An Overview of Research on "People-Fire Interactions"

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ABSTRACT

In this paper, the author describes the recent trend of researches on how people move against a fire, especially those on human behavior for evacuation, classifying them by theme, method, and countermeasures. Many recent researches have applied a simulation model in parallel with increasingly sophisticated contents; however, the author stresses the importance of not posing the eventual goal of each research by misapplication. Further, with the recent increase in studies by researchers such as psychologists, a trend which is much appreciated, the author expects researches in this field will be promoted further through closer commucations.

INTRODUCTION - Necessity and Importance of This Research

It is assumed that the relation between people and fire started its history as early as the appearance of human beings. This paper overviews the present situation of research on the correlation between the violence to people caused by fire and people's protecting efforts against fire to minimize damage, focusing on the recent trend of research on evacuation, directions of future research development and on expectations.

To clarify the necessity and importance of countermeasures to minimize damage, especially casualties, caused by fire, a simple flow chart is presented to identify the role and characteristics of various measures in the whole fire-protection scheme, as shown in Figure 1 below.

If any one of countermeasure-chains shown in Figure 1 is always available to work completely, safety can be maintained, or restored with least damage even when a fire breaks out. However, since any one measure cannot be 100% reliable in reality, generally, a few of them must be combined to achieve the intended goal. For the purpose of fire protection for buildings as well as minimizing casualties and property damage caused by fire, a most effective (i.e., highly reliable and economic) plan is eventually required.

Table 1 presents two major groups of countermeasures, classified into the "physical countermeasures" using equipment and apparatus for fire protection, and the "human countermeasures" emphasizing personal attention and behavior.

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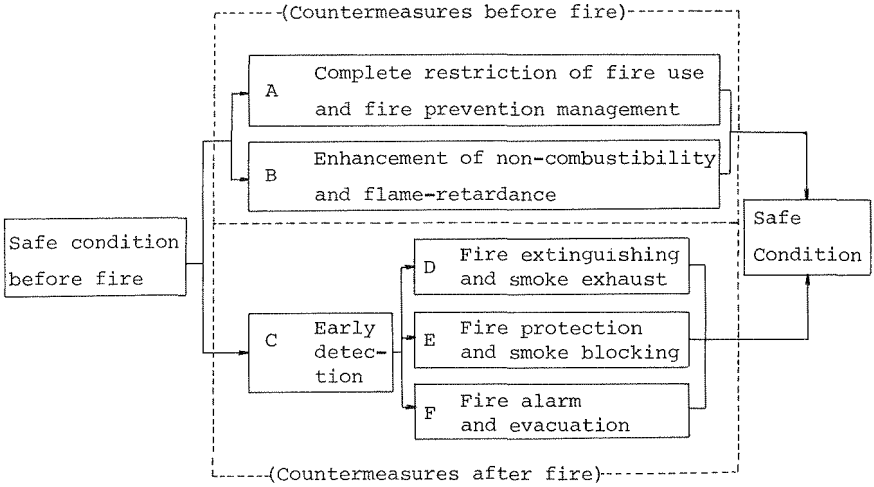
Fig. 1 Flow Chart of Countermeasures against Fire



As shown in Figure 1 and Table 1 above, the field of physical countermeasures has been upgraded through automatization by taking advantage of recent technical innovation. On the other hand, there still exists another field requiring human involvement, which cannot be substituted by physical means, as described in A and F of Figure 1 and (a) and (f) of Table 1. (However, the starred "Actions by firemen" will be taken into account separately.)

In future, more emphasis should be put on research into "human countermeasures" among others, especially on solution of problems concerning with human psychology and behavior in case of emergency.

RECENT TREND OF RESEARCHES

Research on evacuation, which is the most important part of the study of human behavior in fire, was initiated by Dr. Kikuji Togawa about 1955 in Japan through his study "On Evacuation Facilities through Observation of Crowd Flow"[1]. In 1970 and later, the method using a computer simulation has been widely used for developing various behavior models in Japan, U.S.A. and other countries. An overview on the recent trend of these researches is as follows.

Classification by Theme

Research focusing on behavior or time to cope with fire. This is a study to be used in making plans such that an evacuation should be finished by the time the hazard occurs, prepared by summarizing human behaviors in a fire and specifying the time required to complete each stage.

Recent researches have focused on "the time required for evacuation" and "the time to start evacuation", as well as on the basic and average walking speed. For example, a study[2] to specify the required time and

Table 1. Classification of Physical and Human Countermeasures corresponding to Various Fire Stages

