Summary Final Report

Community Response to Natural Hazard Warnings

by

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with

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April, 1981

Executive Summary

This executive summary is composed of selected portions of the attached report. The focus of the project is on processes which determine the nature and effectiveness of dissemination of and response to natural hazard warnings within the local community. Specifically, our purpose is to explore:

(1) the process governing the response of community emergency service agencies to warnings,

(2) the process governing the dissemination of warnings from community service agencies to other community organizations and to the general public, and

(3) the process governing the response of members of the general public to warnings.

The project has three components: a study of community organizations involved in disseminating warnings, a study of household responses to warnings, and a laboratory experimental study of response to warnings. The two field components involved pre-threat studies in 31 communities, some as pretests. Those studies occurred in 1977-1979. Hazard agents were tornado (9 sites), flash flood (11 sites), hurricane (8 sites), earthquake (3 sites) and winter storm (1 site). One community was subject to two different agents: hurricane and flash flood. When a threat occurred in a community already studied, a post-threat follow-up was conducted to provide a pre-post quasi-experimental research design. Six of the sites involved post-threat studies only, as opportune follow-ups of threats to communities not in the original sample.

ORGANIZATIONAL SUMMARY

The organizational component focused on three primary problems affecting the response of community organizations to natural hazard threats. The first problem involved the process of the dissemination of warnings from National Weather Service offices to the local level. Our findings here are as follows:

(1) Commercial telephone service was unreliable for the dissemination of warnings.

(2) The National Weather Service was unable to disseminate warnings directly to one third of the civil defense offices and 40 percent of the broadcast media stations.

(3) Forty percent of the civil defense offices were unable to communicate directly with the local National Weather Service office, as was the case with all law enforcement agencies in one third of the sites.

(4) In 40 percent of the sites, the civil defense office could not communicate with any broadcast media station.

(5) In 50 percent of the sites, no emergency service agency could communicate with any broadcast media station.

As a result of these communication gaps, we further found that:

(6) In one third of the tornado and flash flood post-threat studies, no warnings were issued due to communication failures between the National Weather Service and local emergency service agencies.

(7) In those sites in which warnings were issued, over 50 percent of the organizations studied did not receive the warnings.

(8) In these same sites, an average of one third of the general public did not receive the warnings.

The second problem involved the organizational structure of local civil defense offices and the effect of this structure on the ability of these offices to respond to natural hazard threats. Our findings support the hypothesis that serious coordination problems will exist in sites which have separate city and county civil defense offices. One half of our study sites have this form of civil defense organization. Our findings also indicate that local civil defense offices which are components of other governmental agencies will face difficulties in coordinating community response under emergency conditions. Two thirds of the civil defense offices we studied were components of other governmental agencies. Thus, our research indicates that a majority of local civil defense offices are organized in such a manner as to create coordination problems, rather than solve them.

Finally, we examined directly problems involved in the overall coordination of community response to natural hazard threats. We found that two characteristics of the typical community's civil defense effort--a serious lack of communication facilities and a splintered civil defense function--combined to exaggerate the coordination problems created by each characteristic separately.

HOUSEHOLD SUMMARY

Comprehensive household data on populations at risk to tornadoes, flash floods and hurricanes were gathered prior to the threat of these natural hazards. Post-threat data collection permitted the identification of pre-event household characteristics and orientations which predict the taking of defensive action in response to warnings. Although the character of household response is somewhat different among the three hazard types, a common process of response to natural hazard warnings is discernable.

The initial response of the public to the receipt of hazard warnings is to seek additional confirming information. In all three hazards, the receipt of warnings prompted household heads to seek confirmation of the warning information through discussions with their family, friends, and neighbors, by personally assessing environmental conditions (in tornado and flash flood situations) or by turning to their radios and televisions. An assessment of risk to the current threat resulted from this information-gathering process and prior notions of being at risk to the hazard. It appears that the very general nature of warning messages with their tendency to specify only general geographical referents provides great opportunity for the exclusion of oneself from the "at risk" category.

For those, however, who did define themselves at risk, the next step was serious consideration of alternative defensive actions. Once a family reaches this stage in the decision-making process, they have a high probability of actually evacuating. Another important factor in making this final decision, in all three hazard types, was whether respondents had prior plans for what they would do if a threat like the present one occurred.

In general, the analyses of the household studies have found:

(1) Warning confirmation is a critical first step in the decision-making process.

(2) General warning messages broadcast through the mass media motivate the public to seek additional information, but apparently do not motivate them to take immediate action.

(3) Social contacts with friends, relatives and neighbors are important during the decision-making process.

(4) Many residents who are at risk to natural hazards do not perceive themselves to be at risk.

(5) Risk perception is a critical variable in the continuation of the decision-making process.

(6) Warnings received directly from local authorities facilitate the decision-making process.

(7) Having a plan of what to do and where to go increases the probability of taking defensive actions.

(8) The majority of the public at risk to natural hazards does not choose the strongest forms of defensive behavior (i.e., evacuation and seeking safe shelter) in response to hazard warnings.

EXPERIMENTAL SUMMARY

The laboratory work demonstrates that human response to warnings of natural disaster depends upon:

(1) experience of the responder with prior, similar warning situations,

(2) frequency and detail of the warning messages,

(3) how important the possible results of an impending decision seem to the person issuing or responding to a warning.

Inexperienced individuals take defensive action sooner when warnings are more frequent and more detailed. As people gain experience in responding, they delay response longer reagardless of characteristics of the warning messages. In contrast to the behavior of the inexperienced responder, more frequent and more detailed messages produce even longer delays among experienced individuals than do infrequent or incomplete messages. The inexperienced respond more immediately to first warnings, but their response pattern is quite chaotic. As experience is gained, information is increasingly used in a calculating manner so as to delay response as long as possible or to avoid it altogether. Recommendations for action accompanying warnings will produce quicker response, but the effect is greatest for inexperienced responders.

When two people must respond jointly, as is often the case for families, they appear to take defensive action sooner than do isolated individuals. This shift to a conservative (or "protect each other") strategy is offset in these experiments by having to reach consensus before acting, which requires time not needed by the isolated individual. Although both effects appear in the data, the results are inconclusive: it is not clear from these experiments how delay in response versus lag time in reaching consensus will operate in longer onset situations such as hurricanes. As with individual responders, dyad results show that experience in responding to warnings alters the pattern of response.

