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WHEN SHALL WE LEAVE? FACTORS AFFECTING THE TIMING OF EVACUATION DEPARTURES

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Very little work has been conducted on the dynamics of human behavior in evacuations. This paper documents what is known about the timing of departures in different emergency events. This is followed by an effort to model individual variations in warning receipt and evacuation departures in the Nanticoke, PA hazardous materials fire. Among the factors which are significantly related to the time of warning receipt are the mode of the first warning, the proximity to the site of the emergency and the type of structure inhabited. The only significant variable related to mobilization time is the personalization of the warning. Perceived threat, age and family size were not related to mobilization time. The analysis points to the need for additional research to help understand the variability of human behavior in evacuations.

INTRODUCTION

Social scientists have studied human response to emergency warnings for several decades. Most of the events studied are ones in which people evacuated from hazardous places to other locations. The central focus of the recent empirical research on evacuation behavior has been to explain why some people hear and respond to warnings and subsequently evacuate and why others do not (Lachman et al. 1961; Withey 1962; Williams 1964; Drabek 1969; Mileti 1975; Baker 1979; Perry et al. 1981; Ziegler et al. 1981 Cutter and Barnes 1982; Perry and Greene 1983; Quarantelli 1984; Stalling 1984; Perry and Mushkatel 1984; 1986; Mileti and Sorensen 1988). Thus, to quote the title of a general summary of the warning/evacuation literature, the central research focus has been on the question: "Shall we leave?" (Drabek 1983). In contrast, very little work has been conducted on the complex dynamics of human behavior in evacuations. For example, we have very little data on the time in takes alternative warning mechanisms to notify people to engage in an evacuation (Lindell and Perry 1987). Furthermore, traffic loading rates in evacuation time estimate models are largely hypo-

thetical and not grounded with empirical data (Sorensen et al. 1987; Lindell and Perry 1987; Greene et al. 1981).

Based on general observations we know that people do not leave an area simultaneously. Variation exists in when warning are received and the amount of time people spend deciding to evacuate, assembling family members and resources, and actually engaging in the act of leaving. A paucity of knowledge exists about the factors which determine individual differences in the time it takes to evacuate. In Drabek's (1986) review of the literature, no findings are cited regarding either the timing of warning receipt or the time spent mobilizing to evacuate.

In this paper,to paraphrase Drabek's earlier question, we concentrate on the issue of "When shall we leave?" The next section documents what is known about the timing of departures across different emergency events. A general model of evacuation dynamics is then specified. This is followed by an effort to model individual variations in warning receipt and evacuation departures in the Nanticoke, PA hazardous materials fire.

WHEN DO WE LEAVE?

Data is available on the timing of warning receipt and/or trip departures for several hazardous material accidents (Burton 1981; Rogers and Sorensen 1989; Duclos et al. 1989), several flash floods (Perry et al. 1981), two hurricanes (Leik et al. 1981), and a volcanic eruption (Lindell and Perry 1987). Data indicate that warning receipt and evacuation mobilization times or departure times basically follow a logistic distribution (Sorensen and Mileti 1989). The available data indicates that the rapidity of warning receipt and response is likely influenced by the seriousness of the threat and the urgency of the situation, that is, the time available to respond before the threat is present. In addition, the warning mechanisms used will likely affect the timing or warning dissemination (Lindell and Perry 1987). Research has demonstrated that different warning mechanisms vary in their speed of notification (Rogers and Sorensen 1989).

The timing of human response in an evacuation is also extremely varied. In situations like the Mississauga train derailment, close to 90 percent of the first group of evacuees left within 60 minutes with nearly 60 percent departing in 10 minutes or less (Burton 1981). Similarly, in the Confluence, PA, hazardous materials release, nearly 85 percent of the evacuees were gone in less than 30 minutes after receiving a warning (Rogers and Sorensen 1989). In more protracted situations, the same s-curve pattern occurs, but is spread out over a longer period of time. People appear to adjust the rapidity of their evacuation behavior in accordance with the severity and timing of the impending threat.

Anecdotal information from other studies indicate that a large number of people at risk will quickly take action in a matter of minutes or seconds to escape a potential threat. During the Big Thompson flood, for example, people evacuated from their homes or cars seconds before they were swept away by flood waters (Gruntfest 1978). Thus, theoretically it may be possible that in a very severe and sudden emergency that mobilization curves would be even steeper than the one found at Mississauga or Confluence.

Although we are beginning to understand the differences in the timing of warning and evacuation departures across events with distinct characteristic it is also important to understand variations within a single event. Researchers however have been lax at attempting to explain individual differences in the timing of both warning and evacuation. The next step to furthering this understanding is to use the research record on factors which influence whether people hear emergency warnings to develop a general model from which specific hypotheses may be tested.

WHY DO WE LEAVE WHEN WE DO?

