curriculum, University of Maryland, College Park, Maryland.
[7] Wood, P. G., 1980. A Survey of Behavior in Fires, Fires and Human Behaviour, Chichester: John Wiley & Sons, p. 83.
[8] Sime, J., 1992. Human Behaviour in Fires, Summary Report. Report No. 45, Building Use & Safety Research Unit, School of Architecture, Portsmonth Polytechnic, UK, p. 385.
[9] Pauls, J., 1999. A Personal Perspective on Research Consulting and codes/standards Development in Fire-related Human Behaviour. 1969+1999, with an emphasis on space and time factors, Fire and Materials 23, p. 265.
[10] Proulx, G., 1995. Evacuation Time and Movement in Apartment Buildings, Fire Safety Journal 24, p. 229.
[11] Sekizawa, A., Ebihara M., Notake, H., 1999. Occupants' Behaviour in Response to the High-rise Apartments Fire in Hiroshima city, Fire and Materials 23, p. 297.
[12] Lo, S.M., Lam, K.C., Yuen, K.K., Fang, Z., 2001. A Pre-evacuation Behavioural Study for the People in a High-rise Residential Building under Fire Situations, International Journal on Engineering Performance-Based Fire Codes 2, p. 143.
[13] Zhao, C.M., Lo, S.M., Liu, M., Zhang, S.P., 2009. A Post-fire Survey on the Pre-evacuation Human Behavior, Fire Technology 45, p. 71.
[14] Heider, F., 1944. Social Perception and Phenomenal Causality, Psychological Review 51, p. 358.
[15] Kelly, H. H., 1973. The Processes of Causal Attribution, American Psychologist 28, p. 107.
[16] Malle, B. F., 2001. Attribution Processes, International Encyclopedia of the Social and Behavioral Sciences 14, Developmental, Social , Personality, and Motivational Psychology; Section editor N. Eisenberg, p. 913.
[17] Hayes, N., 1991. Introduction to Cognitive Processes, London: The British Psychological Society, p. 23.
[18] Slovic, P., 1999. Trust, Emotion, Sex, Politics, and Science: Surveying the Risk-Assessment Battlefield, Risk Analysis 19, p. 689.
[19] Kahneman, D., Tversky, A., 1979. Prospect Theory: An Analysis of Decisions under Risk, Econometrica 47, p. 313.
[20] Sun, D. Y., 2007. Public Emergency and Behavioral Decision-making. Beijing: Social Sciences Academic Press, p. 39.
[21] Peng, K. P., 2008. Emergency culture and psychological game, New Capital 6, p. 16.
[22] Zhang, P. H., Chen, B. Z., Lo, S.M., 2005. Personal Decision Behavior before Emergency Evacuation, Journal of Northeastern University (Natural Science) 26, p. 179.
[23] Xiao, G. Q., Wen, L. M., Chen, B. Z., Wang, H., 2002. Human Behaviour Reliability Model of the Building Fire, Journal of Northeastern University (Natural Science) 23, p. 761.
[24] Peng, K. P., Liao, Q. J., 2009. Culture and the Attribution Process and Probability Models: An Exploration, Social Sciences in China 6, p. 31.