Experiments involving both disseminators and responders show that, if disseminators depend on local productivity for their payment, they will be much less likely to issue warnings than will disseminators who are independent of local productivity. Business managers (responders) evaluate disseminators' behavior negatively either if warnings are too frequent, interrupting business needlessly, or if they are inadequate in frequency, detail or type of recommendations for action. As responders gain experience, their actions show progressively less correlation with warnings issued by their disseminators. Both disseminators and responders alter their strategies immediately following a "hit."

RECOMMENDATIONS

The following recommendations derive from the findings just summarized.

National Weather Service Communication Facilities

Among the problems covered by our research is the general lack of reliable communication facilities by which the National Weather Service can disseminate warnings to both the broadcast media and the local emergency service agencies.

(1) Since the broadcast media serves as the primary disseminator of severe weather warnings to the general public and the primary means of disseminating warnings from the NWS to the broadcast media is the NOAA Weather Wire Service, the National Weather Service should undertake a major program to upgrade the NOAA Weather Wire Service to state of the art technology in order for it to be compatible with the multitude of existing computer-driven teletype systems.

(2) Since NOAA Weather Radio has the potential to disseminate warnings of severe weather directly to both individual households and a large range of local community organizations, the National Weather

Service should institute an aggressive public service advertising campaign to bring NOAA Weather Radio to the public's attention. Further, legislation or executive orders should be enacted to require all public and private organizations receiving federal funds--e.g., schools, universities, hospitals, nursing homes, etc.--to purchase and maintain NOAA Weather Radio receivers with tone alert capability.

(3) Because reliable two-way communication between local NWS offices responsible for issuing severe weather warnings and local law enforcement and civil defense offices is crucial to the operation of both the evaluation and dissemination components of warning systems, the Federal Communications Commission, in cooperation with the National Weather Service, FEMA, LEAA, and other relevant federal agencies should establish a nationwide weather warning radio frequency to facilitate two-way communication among all local agencies involved in severe weather warning systems.

Emergency Service Communication Facilities

A second problem uncovered by our research involves the general lack of shared communication facilities among the wide variety of emergency service agencies at the state, county, and municipal levels of government.

(4) Increased emphasis should be placed on existing programs which are designed to upgrade emergency communication facilities of local governmental agencies. Such programs include the "911" emergency telephone system and the integrated communications center for law enforcement, fire protection, and civil defense agencies.

A third problem which limits the effectiveness of community warning systems is the almost total absence of communication facilities for the relay of emergency information from emergency service agencies to the broadcast media.

(5) The Emergency Broadcast System, like the National Warning System, was originally designed to provide a means of disseminating warnings of a national emergency from a national warning point to local communities. Unlike the National Warning System, however, the Emergency Broadcast System has not been implemented in

such a way as to encourage its use as a locally activated warning system. Thus, the Federal Communications Commission should shift the major emphasis of its Emergency Broadcast System program from a nationwide warning system to an integrated network of local warning systems.

Organizational Structure of Civil Defense Offices

A problem of a different nature from those discussed above involves a number of undesirable organizational characteristics of most local civil defense offices at the county and municipal levels of government.

(6) The Federal Emergency Management Agency should place increased emphasis on its program to aid local communities in implementing a comprehensive emergency management plan. Integral to such a program would be incentives for the rational integration of civil defense functions into the routine governmental agency structure.

(7) The Federal Emergency Management Agency should initiate a program to review and evaluate the coordination problems created by multiple emergency operation centers independently staffed by governmental agencies with overlapping jurisdictions. The findings of this program should then be integrated into the comprehensive emergency management program.

Warning Procedures and Message Content

Warning messages are generally not formulated in a manner which motivates optimal response. Standard messages presented by the broadcast media motivate people to seek additional information, but do not induce protective action. In fact, a standard statement may actually reduce response, unless information is also given which convinces residents in susceptible areas that they are at risk.

Warning messages need to be upgraded in the following ways:

(8) Specific local areas at risk should be identified in warnings. Whenever possible, graphic information (i.e., maps) as well as the names of the areas should be used in television broadcasts. Just giving general warnings or names of entire communities does not provide sufficiently specific information to convince people that they are at risk.

(9) Details of appropriate response should be included in warnings. According to the type of hazard, such details might pertain to evacuation routes, location of shelters, probable travel times, or procedures for taking shelter at home. For such detail to be accurate and timely would require extensive upgrading of the knowledge of local broadcast personnel.

(10) Warning procedures should be expanded to include as much personal, local contact as possible. Where local law enforcement and emergency service agencies cannot provide sufficient personnel, efforts should be made to organize and be prepared to activate neighborhood, friendship and family networks in the larger area as part of the warning system. A modest trial demonstration program for such an informal network warning system could be established with moderate cost in one or two communities before attempting to institute comparable programs on a national scale.

(11) Efforts should be made to assure that warnings are consistent in content.

(12) Awareness programs should be instituted which focus on increasing the public's perception that they live in areas at risk, and on inducing development of response plans in the home. For hurricane or flash flood prone areas, such plans should include where to go if evacuating, how to get there, and what to take. For tornado prone areas, awareness programs should emphasize how and when to seek safe shelter. It is plausible that schools and other local public facilities could adopt simulation training for interested families, similar to that used in our experiments, which would make them better acquainted with how to interpret warnings, what actions to take, and how serious the consequences could be if hazard threats are ignored. Again, one or two demonstration projects would provide low cost testing of such a procedure.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This project has focused on the nature and effectiveness of dissemination of and response to warnings of natural hazards. Two components of the project involved field studies of 31 communities, subject to one of four hazards: hurricane, flash flood, tornado or earthquake. One component studied selected organizations in the community regarding the adequacy of the dissemination network, and the other component studied samples of 200 households in each community regarding preparedness and response,

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A quasi-experimental design specified pre-threat studies to be followed by post-threat follow-up studies of the same organizations and households if a major threat occurred. A third component involved laboratory experimental simulation studies of the effects of message content, timing, prior experience, and social structure factors on response to warnings. A number of serious problems with existing dissemination mechanisms have been found, and critical factors affecting response to warnings have been identified. Laboratory and field data are in close accord. Results generally concur with and expand on previous knowledge. Twelve recommendations for improving dissemination and response are provided.

