Journal of Hazardous Materials, 7 (1982) 51—62
Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

WARNING OF DISASTER AND EVACUATION BEHAVIOR IN A JAPANESE CHEMICAL FIRE

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(Received March 8, 1982; accepted April 27, 1982)

Summary

On October 1, 1980 (Wednesday), at Ohbu city in Aichi Prefecture in Japan, a large warehouse facility storing a great quantity of chemical materials caught fire, and the city authorities were forced to evacuate the populated area around the warehouse. Ohbu city has a population of 66,000 and adjoins Nagoya city, one of the largest in Japan. The burned-out warehouse was only 1000 m from the center of Ohbu city.

What factors determine human behavior in such a crisis situation? In order to begin answering this question, this paper assesses the effects the warning information transmitted to the threatened public had upon compliance with an evacuation order.

The event

The warehouse fire began at about noon. Two welders repairing its drain-pipes were about to finish their morning work, when one of them caused stored boats made of glass fiber to catch fire.

The welders and a nearby employee were not able to cope with the fire by using a fire hose. The fire quickly spread and engulfed the 'A' section of the warehouse; the warehouse being partitioned into sections 'A','B', 'C', 'D'. The black pungent smoke was wafted high into the clear autumn sky; the smoke could be seen from Nagoya city about twenty kilometres from Ohbu.

The welders and the other person quickly informed the fire department. Immediately six vehicles came to the scene, but this was inadequate. The fire department of Ohbu city requested the help of nearby cities (e.g. Nagoya). Eventually thirty-five fire vehicles including special units for dealing with chemicals were dispatched. However, the fire was so strong that in spite of the number of fire units which responded, the firemen could not successfully extinguish it for hours.

At 2 p.m., vinyl chloride resin caught fire and poisonous chlorine gas was generated. Thus, city officials became concerned that the gas would spread

*This paper draws from the research done by Professor Keizo Okabe, Makoto Nakada, Yoshiaki Hashimoto, and the author (all of the University of Tokyo). The author is indebted to and thanks Dr. E.L. Quarantelli, and Dr. Ronald W. Perry for comments on earlier drafts of this paper.

0304-3894/82/0000—0000/$02.75

over the residential area near the warehouse. The city dispatched four public information cars around the area to warn residents of the hazard of chlorine gas and asked them to shut the windows of their homes. At first it was unclear what other kinds of chemical materials were in the large warehouse. Finally, the police crime prevention department discovered a list of the stored materials in the warehouse, the list having been prepared in the course of burglary prevention measures. They were surprised to find on the list 4300 kg of hydrocyanic soda (NaCN) which would generate a deadly poison if it came in contact with water. Furthermore the warehouse did not have any neutralizing chemicals for hydrocyanic soda. The owner had registered the warehouse as a regular-type storehouse, not as a special warehouse for hazardous materials, so he did not possess any appropriate neutralizing chemicals.

Evacuation

The Ohbu city office set up a headquarters for countermeasures against the threat at 2:00 p.m., two hours after the fire started. Up to that time the headquarters had only asked people to shut windows. However, due to the awareness of the existence of hydrocyanic soda in the warehouse, a decision was made to warn the population living on the leeward side of the warehouse to evacuate to several designated places of safety, including a nearby elementary school. Eventually, there were to be three separate warnings issued by city public information cars and patrol cars using loud speakers.

The content of the first warning was as follows:

"The city headquarters for countermeasures against fire requests you to evacuate to xxxxx school, since poisonous gas is being generated by the fire."

This first warning was issued at 3:30 p.m., after the discovery of the stored materials list. About 4000 people living leeward of the fire and within 500 m of the warehouse evacuated. At the same time, the headquarters asked the leaders of neighborhood associations to cooperate in the warning effort. But since this was done in a form so as to avoid any responsibility by the city, the leaders did not provide much assistance, i.e., the city asked the leaders to warn the population at their own rather than the city's discretion, even though the warning from these leaders was intended to be seen as official from the standpoint of the population. The second warning was issued at 6:00 p.m. to 2000 people living further away, and included almost exactly the same information as the previous warning.