Previous Research On Factors Affecting Warning Receipt

Researchers have found that the information channel used for the dissemination of emergency public warnings has a clear effect on enhancing the receipt of a warning, although the findings are not always consistent. The mass media is typically the most effective (Perry, Lindell and Greene 1982; Quarantelli 1980) and the broadcast media of television and radio have been the primary source of hearing warnings among all types (Turner 1983). Some evidence suggests that television is more effective than radio (Turner et al. 1981; Baker,1979); however, an equal amount suggests that radio is more effective than television (Dillman, Schwalbe and Short 1983; Drabek and Stephenson 1971). Additionally, it has been found (Turner 1983) that the electronic media are more effective initially, but that newspapers are more important as time goes by over several weeks or months. It is likely that such observations come from research on events which are slow in unfolding.

It has also been documented (Perry and Lindell 1986; Lindell and Perry 1987) that personal contact with the public can be an effective way to enhance the number of people who hear a warning. Also the number of different information channels used to disseminate warning message en-

hances the number of people who hear and/or remember that they heard a warning (Turner et al. 1981; Lindell and Perry 1987).

Additionally, proximity to the potential impact site enhances hearing a warning (Rogers and Nehnevajsa 1984; Landry and Rogers 1982; Mileti, Drabek, and Haas 1975; Diggory 1956). Membership in voluntary associations has been found to increase the number of warnings received (Perry et al. 1981). General community involvement is also positively related to hearing warnings (Perry and Lindell 1986; Perry and Greene 1982; Turner et al. 1981; Sorensen and Gersmehl 1980; Scanlon and Frizzell 1979). Other factors found to enhance hearing warnings are frequent interaction across a kinship system (Landry and Rogers 1982; Perry and Greene 1982; Perry et al. 1981), and the maintenance of close relationships with relatives (Landry and Rogers 1982; Perry et al. 1981; Perry 1979).

Older people are less likely to hear a warning than middle-aged or younger people (Mack and Baker 1961; Friedsam 1962; Mileti 1975; Rogers 1985; Perry et al. 1981; Turner et al. 1979; Perry 1979a; Turner 1976). Other factors associated with hearing a warning are socioeconomic status (Perry and Greene 1982; Turner et al. 1981) which is positively related to hearing a warning. Having children increases the likelihood of hearing a warning (Turner et al. 1981). Women are more likely to hear a warning than men (Turner et al. 1979).

Certain cultural elements of the people who could hear a warning have also been shown to affect hearing a warning. For example, Perry et al. (1981) have documented that belonging to a closely-knit subculture like that of the Mexican-Americans enhances the odds of hearing an informal message. Other findings indicate non-english speaking groups are less likely to hear a warning (Perry and Mushkatel 1986). Sorensen (1987) pointed out that highly mobile people who are away from home when warnings are issued have a lower probability of hearing the warning.

Knowledge about the disaster agent (Turner et al. 1984) is positively related to hearing a warning. Fatalism is negatively related to hearing a warning (Landry and Rogers 1982; Turner et al. 1981). Prior disaster experience is positively related to hearing a warning (Perry and Lindell 1986; Landry and Rogers 1982; Turner et al. 1981; Anderson 1969).

Finally, the physiological ability of receivers to hear warnings is important, although poorly understood. Nehnevajsa (1985) concludes that there is a decrease in the ability of people to hear warning signals on summer nights when windows are closed and air conditioners or fans are in operation.

Specifying A General Model

A general model of the timing of warning receipt and evacuation departures is specified as follows. First, and most obvious, the time of departure is a function of the timing of warning receipt and the amount of time it takes to prepare to leave (mobilization time). This relationship is not of great theoretical interest. What is of interest is explaining variation in when warnings are received and in mobilization times. Variation in the timing of warning receipt, based upon the above review, is hypothesized to be related to three broadly defined factors:

- social context or the activities and location of people at the time of the emergency;
- social structure or the nature of the family, role, network , ethnicity, physiology and so forth; and
- warning system structure or the attributes of the warning including channel and message.

Researchers have not empirically investigated factors influencing mobilization time. In this model it is hypothesized to be explained by the above three factors and by two additional factors including:

- physical constraints or factors that would prevent or delay people from leaving
- threat or the severity of the real or perceived threat that is causing the evacuation.

The specific variables used to test these hypotheses will be discussed in the next section.