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I. Introduction

This report is a summary of the work accomplished, and of the major findings and recommendations, of a three year research project concerned with dissemination of and response to warnings of natural hazards. To keep this summary as concise and practical as possible, we will not provide much detail of analysis, but will concentrate on what was found and what those findings imply for improving current policies and practices. Similarly, the report will not contain a lengthy examination of prior work in this area or of the theoretical bases for our work. A book length report is also being prepared which will contain such details. It should be recognized that a summary report of such a large and complex project cannot contain elaborate analyses which pursue nuances of the data, but must focus on primary findings.

Since the early 1960's, social scientists have recognized that complete warning systems must perform a number of quite different functions, which must be carried out by quite different organizations, groups or individuals. To be effective, those functions and the organizations, groups or individuals which perform them, must be integrated into a common information network. This recognition led to the concept of the "integrated warning system" which has dominated social science disaster research for the past two decades (Fritz, 1961; Moor et al., 1963; Williams, 1964; McLuckie, 1970, 1973; and Mileti, 1975). Most researchers identify three basic functions essential for a successful warning system: 1) evaluation of the threatening event, 2) dissemination of an appropriate warning to the threatened population, and 3) response of the threatened population to the warning.

The focus of this project is on processes which determine the nature and effectiveness of dissemination of and response to natural hazard warnings within the local community. Specifically, our purpose is to explore;

(1) the process governing the response of community emergency service agencies to warnings,

(2) the process governing the dissemination of warnings from community service agencies to other community organizations and to the general public, and

(3) the process governing the response of members of the general public to warnings.

We assume that these are distinct processes, meaning that there are separate factors involved in organizational response as opposed to individual or household response. Also, factors which determine effective dissemination of warnings are not necessarily those factors which determine appropriate response to warnings.

To sort out those separate factors, this study was designed with three components and two time phases. There were two field work components, involving extensive studies of 1) organizations and 2) households in a large number of communities throughout the United States. In addition, 3) a laboratory experimental component tested some aspects of dissemination and response more accurately than can be done in the field. The two phases pertain to the field work. Whenever possible, if a community under study experienced a natural hazard event during the period of the research, that community was restudied to provide both 1) "pre" and 2) "post" event comparative data. Details of the research design are provided in Chapters II through V. Findings are reviewed in Chapter VI, followed by recommendations for improving the warning system.

Funding for this work was obtained initially by a grant from the National Science Foundation. Subsequent support has come from the Defense Civil Preparedness Agency, now part of the Federal Emergency Management Agency, and from the National Weather Service. We have continually received extensive encouragement, technical assistance and practical advice from these sources. The success of the project is in large part a consequence of their help.

Throughout the project, we have also received able and insightful assistance from our Advisory Committee. It has been a pleasure to know and work with a group of experts from such diverse areas. That they can collaborate successfully with each other and with us, across boundaries of expertise and of applied versus academic concerns, attests to their degree of commitment to the purposes of the project and to their personal warmth and enthusiasm. A list of project managers and Advisory Committee personnel appears at the back of this report.

The project was funded through the Department of Sociology and the Minnesota Family Study Center at the University of Minnesota. Principal investigators were Robert K. Leik, John P. Clark, and T. Michael Carter. Due to the complexity of the project, primary responsibility for separate

components was divided among the principals: the organizational studies were headed by Professor Carter, the household studies by Professor Clark and the experimental studies by Professor Leik. A number of exceptionally capable and dedicated graduate students and other research personnel, plus a much overworked secretarial staff, made the work possible. Special recognition is due to our office manager and senior secretary, Kristen Trelles, and to Mary Ann Beneke, executive secretary of the Minnesota Family Study Center, for continued help in preparing and processing mountains of applications, personnel forms and financial records. To all the above, we hope this report at least partially justifies their efforts.

II. Overview of Field Studies

Both field components (organizational and household) concerned the same hazard agents, followed the same pre-post quasi-experimental design, were intended to study the same sites, and used interviews as the method of gathering data. To avoid duplication, these facets will be discussed briefly here as an overview and introduction to more specific findings contained in Chapters III and IV.

HAZARD AGENTS

Early discussions with the National Science Foundation and with persons from agencies that would be probable users of the results of this research identified three weather agents of primary concern: tornadoes, hurricanes and flash floods. Earthquakes were added to the list of agents due to increasing federal concern over the possiblity of major quakes and the growing efforts to develop sound earthquake prediction technology. These four agents were therefore specified in the research design. A fifth agent, winter storms, received limited attention in one site, in response to interests expressed in an early advisory committee meeting.

PRE-POST DESIGN

One serious drawback of prior research on the warning-response system was an undue reliance on after-the-fact information. No matter how honest and willing a respondent might be, recollections of pre-threat facts and attitudes are very likely to be either obscured or colored by subsequent events. Consequently, a plan was developed which required selecting a number of high-risk sites for each of the specified hazards. These sites would be studied prior to a threat occurring. In all pre-studied sites subsequently threatened enough to cause full scale activation of the warning system, a post-threat follow-up study of the same organizations and households would occur. Thus, if enough initial sites were subsequently threatened, a reasonable pre-post quasi-experimental design would result.

SITES

In all, 31 sites were studied in some degree. The original site-sampling plan called for consultation with the National Weather Service and the United States Geological Survey to select sites judged to be maximally at risk to the specified agents. In an effort to balance budget constraints against demands of the pre-post design, it was decided that six sites at risk to each weather hazard, plus three at risk to earthquakes, were to be chosen. Following that plan, 21 sites were identified. In addition, three suburban sites in the Minneapolis-St. Paul metropolitan area were selected for the household studies.

One of the original six flash flood sites experienced a flood before the start of the main data collection effort. A "post-threat only" study was therefore conducted in this site as a pretest of the post-threat interview procedures. Such post-threat-only studies came to be known as "preless post" cases, a term that will be used here. In order to maintain the design of six sites per weather hazard agent, an additional site was selected.