Because the direction of the wind changed from a northwesterly one to a northeasterly one around 8:30 p.m., the area to be evacuated had to be added to, and the initially designated shelters also had to be changed, since those shelters were very near the warehouse and had become leeward. Finally, the third warning was issued. This warning involved a somewhat larger area; people who were newly leeward of the fire and within 1000 m were warned at 9:45 p.m. As a result of these three warnings, some 8000 people evacuated. Accord-

ing to our research data, 25.8% of these left after the first warning. The corresponding rate for the second warning was 35.5% and for the third warning, 57.9%.

The later the reception of the warning, the higher the proportion of those who evacuated. This seems due to mainly two reasons. The first is that most of the evacuees had a strong tendency to wait to leave until they could evacuate with their families (93% left with their families), as has been found in other evacuation studies (Moore et al. [19], Drabek and Boggs [12]). The first two warnings were issued when many commuter families would not have had all members present. The second reason has to do with the change in the direction of the wind after 8:30 p.m. This exposed part of the population to danger which had not been threatened before.

Response of the mass media

The mass media did not report news about the fire quickly, which was unusual compared with other cases of accident and disaster reporting in Japan. In general, the media reported initially only a few hours after the outbreak of the fire. However, by 3 p.m. there were many news reporters around the burning warehouse and helicopters from news agencies circled over it. News of the fire was relayed from the reporters in front of the warehouse, e.g. on NHK (the largest network system in Japan), at 3 p.m., 5:45 p.m., 6:40 p.m., 7 p.m. The warnings were also broadcast. Explanations of the danger from the hydrocyanic soda were given at least once on the 5:45 p.m. news.

As certain specific information such as the details of the evacuated area was not mentioned in the media accounts, information about who had evacuated was unclear to people outside the city. So an enormous number of telephone calls from relatives or friends came into the city which finally caused overloading of the telephone lines.

End of the event

The fire was brought under control by the next morning after burning 3500 m^2 (compared with 323 m^2 destroyed by fire in Ohbu city in the whole of 1979). No trace of hydrocyanic gas was ever detected, but a quarter of our respondents described below had sore throats or smarting eyes. Warnings to evacuate were canceled at 6:30 a.m. There still remained, however, the problems of water pollution caused by the neutralizing chemicals used and the possible problem of dioxin. This was similar to the problem faced at the Seveso disaster in Italy in 1976 [1].

The research findings and discussion

Some disaster researchers have found that there are several types and many determinants of evacuation [2, 3]. First we will examine the effect of warning information on evacuation. This kind of study has not been performed systematically and empirically [3] except in the excellent study by Perry et al. [4],

but our research focused primarily on this point. After analysing this, the behavior of non-evacuees will be analysed, and the other determinants of evacuation will be discussed to some extent.

What are the determinants of people's evacuation decision-making when they are given warning information? From the point of decision-making theory described by the author elsewhere [5], there are four basic important factors in emergency decision making. The first two factors relate to the definition of the situation. More specifically this involves the perception of the existence of danger, and the perception of the imminence of it. Perry [6] discusses these in different terms such as the perception of threat as real and perceived personal risk. The third factor is concerned with man's outer coping, which means man's coping with the danger in the outside world, for example, coping with fire. The most important factor for this coping is the possibility of possible concrete coping action, that is the existence of an alternative. (The existence of only one alternative course of action is sufficient. The decision-making is about the choice or non-choice of that alternative.) The fourth factor concerns man's inner coping, which means man's coping with his own emotions. If the emotion or the fear is strong enough, people cannot undertake outer coping because their ability to cope is pre-occupied with inner coping [7]. The effects of these elements, with the exception of emotion, will be discussed below.

The research findings

A sample of 1134 housewives was drawn randomly from the area where the warnings were directed. The field research was done by telephone from October 8—14. Around 62.9% of the total sample provided useful information ($N = 713$). Respondents were called several times on the phone.