	Physical Countermeasures		Human Countermeasures
Prevention of Fire Ignition	Ignition source	Prohibition (restriction) of use of fire	(a) Strict management system for fire prevention
	Materials to be ignited	(b) Use of non-combustible (flame-retardant) materials	
Fire extinguishing, blockage of fire spread, and leading for evacuation after fire		Against flame (heat, light)	
		Against smoke (poisonous gas)	
	(1) Early detection	Heat detector Light detector	(c) Night watch by guards, Detection by human senses such as eye, ear, and nose
		Smoke detector Gas detector	
	(2) Fire-extinguishing, Smoke Exhaust	Sprinkler, Hydrant Fire extinguisher Fire fighting Fire engine	(d) Water sprinkling and discharging Operation of apparatuses Actions by firemen*
		Smoke control system Smoke exhausting car	
	(3) Fire protection Smoke blocking	Fire compartmentation (fire wall) Fire door (shutter)	(e) Manipulation of devices, etc.
		Smoke partition Smokestop door (hanging wall)	
	(4) Notification Conveyance Guiding Evacuation	Evacuation route (stairs), exit for emergency (door, lamp, signs, and announcement)	(f) Manipulation of push buttons Dispatching/receiving of alarm Judgement on the spot, Guiding Evacuation
		Same as the above	

the starting time for evacuation through behavioral experiments and simulations, as well as a study by T. Kato[3], was made to study the time to reach the site of the fire after noticing a fire alarm, begining fire fighting and reporting to a fire station by phone, or giving evacu-

ation directions to the occupants.

Further, a study[4] is made using statistical data of fires on the time elapsed from the outbreak to detection, the time elapsed until a fire station acknowledges, and the time to start evacuation.

Research focusing on human physiology, psychology and human capability.

(1) Capability of the mentally and physically handicapped people and a study of the means of evacuation from their accommodation. A study[5] was made of the time required for relocating patients in hospital by stretcher and wheelchair through experiments, as well as a study[6] with regard to the time elapsed until the mentally retarded awaken from sleep at night in a mental home through observation of fire drills.

There exists another study[7] entitled "The Evacuation of Non-Ambulatory Patients from Hospital and Nursing Home Fires: A Framework for a Model" by J. Archea, as well as a study on "Moving Ability of Hospitalized Patients in case of Evacuation"[8] by K. Shida, et al.

(2) Study of quantification of behaving ability under psychological or physiological stress. A series of studies have been made by Dr. Jin and others of the Fire Research Institute in an attempt to evaluate peoples ability to select routes for evacuation in smoke. One of these studies is being presented in this symposium[9].

Further, there exist a similar study by A. Hokugo[10], an experimental study of using a maze by Y. Watanabe[11,12,13], and a study of the effect of carbon monoxide by M. Yung [14,15], et al.

Research on education for fire protection (philosophy and knowledge). Researches have been made recently on what kind of educational training is effective to improve and spread consciousness for fire protection. Doctors C. Hayashi and K. Mizuno of the Mathematical Statistic Research Center of the Ministry of Education started to make studies of this field several years ago, and some of their results have been published [16,17].

Classification by Method

By case analysis. As of individual fires causing large casulaties or property loss as well as fires which are regarded as valuable data due to their specific cause or damage, 19 have been reported (41 reports alltogether) since 1956 in Japan, these 19 cases include fires in hospitals, high-rise condominiums, theaters, social welfare facilities, cabarets, etc. including 5 department stores (16) and 5 hotels (9) reports. Besides them, a few more reports are made on results of investigation and statistical analysis of past cases.

Examples include "Evacuative Behavior in case of The Osaka Science and Technology Center Fire"[18] by S. Horiuchi, Y. Murosaki, A. Hokugo, et al, "The MGM Grand Hotel Fire: a Case Study of Human Reaction to Fire"[19] by Dr. Bryan, Report on Investigation Results of 112 Unusual Fire Cases[20] by Tokyo Fire Department, "A Study on Behavior Patterns in Fire in Relation to the Type of Building"[21] by A. Hokugo, and so on.

By simulation.

(1) Link with smoke movement. Studies have been made evaluating safe escape by linking an evacuation simulation with forecasts on the dropping of smoke layers in a relatively spacious room, or for making smoke movement forecasts or smoke control plans by linking a smoke movement simulation with the position of an opened door and the time required as obtained from an evacuation simulation.

Examples include "BFIRES II: A Behavior based Computer Simulation of Emergency Egress during Fires"[22] by F. Stahl, "Computer Simulation for Total Fire-Safety Design of the New Japanese SUMO Wrestling Headquarters and Stadium"[23] by H. Sato. et al, "Design Method of Smoke Control and Evacuation"[4] as one of comprehensive projects by the Ministry of Construction, and so on.

(2) Simulation for supporting behaviors. Studies have been made, incorporating into evacuation simulations the behavior of those who are engaged in leading, supporting, transferring by stretcher, rescue, etc. during evacuation, so as to determine priorities of people to be rescued in accommodation for the handicapped or for determining the manpower necessary for leading them to safety.

Examples include "Escape and Rescue Model"[24] by D. M. Alvoid, "A Study on Evacuation Simulation for Supporting Behaviors"[25] by Y. Murosaki, et al, and "An Evacuation Method of Life Risk in case of Building Fires"[26] by K. Shida, et al.

(3) Simulation as a game. Development and researches for training simulators during evacuation are currently being made.

Examples include "Future Directions for Research and Development"[27] by J. Sime, "Attack to the Simulation Game for Hotel Fires"[28] by K. Kobayashi, and "An Attempt of Evacuation Practice as a Game"[29] by K. Iwaki.

By experiments.

(1) Identifying the flow coefficient and confluence ratio by experiments.