It was essential that some of the selected sites would, after initial pre-threat studies, experience sufficient threat to activate their warning systems. Then a post-threat study could be conducted. However, a contingency plan was developed to assure some post-threat data, in the event that initial sites were not threatened during the period of study. Accordingly, preless post studies were conducted on the first three significant flash floods which occurred during the main data collection year. (One of those floods occurred in a site already designated as a hurricane site, and later threatened by a hurricane as well). In addition to the four preless post studies, flash flood warnings were issued for four of the six pre-threat sites, and post-threat interviews were conducted in these sites as well.

The primary goal of site selection for the six hurricane sites was to gain an adequate coverage along the Gulf and Atlantic Coasts. In addition to these six sites, similar but less systematic data were gathered during the pretest year for two additional hurricane sites on the Gulf Coasts. Because no hurricanes occurred during the main data collection year, post-threat studies were conducted in three of the original sites the following year, maintaining the pre-post design but with somewhat greater time lag between measurement periods than was planned at the outset. As noted earlier, a brief organizational study was also conducted in one other site to determine the relevance of our procedures for studying severe winter storms. Only the tornado, hurricane and flash flood data will be considered in this report.

INTERVIEWING

The only way to obtain the type of thoughtful and detailed information needed from a very large number of respondents was to interview them. Mailed questionnaires could not provide for explanatory probes, encouragement to provide personal accounts, or assistance in recalling details. Similarly, response rates are typically much higher for interviews than for mailed questionnaires. For various reasons, it was concluded that the organizational respondents had to be interviewed face-to-face. However, with less stringent interview demands and public relations considerations, the far greater number of household interviews were conducted via long distance telephone, with automated data entry directly to computer files.

Details of organizational and household sampling appear in the next two chapters. Overall numbers of interviews completed, by pre or post phase, organization or household interview, and site, are provided in Table 2.1. Altogether, 9,283 interviews were conducted. A very large body of data is contained in those interviews; much of it has been entered into computer files. Those data will continue to be analyzed in the coming months and even years. Chapters III and IV can only tap major findings and hint at the extent and depth of information obtained by the project.

Table 2.1

Number of Completed Interviews,
By Phase, Type and Site, 1977-1979

	Pre-threat		Post-threat		Preless Post	
	Hshld.	Organ.	Hshld.	Organ.	Hshld.	Organ.
TORNADO SITES						
Tupelo, MS	200	32	137	31		
Tulsa, OK	220	35	122	34		
Salina, KS	203	35				
Council Bluffs, IA	208	35	130	35		
South Bend, IN	199	35				
Madison, WI	202	39				
Shakopee, MN	152		104			
Fridley, MN	138		100			
Maplewood, MN	134		77			
FLASH FLOOD SITES						
Atlanta, GA	204	30	128	31		
Sedona, AZ	72	37	41	32		
Boise, ID	201	33	135	32		
Wheeling, WV	204	32	144	33		
Muncy, PA	204	30				
Heppner, OR	204	24				
Clarksburg, WV					197	24
Canyon, TX					181	33
Rochester, MN					198	36
New Orleans, LA					193	46
Kansas City, MO					174	
HURRICANE SITES						
Corpus Christi, TX	220	48				
Port Arthur, TX	216	*		**		
New Orleans, LA	202	46	119	45		
Mobile, AL	228	*	142		366	45
St. Petersburg, FL	202	44				
Miami, FL	240	45	151	47		
Brigantine, NJ***	202	39				
Newport RI	204	41				
EARTHQUAKE SITES						
San Bernardino, CA	207	58				
Palmdale, CA	202	53				
Seattle, WA	203	65				
WINTER STORM SITES						
Eau Claire, WI		33				
TOTALS	5071	869	1530	320	1309	184
GRAND TOTALS	7910 Households			1373 Organizations		

NOTES: *Open-ended pretests conducted, no data coded.
**Small open-ended study to investigate events leading to unnecessary evacuation of Sabine Pass during Hurricane Claudette.
***Organizational data focused on both Brigantine and Atlantic City, N.J. whereas household data focused only on Brigantine.

III. Organizational Studies

SUMMARY OF RESULTS

In the organizational component of our research, we focused on three primary problems affecting the response of community organizations to natural hazard threats.

The first problem involved the process of the dissemination of warnings from National Weather Service offices to local community organizations and the general public. Our findings here are as follows:

(1) Commercial telephone service was unreliable for the dissemination of warnings.

(2) The National Weather Service was unable to disseminate warnings directly to one third of the civil defense offices and 40 percent of the broadcast media stations.

(3) Forty percent of the civil defense offices were unable to comunicate directly with the local National Weather Service office, as was the case with all law enforcement agencies in one third of the sites.

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(5) In 50 percent of the sites, no emergency service agency could communicate with any broadcast media station.

As a result of these communication gaps, we further found that:

(6) In one third of the tornado and flash flood post-threat studies, no warnings were issued due to communication failures between the National Weather Service and local emergency service agencies.

(7) In those sites in which warnings were issued, over 50 percent of the organizations studied did not receive the warnings.

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The second problem involved the organizational structure of local civil defense offices and the effect of this structure on the ability of these offices to respond to natural hazard threats. Our findings support the hypothesis that serious coordination problems will exist in sites which have separate city and county civil defense offices. One half of our study sites have this form of civil defense organization. Our findings also indicate that local civil defense offices which are components of other governmental agencies will face difficulties in coordinating community response under emergency conditions. Two thirds of the civil defense offices we studied were components of other governmental agencies. Thus, our research indicates that a majority of local civil defense offices are organized in such a manner as to create coordination problems, rather than solve them.

Finally, we examined directly problems involved in the overall coordination of community response to natural hazard threats. We found that two characteristics of the typical community's civil defense effort--a serious lack of communication facilities and a splintered civil defense function--combined to exaggerate the coordination problems created by each characteristic separately.

III. Organizational Studies

BACKGROUND AND PREVIOUS RESEARCH

The purpose of the organizational component of this research is to gain a more complete understanding of the factors and processes which determine the response of community organizations to natural hazard threats. The National Oceanic and Atmospheric Administration (NOAA) has, for a number of years, conducted surveys of key local officials in areas affected by major disasters. These surveys have provided useful insights into the problems encountered during disaster events. While the primary focus of these surveys has been on NOAA and National Weather Service (NWS) operations, they have also provided information on the interaction between these federal agencies and local officials. In addition to these NOAA surveys, numerous field studies conducted under the auspices of the Disaster Research Center at Ohio State University have provided more analytic insights into the processes involved in the response of local organizations to disaster events.