About 64% of the respondents had received warnings. While only 20.7% of those who did not receive warning evacuated, 38.3% of those who did left their homes ($p < 0.05$ by chi square). Overall, the evacuation rate is lower than that reported in other evacuation studies involving chemical hazards [8—10]. In order to ascertain the reason for this we must analyse the effect of the warning in detail.

Since the headquarters warned Ohbu residents to leave the area, it had the definite aim of rapid evacuation. However, to achieve this it was necessary for the warning to go through two basic steps. The first was whether the warning was received accurately by the residents. The second step was whether the residents had an accurate understanding of the warning, whether they felt like evacuating, and whether they eventually evacuated, in fact. Concerning the accurate transmission of the warning information (1st step), we asked our informants what they understood from the warning. The 457 people (64.1% of the total) who received one or more of the official warnings, were asked to explain what information was in the warning they received. Responses to this question are as follows:

— 53.8% of the recipients of warning remembered hearing about "poisonous

gas"; these respondents remembered that the warning identified the presence of such a danger,
- 48.6% of the respondents remembered that the warning involved a request to "evacuate immediately"; these respondents were impressed by the imminence of the danger,
- 38.1% of the recipients remembered that the warning told them "what place to go to"; these respondents remembered that the warnings contained suggestions for concrete coping actions,
- only 11.4% of our respondents remembered all three of the above, that is, they remembered that the warning described the presence of the danger, its imminence, and suggested protective action.

These data identify some of the first barriers to the implementation of the evacuation orders. It is shown that only about a ninth of the residents received warning information that was sufficient to motivate them to evacuate. This is probably due to the fact that the announcements by moving public information cars made it very difficult to hear the warning in detail, and the neighborhood associations did not work well, as mentioned earlier.

The next question of importance is, whether or not the warning recipients understood the presence of the danger as was intended by the city authorities. This represents one of the most critical problems in warning response research. In order to get people to evacuate, authorities must be able to communicate the nature and extent of the danger effectively to the threatened population.

The findings show that 60% of those who reported hearing about the "poisonous gas" more or less felt danger. In contrast, only about 40% of those who did not hear about the poison, felt any danger. The difference is statistically significant. Nevertheless, the fact that 40% of the people who heard about the "poisonous gas" did not perceive the situation as dangerous suggests that the message of the city authorities did not properly communicate the situation. Furthermore, those who remembered hearing the warning to evacuate immediately had a tendency to feel more in danger than those who did not receive such a part of the warning content (53.9% vs. 29.0%, $p < 0.01$ by chi square).

The findings also show that what was more important was how the residents of the area felt rather than what they heard. Table 1 shows this, indicating that the rate of evacuation correlates with what people felt, not with what they heard, that is, even if they heard the order, people would not leave unless they felt the imminence of the danger. This data suggests that whether or not a person evacuated was more a function of what they believed about the imminence of the danger, rather than what the warning told them to do; the highest proportions of persons evacuated when they felt the danger was imminent.

We also think that the reluctance of city officials to directly issue warnings was one of the causes of the ineffectiveness of the warnings. The officials were unwilling to inform the residents of the concrete content of the "danger". In our interviews with officials they admitted that they were somewhat afraid

TABLE 1

Pattern of imminence and evacuation behavior

Pattern of imminence	Evacuation	
	Evacuated (%)	Did not evacuate (%)
Heard about evacuating immediately and felt imminence	61.9	38.1
Heard about evacuating immediately but felt no imminence	21.8	78.2
Did not hear about evacuating immediately but felt imminence	55.1	44.9
Neither heard about evacuating immediately nor felt imminence	24.9	75.1

chi square; $p < 0.01$.

of causing so-called 'panic', so they had not mentioned many specific details about the possible dangers. This seems to have created the impression that the situation was not very serious or imminent [cf. 11].