Attempts have been continuously made through a series of experiments to clarify the flow coefficient (flow rate) and confluence ratio in a corridor and staircase, which is regarded as a premise for calculation of evacuation.

Examples include "Experimental Study on Escape Direction"[30] and "An experimental Study on Confluence of Two Foot Traffic Flows in Staircase"[31] by A. Hokugo.

(2) Identifying the time for reporting and stretcher-transferring by experiments.

This is omitted here, because they are already mentioned above.

By system engineering method.

Studies are made using a network model of escape routes for evalua-

tion on planning of buildings.

Examples include "On Measuring Escapability from a Maze"[32] by H. Yoshimura, "Network Models for Building Evacuation"[33] by L. G. Chalmet, R. L. Francis, and P. B. Saunders, and "Study on the Evaluation of Planning for Safe Escape with Consideration of Smoke Movement"[34] by T. Terai, K. Matsushita, et al.

Classification by Countermeasures

In terms of reliability of facilities and equipment. Studies have been made on how people act when a fire detector incorrectly alarms and on the relation between equipment inspection and malfunction. The following studies clarify reliability and effectiveness of facilities using data from the inspection of fire extinguishing equipment conducted by fire officials, as well as examining to what extent reliability can be improved through proper maintenance.

M. Tsujimoto : Operational Reliability of Fire Door Interlocking with Smoke Detector[35]

T. Jin : Operational Situation and Evaluation of Fire Protection Equipments[36]

M. Kobayashi : Systems Analysis of Building Fire Safety[37] -- Part 2: Effectiveness of Fire Extinguish Equipments

K. Nakamura : Seeking for Safe Residential Space: Technique to cope with Emergencies[38]

In terms of management system. The Fire Defense Agency prepared the following manual regarding the management system for the nighttime fire protection at inns and hotels in cooperation with the Fire Protection Equipment and Safety Center. This manual shows how to evaluate whether the necessary actions would be completed within the allowable time fixed as required to cope with fires.

K. Kobayashi : Instruction Manual on Management System for the Nighttime Fire Fighting at Inns and Hotels[39]

The following is the summary of the foregoing:

(1) Recent researches are apt to be increasingly sophisticated, taking advantage of the computer simulation method for developing behavior models, incorporating various related factors and making forecasts on egress behavior in case of emergencies.

(2) Also researchers in engineering fields, researchers in psychology, statistics, sociology, etc. have accomplished more and more studies. Studies related to fire prevention (protection against outbreak of fires, anti-fire education, etc.), are now being made in a wider range than ever after a period of low activity.

KEY CHALLENGES IN FUTURE RESEARCH

Problems on Forecasts of Evacuative Behavior

As mentioned above, recent studies using computer simulations to make forecasts on evacuation behavior during fires seem to have become more sophisticated and more active.

However, this trend may lead to researchers losing the original goals of their studies, possibly leading to providing incorrect results.

For example, in facilities such as hospitals, homes for the aged, infant homes, etc. homes to accommodate physically and mentally handicapped people, for whom conventional means of egress are inappropriate, the first and most important step is to complete divisions for fire extinguishing and smoke blocking by early detection of fires (shown in C, D, E of Figure 1, and in (c), (d), (e) of Table 1). Then, appropriate measures should be taken for assisted and escape.

On the other hand, in department stores, theaters, halls, etc. accommodating many and unspecified people, it is more appropriate to put emphasis on guidance and escape than to make counterplans of divisions for fire protection and fire fighting.

As an evaluation method of evacuation plans, it is risky to pay attention only to the time criteria such that "if the time consumed for evacuation to a safety area by all the people involved does not exceed the given time, it is regarded safe". Reviews must be made by making a point of "selection of escape directions", "detection of points causing stagnation or confusion of the crowd among escape routes and preventive means against occurrence of dangers such as tumbles at these points".

Necessity of Research on Preventive Means before Fire

As shown in Figure 1 and Table 1 above, the field of fire prevention has been less studied compared to means to be taken after fire outbreaks. Especially in the field of A and (a) shown in the said Figure and Table, topics such as psychology must be accomplished, because human factors are deeply involved; however, efforts in this field have been insufficient so far. Therefore, the recent trend to increase studies by researchers in human sciences is highly appreciated, and closer communications among researchers in each field is a key in future development.

Since few researches have been made in this field on the whole, the following tasks are expected to be tackled in future.

(a) Research on the mechanism of fire outbreaks, especially people are involved, must be made for effective implementation of preventive means.

(b) In terms of fire prevention for the aged, infants, and the handicapped, research must be made on some effective methods combined with other means, such as the use of a pocket-sized alarm in an emergency report and flame retardant fabrics for clothes and bedding, and so on.

Promotion of Research for Decrease of Casualties due to Residential Fires

In seeking to decrease fatalities due to residential fires, which account for 70-80% of the total fatalities by fire, the use of a fire

detector and simple sprinkler for home use, showing a successful result in the U.S., should be widely spread. In the light of this, research and investigation must be made on enlightenment and spreading activities for citizens, especially for all family members including women and children, as well as on administrative guidelines and method of assistance.

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