To a large extent, the questions on which this component of our research focuses are based on this existing literature. Through our pre-post design, we have attempted to document both the manner in which our study sites differ with respect to the basic organizational structure of their civil defense or emergency service functions and the manner in which these differing organizational structures affect the effectiveness of their response to natural hazard threats. In particular, our research focuses on three quite specific problems which have been repeatedly cited as affecting the effectiveness of a community's response to natural disasters.

First, we will analyze the fundamental problem of the processes involved in the dissemination of warnings from the local office of the NWS to relevant local community agencies or organizations. Next, we will examine the problem of how a community's civil defense or emergency service functions are integrated into the routine organizational structure of the governmental agencies and the effect of this on the community's ability to coordinate response under emergency conditions. Finally, we will focus on the problem of coordinating the activities of all relevant community organizations involved in the response to natural hazard threats. In this summary volume we will present only the major findings and recommendations relevant to each of these problems; the detailed data on which these findings are based will be presented in a later technical document.

METHODOLOGY

Prior to our examination of these three research problems, we must lay out in some detail the research procedures utilized in the organizational component of our study. In this section we will explain first the procedures used to select the organizations which were interviewed in each community. Next, we will describe the types of information or data collected in each of the three types of studies conducted.

Sampling of Organizations

The organizational component uses a somewhat different definition of a study site than does the household component. This was necessary since many of the organizations involved in a given community's response also have responsibilities for other communities. Thus, the primary unit of study in the organizational component is the county in which the study community is located. Given this definition, we focused on relevant organizations which had responsibility for the county, the study community, and a "small town" within the county.

The organizations selected for study can be conveniently classified into the following ten categories:

(1) the National Weather Service Office with warning responsibility for the county,

(2) state and local governmental emergency service agencies--e.g,, civil defense, law enforcement, fire protection, etc., agencies at the state, county, city, and town levels,

(3) specialty agencies at the federal, state, or local levels--e.g., the Army Corps of Engineers, and such local agencies as levee boards, drainage districts, bridge authorities, port authorities, etc.,

(4) state and local public works agencies,

(5) local public and private school systems and colleges,

(6) local broadcast and news media,

(7) local vounteer agencies--e.g., American Red Cross, Salvation Army, amateur radio operators, etc.,

(8) local emergency hospitals,

(9) local public and private utility companies--e.g., water, natural gas, electricity, and telephone, and

(10) a sample of various types of private industry in the county--e.g., major manufacturing plants, hotels and resorts, large office buildings, shopping centers, etc.

In general, between 30 and 50 organizations were selected in each study county. The variation in the number of organizations was due primarily to the population size of the county and to which hazard was being examined--e.g., more organizations are involved in a community's response to hurricane warnings than tornado warnings. Specific organizations were selected by two primary criteria. First, a basic list was compiled of organizations which previous research has shown to be involved in a community's response to natural hazard threats. Any community organizations which fell into the categories on this list were automatically selected for the study. Second, copies of the community's civil defense preparedness plan were obtained and any additional organizations mentioned in these plans were also selected for study. In only a few isolated instances were we informed that a relevant organization had not been included.

Procedures and Measurement

As explained earlier in Chapter Two, three types of field studies were conducted under this project: (1) the pre-threat study, (2) the post-threat study in a site which had been the subject of a pre-threat study, and (3) a post-threat study in a site which had not been the subject of a pre-threat study. To a significant extent, the information or data collected differed among the type of study conducted. In this section we will describe the basic types of information collected and how this varied across study types.

The basic type of data collected in this organizational component involves the extent to which each organization studied had some form of contact with each of the other organizations in the same site. That is, we concentrated on inter-organizational contacts or relations. The principle underlying this strategy was that of the "organizational network." The list of organizations to be studied in each site was presumed to represent the population of organizations which would have to coordinate their activities in the event of a natural hazard threat. One primary purpose of our research, then, was to determine the structure of this network--i.e., which organizations were in contact with which other organizations--and how this structure affected the overall response of the community to the natural hazard threat. In all, four types of such inter-organizational contact were examined.

First, we examined the inter-organizational contacts which occurred on a routine basis--i.e., which occurred under normal or non-emergency situations. The purpose for collecting these data was to determine the extent to which the organizations included in each site routinely interacted with each other. This information could then be used as a baseline measurement to be compared with contact which occurred during the threat or emergency period. Second, we collected detailed data on each organization's ability to communicate with the other organizations via a variety of communication modes. Specifically, we examined the reciprocal--or two-way--communication linkages between organizations for the following modes: (1) two-way radio, (2) hot-line telephone, and (3) two-way teletype. Next, we determined each organization's ability to transmit information to other organizations or to receive information from other organizations via the following types of communication modes: (1) one-way teletype, (2) single- or multiple-band radio monitors or scanners, and (3) one-way telephone systems. These data allow the construction of a model describing each study site's warning dissemination system.

The final two types of inter-organizational contact data collected dealt with contacts between organizations under either (1) hypothetical or (2) actual emergency conditions brought about by a natural hazard threat. In each case a scenario was constructed which described the development of the hazard. For each stage of the scenario, each organization was asked to describe its expected or actual contacts with other organizations. The data collected in this section of the post-threat studies form the basis for evaluating the effectiveness of both the warning dissemination system and the overall response of the community to the natural hazard threat.

The above four types of inter-organizational contact data were collected via personal interviews with appropriate officials of each organization. These data constitute the bulk of the information to be utilized in this organizational component. In addition, however, Professor Carter was able to travel to two hurricane sites--Hurricane David in Miami, Florida and Hurricane Frederic in Mobile, Alabama--prior to the issuance of a hurricane warning by the National Hurricane Center. In both cases, Professor

Carter stayed in the County Civil Defense Emergency Operations Center and took notes on the events which took place. These notes will be used in the comparison of the response of these two sites to hurricane threats.