Next, if we relate the pattern of the perceived danger and imminence to the actual evacuation, we can see clearly how the perception of danger and imminence were important. Figure 1 shows the calculated rates of evacuation among four types of warning recipients based upon whether or not the

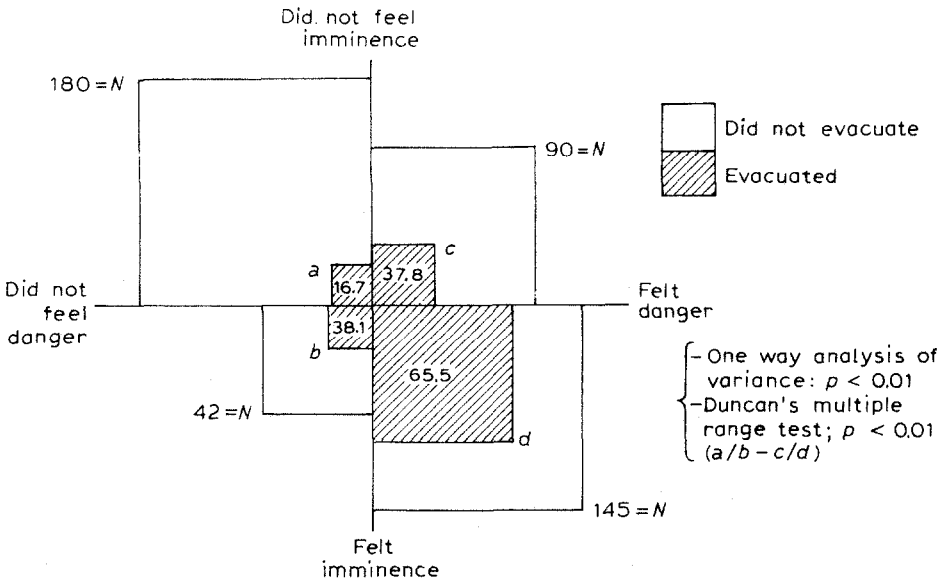

Fig. 1. Differences of rates of evacuation among types of warning receptions.

individual felt imminence and whether or not danger was felt. Three distinct categories can be differentiated in this pattern, that is:

Category 1: those who felt both danger and imminence; the rate of evacuation is 65%,

Category 2: those who felt danger, or imminence; both rates are about 38%,

Category 3: those who felt neither danger nor imminence; the rate is 17%.

These findings indicate the second hindrance to evacuation effectiveness. The city authorities were not successful in making people feel that they were in danger. More is necessary than just to inform people of danger or imminence. They must also feel they are in danger or in an imminent threat situation. This is in line with the author's decision-making theory mentioned above.

Earlier disaster research suggests that other factors like the source or the medium of the warning messages can be important in relation to the adaptive responses [4, 12]. (Some of the findings are too contradictory to be able to generalize (see ref. 13).) As concerns this point in the Ohbu case, the city authorities used two media for relaying information when they issued the warnings. The one involving patrol cars and public information service cars is an impersonal or one-way communication medium. Using the neighborhood association involves a personal or two-way communication medium.

Those who received the warnings from the former medium are in the majority. They total more than 80%. On the other hand, those from the latter medium total only slightly more than 10%. (Those who heard warnings from neighbors, relatives, or mass media add up to only a few percent. So, most of the information sources were official.) In addition, those hearing warnings from both the public information cars and the neighborhood association total only 5%. These findings made it clear that the diffusion of the warning through the neighborhood association was not effective.

However, when people got warning information through the personal medium, they were very likely to evacuate. This fact is presented in Table 2. When warnings were received through the neighborhood association, the rate of evacuation was more than half, whereas through other sources, the rate was only about 36%. The efficacy of the personal medium in this situation is

TABLE 2

Evacuation rate by warning medium (%)

Neighborhood Association	Public information car or patrol car: Yes	Public information car or patrol car: No
Yes	58.3	52.9
No	35.8	35.7

One-way analysis of variance: $p < 0.05$.

consistent with research findings of traditional persuasion studies and mass media influence studies [14, 15].