Nanticoke, PA Warning and Evacuation

To explore factors effecting the timing of warning receipt and evacuation departure we examine data from citizens who were warned and evacuated in response to a hazardous materials incident. The warning and evacuation at Nanticoke, PA was caused by a fire at the Spencer Metal Processing Plant which threatened to burn toxic chemicals on site. The accident occurred about 15 minutes after midnight on March 24, 1987. Local officials were somewhat slow in assessing the gravity of the situation. After consulting CHEMTREC officials decide to act on the worst case scenario. The official evacuation began at about 2:20 am. Records indicate the sirens for the Susquehanna nuclear power plant were sounded at 2:21 am and EBS broadcasts commenced at 2:30 am. It is likely that due to fire truck or other emergency vehicles responding to the incident that some

portion of the public was hearing other sirens from 12:30 on. The evacuation was a staged effort with the city divided into 7 sectors. Areas nearest the plant were the first to evacuate. At 2:50 am official decide to evacuate the northwest and west parts of the city. At 3:42 the evacuation of the remainder of Nanticoke began.

Shortly after the incident, the Centers for Disease Control, in the Department of Health and Human Services, Atlanta, GA conducted a telephone survey in Nanticoke. The general results of this survey along with the methodology are published elsewhere (Duclos et al. 1989). The data was collected using a systematic sample of 788 of 5516 telephone numbers in the cross directory for the Nanticoke area. A total of 578 people responded for a response rate of 73 percent. Data from the survey was obtained from CDC for use in this analysis (Binder 1990). The Nanticoke data is valuable as the survey included questions on both the timing of warning receipt and the timing of the evacuation departure. This allows us to test several hypotheses about factors that may influence variations in the timing of human behavior in an emergency evacuation.

Since the data used in this analysis is derived from a survey in which no control could be exerted over the variables included and questions used, measurement problems exist in the analysis. Using the available data, indicators were developed to represent the general constructs discussed above. The analysis therefore tests only the relationships between these specific antecedent indicators and the three subsequent dependent variables. The explanatory power of the general model can only be treated in a limited fashion.

Analysis

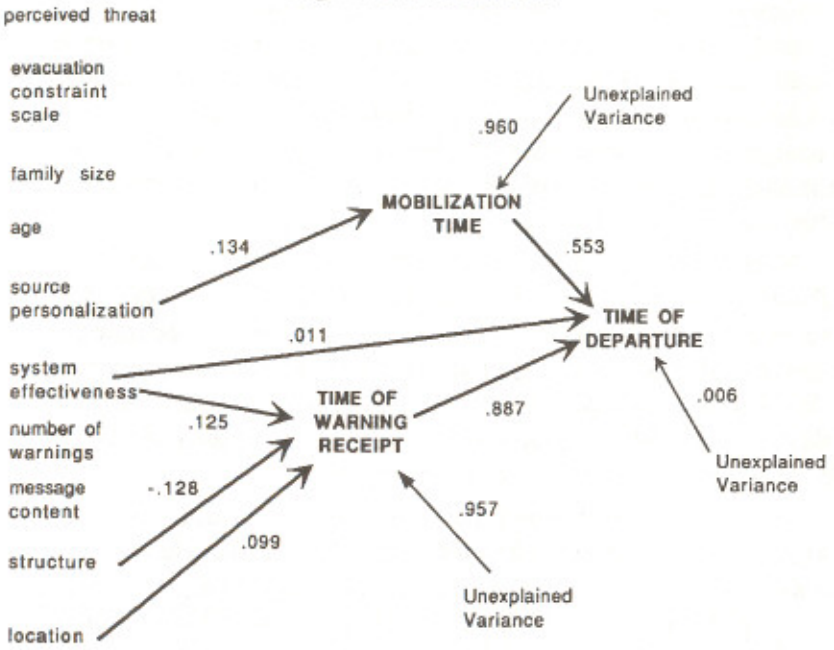
To test the significance and direction of relationships between antecedent variables and time of warning receipt, mobilization time and time of departure, ordinary least squares regression was used. Since we are dealing with processes that are clearly sequenced over time the logic of path analysis is employed.

Time of departure was measured as the number of minutes after midnight that the respondent reported leaving their house. Time of warning receipt was measured as the number of minutes past midnight that the respondents reported hearing the first warning about the event. Mobilization time was calculated as the difference between the two times.

Results of the analysis are shown in Figure 1. Paths are shown where the relationship is significant at $p \leq 0.05$. Standard coefficients are provided

for the significant paths. The variance explained (adjusted R squared) and unexplained variance is shown at each stage of the model.

Figure 1. Path Model



As expected, time of departure can be explained by time of warning receipt and mobilization time, although time of warning has a stronger effect on the departure time. This, however, is partly a statistical artifact. Furthermore it is not highly useful in improving warning effectiveness or developing improved evacuation plans, although it does confirm the importance of rapid warning to support a rapid response. What is of interest is to examine the relationship between the antecedents and the two intermediate variables.

Threat. It was hypothesized that the greater the perceived threat the lower the mobilization time. The rationale for this hypothesis follows from the macro perspective that groups of people respond more quickly to more serious threats. Therefore, individuals who perceive a greater level of threat should respond more quickly. Perceived threat was measured as a three point scale of no danger, some danger, and imminent severe danger. The results show no significant relationship with mobilization time.