In the pre-threat studies, data were collected on (1) routine inter-organizational contacts, (2) inter-organizational communication modes, and (3) inter-organizational contacts under a hypothetical scenario. In the post-threat studies in sites which had been the subject of a pre-threat study, data were collected only on inter-organizational contacts under the actual threat scenario. Finally, in the post-threat studies in sites which had not been the subject of a pre-threat study, data were collected on (1) routine inter-organizational contacts, (2) inter-organizational communication modes, and (3) inter-organizational contacts under the actual threat scenario.

RESULTS

In examining the process governing the dissemination of natural hazard warnings through a community's inter-organizational network, we have classified the organizations into five major groups: (1) the local NWS office, (2) the local primary emergency service agencies, (3) the local secondary emergency service agencies, (4) the local broadcast and news media, and (5) those local organizations which must respond internally to the warning but have no responsibility for the community at large. Obviously, a sixth group in this process would be the general public. Figure 3.1 (p. 16) presents a schematic diagram of a typical warning system in which each set of communication or dissemination linkages is labeled. Given this general model of the warning dissemination system, we will focus on the four following major points:

(1) the extent to which reliable communication linkages exist in a given community within and between these five groups of organizations,

(2) the extent to which the existing communication linkages in a community are utilized during a threatening natural hazard event,

(3) the correspondence between the pre-threat or planned warning system and the actual operation of the warning system during a natural hazard threat,

(4) the proportion of the general public which receives the natural hazard warning depending upon the type and timing of the hazard

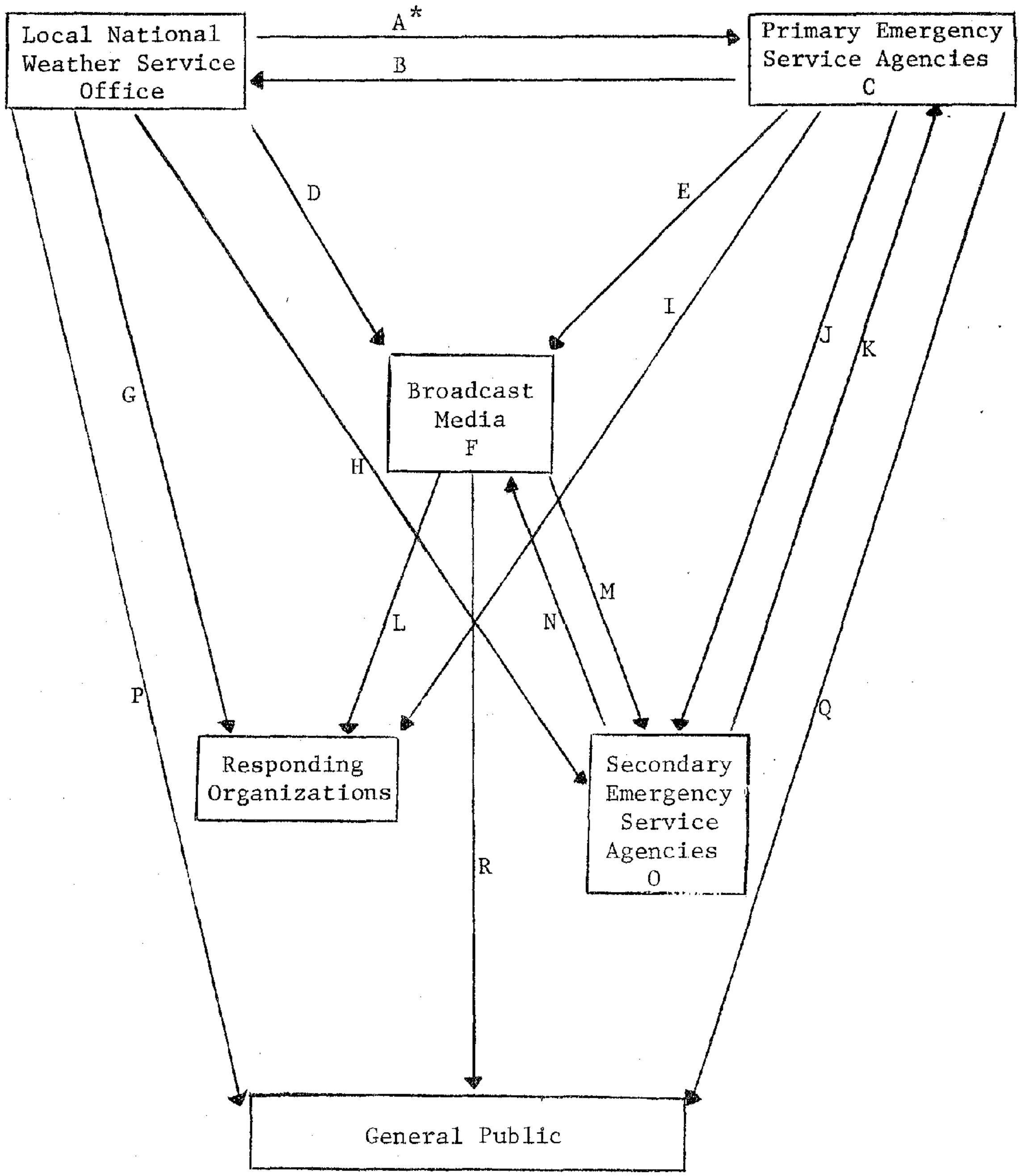

Figure 3.1 Communication Linkages Among Organizations in a Community Warning System.

*Letters on linkage arrows are used to key the figure to text discussion of primary modes of communication.

and the effectiveness of the organizational component of the warning dissemination system.

Before reviewing our findings on the extent to which these five groups of organizations are linked by reliable communication modes, we must briefly identify the specific organizations included in each group. As before, the primary emergency service agencies include the civil defense, law enforcement, and fire protection agencies. The secondary emergency service agencies include the public works agencies, voluntary service agencies, hospitals, utilities, and the specialty agencies. Finally, those agencies which must simply respond internally to warnings include the schools and private industry. In this section, we will not regard commercial telephone service as a reliable communication mode. In the vast majority of the post-threat studies we have conducted, commercial phone service has failed due to either system breakdowns or system overloads. Our data indicate quite clearly that an effective warning system cannot depend on commercial telephone service.