In order to assess the relative weights of these important elements as well as other demographic or situational variables in evacuation decision making, the author did a multivariable analysis, which is called "Hayashi II". This is a kind of discriminant analysis using dummy variables; that is, this analysis is an extended version of the discriminant analysis which uses nominal or ordinal variables as independent variables [16, 17].

TABLE 3

Multivariate analysis of evacuation behavior

Variables	Values	Standardized score[a]	Partial correlation coefficient
Direction of the wind	1. Always leeward	15.74 × 0.0001	0.338
	2. Leeward (the 1st half)	−5.36	
	3. Leeward (the 2nd half)	−25.03	
	4. Never leeward	−14.66	
Distance from the storehouse	1. Within 500 m	0.72	0.044
	2. 501—1000 m	−4.15	
Age	1. 20—29	12.80	0.162
	2. 30—39	1.73	
	3. 40—49	−4.59	
	4. 50—59	−4.03	
	5. over 60	−10.51	
	6. DK.NA.	−8.05	
The number of children and elderly	1. 0	−4.49	0.117
	2. 1	−2.90	
	3. 2	5.82	
	4. more than 2	4.19	
Personal media	1. no	−1.73	0.120
	2. yes	11.90	
The place of reception	1. Not at home	5.52	0.055
	2. At home	−0.76	
About the place to go	1. Did not hear	−1.97	0.066
	2. Heard	3.26	
About the imminence	1. Felt	9.89	0.187
	2. Did not feel	−6.85	
About the danger	1. Felt strongly	16.39	0.268
	2. Felt a bit	4.02	
	3. Did not feel	−11.27	

Correlation ratio (η): 0.329.

[a]Positive value of standardized score means that the value is effective towards the evacuation.

The variable of wind direction, which indicates the strength of the direct influence of the fire, e.g. gas smell, is the most influential variable on evacuation. This is directly relevant to the finding that in nonnuclear disasters the evidence of the threat, that is, the visibility of the danger was important [18].

The variable of whether danger was or was not felt, has the second greatest partial correlation, the coefficient of which is 0.268. The third variable is that of the feeling of imminent danger, the coefficient of which is 0.187. Although these last two variables are less powerful when compared to the wind direction variable, they are more important than demographic variables such

TABLE 4

The reasons for non-evacuation (multiple answers)

	% of the total non-evacuees	Thought of evacuation		Felt anxious	
		% this categ.	% rest	% this categ.	% rest
Related to the respondent's own judgement	50.6	47.3	44.4	55.5	51.9
1. Stayed and sized up the situation	37.3	48.6	44.2[a]	56.9	51.8[a]
2. Thought home safe	36.7	29.8	55.2	44.9	58.8
3. Thought home safer than the shelter	15.9	45.5	45.9	51.9	54.1
4. Thought nowhere was safe	1.0	40.0	45.9	80.0	53.4
5. Just reluctant to leave	2.3	36.4	46.1	54.5	53.7
Related to the family members or neighbors	34.7	50.0	43.7	63.1	48.7[a]
1. All family members were not together	9.1	68.2	43.6[a]	79.5	51.1[a]
2. Reluctant to evacuate because of children, elders, or sick persons	8.9	55.8	44.9	51.2	54.0
3. No one evacuated in the neighborhood	17.3	38.1	47.5	63.1	51.8[b]
4. Other reasons	7.8	44.7	46.0	55.3	53.6
Related to the defects of the evacuation order (Total)	17.4	36.9	47.8	52.4	54.0
Could not evacuate because of role demand	3.1	53.3	45.6	46.7	53.9
Reluctant to evacuate without car	5.2	60.0	45.1	64.0	53.2
Thought absence would make home insecure (including the fear of looting)	4.5	45.5	45.9	45.5	54.1
All other reasons	18.1				

[a] $p < 0.05$ by chi square.
[b] $p < 0.10$ by chi square.

as age, or number of children and elders in the family. But the existence-of-alternative variable, our analysis shows, has little weight in the prediction of evacuation, mainly because only a third of the evacuees went to the designated places; most went to the homes of relatives or friends as often happens in cases of evacuation [3].