Constraints. A number of factors could act as constraints to a timely evacuation. Among some suggested by other researchers is having family separated at the time of an evacuation (Drabek and Stephenson, 1971), having pets to attend to (Burton 1981), not having a vehicle to use (Perry

1979b), lacking a place to evacuate to (Drabek and Boggs 1968), having physical impairments or experiencing health problems (Vogt 1990; Mileti and Sorensen 1988). The portion of the sample experiencing any of these problems was too small to assess each separately. Therefore, to assesses these constraints, an additive scale of constraints was created for each of the above categories the scale measured the number of the above conditions at a household and ranged between 0 (no constraints) and 5 (all constraints). The hypothesis was the more constraints the longer the mobilization time. The analysis, however, found no significant relationship between the scale score and mobilization time.

Social structure. Two variable were hypothesized to affect both mobilization time and time of warning receipt. As the age of the respondent increased the mobilization time would increase as would the time it took to receive warnings. Since older people are less likely to hear warnings it was felt that they would also be more likely to hear them at a later time. In addition it was felt that they would require a longer time to act in response to the warning. The analysis does not support either.

It was also hypothesized that larger families would receive warning earlier but would take longer to respond. Larger families have more extensive social networks and ties and thus would be more likely to hear a warning an to engage in warning family members. On the other hand a larger family poses the need for more time to organize and prepare for the departure. Again neither hypotheses is supported.

Warning systems. Warning systems were characterized by 4 variables. The first was the degree of personalization offered by the system, that is whether the warning was made personally by a friend or relative, by an emergency worker or impersonally by siren or media. It was hypothesized the more personal warnings would decrease mobilization time. The findings from the modelling effort support this hypotheses.

Warning systems were also characterized by their effectiveness. This was measured by the rank order of the effectiveness of the technologies used to disseminate a warning message. Order was based on previous research on warning diffusion (Rogers and Sorensen, 1989). It was hypothesized that as the effectiveness of the technology from which the respondents received their first warning increased, the time of warning decreased. The analysis supports the hypothesis.

Third, it was hypothesized as the number of warning received increased the time of warning receipt and mobilization time would also increase. The analysis does not support either.

Finally, it was hypothesized that as the quality of the message increased as measured by the amount of information the respondent could remember hearing in the warning the mobilization time would decrease. Again no significant relationship exists.

Social context. Two factors associated with social context were included in the analysis. First we explored whether the type of structure that people lived in would effect the timing of warning receipt. It was felt that people living in single family homes would receive a warning earlier than people living in apartment buildings or than people living in mobile homes. The rationale is that the emergency infrastructure would target more traditional neighborhoods earlier than more transient neighborhoods. The analysis shows a significant relationship although it is fairly weak.

Location was measured by the order of evacuation. The first groups were closest to the plant site while the last group was furthest away. We hypothesized that those closest would receive warnings earlier than those further away. The results show that the hypothesis is supported, albeit in a weak fashion.

CONCLUSIONS

This paper represents the first known attempt to statistically examine individual variation in the timing of warning receipt and evacuation departure. While conclusive evidence exists that such variation will occur, the reasons behind individual differences are still somewhat inconclusive. The single most important factor in determining when people will leave is when they are warned. The warning mechanism had a significant but minor direct effect of the timing of departure. Little of the variance in the timing of warning receipt or mobilization time could be explained by the model. This is probably due in part to measurement problems. It leaves wide open the need for better models to explain the variation.

Of greater interest are the factors which did or did not covary with time of warning receipt or mobilization time. The most significant finding was that the time of warning receipt varied by the way people received the warnings. Based on this finding diffusion curves were constructed for each general warning type—sirens, informal, route, and media. These curves confirmed that the time of warning varied by warning type. The second most important findings was that personalization of the message led to a decreased time to respond. This presents a minor dilemma to the emergency official because personalized warning mechanisms have slower dissemination times.

Also of import were the factors that were not significant. Both age and family size were not related to either time of warning receipt nor mobilization time. That older people are not significantly delayed in hearing and responding adds more to the controversy about whether the elderly are more vulnerable to disaster.

While proximity was significantly related to when the warning was received, the evacuation strategy was a time phased evacuation. People at greater distance mobilized as quickly as those close in. Furthermore, level of perceived threat did not lead to faster response.

Overall this paper raises the general question of what determines when people hear a warning and respond to it. The analysis provides only a sketchy answer. The existing understanding of why people evacuate in response to emergency warnings, in contrast, is quite robust. This knowledge, however, was developed over a period of 25 years and involves several dozen empirical studies. Developing an in-depth knowledge of the social dynamics of behavior by those who do respond is an issue that will likely take an equal if not greater level of investigation. It is certainly a topic ripe for further investigation.

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