Throughout this next section we will repeatedly refer to a number of communication systems which are in common use in our study sites. Later discussions of these systems will be expedited if these systems are explained before proceeding. The National Weather Service maintains two primary systems for the dissemination of both routine weather forecasts and severe weather warnings: (1) the NOAA Weather Wire Service (NWWS) and (2) the NOAA Weather Radio (NWR). The NWWS is a teletype communications system carried over telephone lines from NWS offices to private or public organizations which subscribe to the service. The recently implemented NWR program consists of a network of FM high-band radio stations operated by local NWS offices. Both of these systems are designed solely for the dissemination of information from the NWS; i.e., they are one-way systems.

A common two-way system by which the local NWS offices communicate with each other and selected primary emergency service agencies is the National Warning System (NAWAS). NAWAS is a hot-line telephone network organized in such a way that a national warning can be issued from one of two national warning points to a warning point within each state. Within each state, the state warning point can then disseminate the warning to selected regional points. However, any organization on the NAWAS network can communicate directly with any other organization in the same state. Thus, its primary use is as an intra-state emergency communication system.

Local law enforcement agencies commonly have two primary systems by which they can communicate with each other: (1) the nationwide radio frequency designated for emergency inter-system use by the Federal Communications Commission (155.475 Mh) and (2) the inter-system law enforcement teletype network. The teletype network is commonly controlled by the state police or highway patrol which relays messages among local agencies. In most states, arrangements have been worked out between the NWS and the state police for the relay of severe weather warnings on this system. In such cases the state police subscribes to NWWS and relays the warnings received via this system.

Another system which allows for emergency communication between primary emergency service agencies and the broadcast media is the Emergency Broadcast System (EBS) which is administered by the Federal Communications Commission. The design of this system is centered on a Common Program Control Station (CPCS) in each geographical area which receives an emergency message and relays it to other broadcast stations via a tone activated radio link. In only a few cases, however, do local primary emergency service agencies have direct communication links with the CPCS station.

Link "A" in Figure 3.1 represents communication modes by which the local NWS office is able to issue warnings to the primary emergency service agencies. Over all of our study sites, only three modes are generally available to the NWS for this purpose: (1) NAWAS, (2) NWWS, and (3) NWR. A few selected sites--e.g., Mobile, Alabama, Miami, Florida, and Tulsa, Oklahoma--have locally designed radio systems or hot-line telephone systems for this purpose. Taken together, there are 32 separate civil defense offices in our 22 study sites. The local NWS office has no communication links with 11 of these offices. However, in each of the study sites the NWS office is able to transmit warning messages to at least one of the law enforcement agencies via a link between the NWWS and the law enforcement teletype network. NWR represents the dominant communication mode between the NWS and fire protection agencies, to the extent that such links exist.

Except for the few locally designed radio systems, the only mode of communication in Link "B"--which represents the ability of the primary emergency service agencies to feed information back to the NWS--is the NAWAS system. Only 18 of the 32 civil defense offices have this ability to relay information to the NWS office. Likewise, in seven of the 22 study sites none of the law enforcement agencies was able to communicate directly with the NWS office. Communication from fire protection agencies to the NWS was essentially nonexistent in our study sites.

Link "C" represents communication modes among the various primary emergency service agencies. We found more site-to-site variation in this set of linkages than in any other set represented in our model of the warning system. In the majority of study sites, two primary modes existed for communication among the various law enforcement agencies: (1) the nationwide radio frequency designated for inter-system use by the Federal Communications Commission (155.475 Mh) and (2) the inter-system law enforcement teletype network. In a few isolated sites a number of the law enforcement agencies had access to the NAWAS system. It should be pointed out that possession of these two primary modes was far from universal among all the law enforcement agencies studied during this project. While most of the larger agencies had the teletype system, relatively few of the small town police departments had access to the system. The possession of the inter-system radio frequency, on the other hand, varied dramatically by region. In more than one-third of our study sites, we found at least one law enforcement agency that had no communications mode with the other law enforcement agencies included in the study. In five of the sites, a serious lack of communication modes among the law enforcement agencies was found.

Of equal importance in terms of the warning dissemination system are the linkages between law enforcement agencies and the civil defense offices. To the extent that they exist, these linkages are primarily of two types: (1) NAWAS and (2) the civil defense office possessed radio transceivers supplied by other governmental agencies. In our study sites, 17 of the 32 civil defense offices do not have NAWAS links with law enforcement agencies in their area. Likewise, 13 civil defense offices do not have radio links with law enforcement agencies. In all, 12 civil defense offices in nine sites have no communication mode with any law enforcement agencies.

Links "D" and "E" in Figure 3.1 represent the most important links of the system in terms of disseminating warnings to the general public since our research indicates that the vast majority of the public receives warnings directly or indirectly from the broadcast media. Due to the large number of broadcast stations in many of our study sites, we only interviewed the primary EBS stations in each community. Thus, our findings here will indicate a higher degree of communication capability than if all broadcast stations had been interviewed. As before, the primary modes of communication between the NWS and the media are NWWS and NWR. However, approximately 20 percent of the broadcast stations interviewed do not subscribe to NWWS and about another 20 percent do not have NWR receivers. Thus, 40 percent of the primary EBS broadcast stations have no reliable means of receiving warnings from the NWS. The situation is much worse when examining linkages between the primary emergency service agencies and the broadcast stations. In no case do more than about 15 percent of the stations have any links with any of the emergency service agencies. In fact, in 11 sites none of the stations interviewed had any links with any of the emergency service agencies.

Link "F" represents communication modes among the broadcast stations. The only system we found here is the EBS radio link between the CPCS station and the other stations in the area. While it is mandatory, by FCC rules, that each broadcast station have a receiver capable of monitoring the CPCS station, active participation in the EBS is voluntary. Thus, although the NWS routinely requests EBS activation in its warning messages, the system is rarely activated by the local broadcast stations.

Next, we found a series of potential links to be almost void in our 22 study sites: (1) Link "I" representing modes from the primary emergency service agencies to the responding organizations, (2) Links "J" and "K" representing modes between the primary emergency service agencies and the secondary emergency service agenices, (3) Link "O" representing modes among the secondary emergency service agencies, and (4) Link "N" representing modes from the secondary emergency agencies and the broadcast stations. In all 22 sites, the dominant means of communicating along these links was commercial telephone. Links "L," "M" and "R" are from the broadcast media to responding organizations, secondary emergency service agencies and the general public. All three links are by broadcast only.