The correlation ratio of these variables in the explanation of evacuation is insufficiently significant. As pointed out by Drabek [2], Perry [18] and Moore et al. [19], there are other determinants that make people evacuate. The main determinants are the social relationships among people. When we analyze the non-evacuees, clues about this point appear. Table 4 shows the multiple answering of the reasons for non-evacuation. About 34% of the non-evacuees pointed out reasons relating to social relationships. Reasons such as the absence of some family members, or a reluctance to evacuate because of elders, children, or patients in the family are especially relevant here.

Seven out of ten of those who did not evacuate because all the family members were not together, thought of evacuation or wanted to evacuate. A great majority felt anxious about not evacuating. These rates are rather high among the non-evacuees. So the absence of some family members was one hindrance to adaptive action.

Another reason given, which is related to social relationships, is that "No one evacuated in the neighborhood". This reason seems to point to the conformity effect of others rather than the soothing effect, because the people in this category felt a little more anxious but thought less of evacuation than the other non-evacuees (but it must be noted that the relationship was not statistically significant).

A further noticeable fact is that the reasons given by non-evacuees who stayed home due to their own judgement of the situation, suggest the existence of a feeling of invulnerability among the non-evacuees. A third of the non-evacuees thought their homes were safe enough in spite of the evacuation orders, and only less than a third of them thought of evacuation. This is consistent with our earlier contention, that is, one cause of the ineffectiveness of the evacuation was the failure of the city authorities to make people feel that the danger was existent.

Conclusion

The research findings in the Ohbu study have much in common with other disaster studies. First, we found the important determinants of evacuation decision making are similar to those reported by Perry et al. [4], although our Ohbu study is not so extensive as his. We found a joint effect of the perception of the reality of the danger, and the perceived imminence of that danger on evacuation decision-making, and this roughly corresponds to the joint effect of the perception of threat as real and personal risk as reported by Perry et al. Our finding is also consistent with other studies. For example, Fritz and Williams [20] found that people would seek safety only if danger is recognized

as being imminent and personal. Janis and Mann [21] emphasize that the determinants of decision-making are personal risks of changing or not changing the current course of action, the perceived hope of alternatives, and time pressure. Second, we found that families evacuated as units and noticed that, as the first two warnings were issued before the reunion of the families, the evacuation rate before that time was fairly low. These findings fit well with the generalization that the family acts as a unit when evacuating [3, 13].

On the other hand, our research data differed in some aspects when compared with some American and Canadian natural disaster studies. First, we found reception of warnings was mostly from official sources, whereas reception from peers was very low (against what was reported by e.g. Drabek [2], and reception from the mass media was also low (against what was reported by Quarantelli [3]). Second, in American and Canadian natural disasters, the local police plays an important role in evacuation behavior [e.g. 2, 9, 10, 22], but in the Ohbu case there was no trace of the police asking the people on a door-to-door basis to evacuate. The police did not play an important role in the dissemination of warnings either. The countermeasures against the fire were set up mostly by city officials, even though their reaction was also very slow and inappropriate. A third source of difference relates to what we found about the neighborhood associations. The neighborhood association has as its smallest unit 10 to 20 neighboring families. Usually 5 to 10 such units make up a neighborhood association in a city block. In turn, the leaders of neighborhood associations construct another organization called the "self-governing association". This "self-governing association" is in fact far from self governing; it is linked strongly to city authorities and the city takes advantages of the association to inform the population of different administrative matters and exert its influence. This is a reason why an effort was made to disseminate the warnings partly through the neighborhood associations.

We conclude this paper with one recommendation. There is an urgent need for further study of the joint effects of warning content, family roles, and interaction among affected residents in disaster situations.

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