Except for a few cases in which secondary emergency service agencies or utilities subscribe to NWWS, the remaining links from the NWS--Link "H" to the secondary emergency service agencies and Link "G" to the responding organizations--are all represented by NWR. There is considerable variation among these types of agencies in terms of their possession of NWR receivers. Approximately 60 percent of the interviewed utilities and school systems have NWR receivers, compared to 45 percent of the hospitals, 30 percent of public works agencies, and only 15 percent of universities.

Links "P" and "Q"--indicating links to the general public from the NWS and the primary emergency service agencies--are represented by NWR and sirens, respectively. Our household data indicate that, to date, relatively few households have purchased NWR receivers. Although there is some variation across study sites, the average purchase rate is less than 20 percent. Sirens, on the other hand, are widely used by emergency service agencies to warn the public in quick onset situations such as tornadoes. In those post-threat tornado studies in which sirens were used, less than half of the sampled households reported in an open-ended question that they heard the sirens. In one site, many of the sirens did not work, and in another site they simply were not used.

In summary, our data indicate rather convincingly that serious gaps exist in the communication systems currently in use in our 22 study sites. Most organizations or agencies central to the functioning of an effective warning system are only able to communicate with other central organizations via commercial telephone service. Given this situation and the proven unreliability of the commercial telephone service, it should not be surprising that we have studied few effective warning systems in the post-threat studies. In one of the three tornado post-threat studies and in two of the eight flash flood post-threat studies, no warnings were issued by the NWS because of communication failures between the NWS and the primary emergency service agencies. In the remaining two tornado post-threat studies, approximately 53 percent of the interviewed organizations did not receive the warning issued by the NWS. The percentage of organizations which did not receive warnings in the remaining six flash flood studies averaged about 57. Thus, in our post-threat studies, over half of the organizations we interviewed were unaware that warnings had been issued during the height of the natural hazard threat. Given the extended warning period present in hurricane situations, we naturally found that all organizations were aware of the warnings which had been issued in our three post-threat studies.

In six of our sites--two tornado and four flash flood--we were able to compare the pre-threat or expected warning system with the manner in which it actually operated according to data collected during the post-threat study. Among the two tornado sites, only 47 percent of the anticipated warning links were actually utilized. This percentage fell to 37 in the four flash flood sites. Had all anticipated warning links been utilized, 40 percent of the organizations in the two tornado sites would not have been warned--versus 53 percent who were not warned--and 30 percent of the organizations in the four flash flood sites would not have been warned, versus the 57 percent who were not warned.

In interpreting these data, we think it is clear that three primary problems exist at the local level which seriously reduce the probability that any given community's warning system will operate effectively when needed. First, the communication linkages among the organizations most central to the warning system are inadequate and in most cases simply nonexistent. Second, there is evidence that the planned warning systems--as indicated by our pre-threat data--are inadequate in that significant proportions of the organizations would not be warned even if these plans were faithfully followed. Finally, our post-threat data indicate that warning systems are rarely implemented as planned with the result that the effectiveness of the marginal planned warning systems is further reduced. The combination of these three factors in the typical community operate so as to almost guarantee that the local community warning system will fail when needed.

Finally, by using the household data, we can estimate the percentage of the general public which receives severe weather warnings. Obviously, one factor which determines this percentage is the speed of onset of the hazard--i.e., one would expect higher percentages for hurricanes than for flash floods and tornadoes. The percentage of the sampled households which received the NWS's warning message was 88 percent in the three hurricane post-threat studies, 81 percent in the three tornado post-threat studies, and 63 percent in the six flash flood studies. Thus, like the organizational component of the warning system, significant porportions of the general public were unaware of any warnings at the height of the natural hazard threat.

Organizational Structure of Local Civil Defense Offices

In this section we will examine two closely related problems facing local communities in the organization of their civil defense or emergency service agencies. First, we will describe the manner in which our 22 study sites have attempted to integrate these functions into the routine organizational structure of governmental agencies. Second, we will attempt to determine the effect that different integration strategies have on the community's ability to coordinate response under emergency conditions. These questions are quite relevant to the recent programs advanced by the Federal Emergency Management Agency (FEMA) to promote the concept of comprehensive emergency management.

In describing the integration strategies employed by our 22 sites, we will use three dimensions of organizational structure. First, since our study sites are defined as counties, we will distinguish between sites which have unified city-county civil defense offices and sites in which both the city and the county maintain separate civil defense offices. Second, for each civil defense office, we will distinguish between those which have full-time directors and those which have part-time directors. Finally, for each civil defense office, we will distinguish between those which have independent agency status and those which are a component of another agency. The argument we will develop, using previous research and our own data, is that the preferable integration strategy would be to have an integrated city-county civil defense office with an independent agency status and a full-time director.

Our 22 study sites are split evenly between those with unified city-county civil defense offices and those with separate city and county civil defense offices. This split, however, does not follow any identifiable pattern in that the strategy employed does not appear to be related to the population size of the county, its previous experience with natural disasters, etc. This split yields 32 separate civil defense offices--in one site no county civil defense office exists. Of these 32 offices, 22 have part-time directors and 10 have full-time directors. It is important to note that only three of the part-time directors are not full-time public employees. That is, in the vast majority of cases, part-time civil defense directors are public employees with other responsibilities who are expected to devote some portion of their time to civil defense duties. Finally, 22 of the civil defense offices are components of other governmental agencies, while ten occupy the status of an independent agency.

When these dimensions are cross classified, over half of the civil defense offices--17 of the 32--are found to have what we consider to be undesirable organizational characteristics. That is, they are located in sites with separate city and county civil defense offices, are components of other agencies, and have part-time directors. In only five of the 22 sites is the civil defense function organized optimally.

Our argument concerning the desirability of certain organizational characteristics for civil defense offices is based initially on the previous research undertaken at the Disaster Research Center of Ohio State University and a report by Anderson (1970), in particular. Anderson pointed to the marginality of the typical civil defense office and, using traditional organizational theory, deduced a number of problems such offices would encounter. In an earlier paper, Professor Carter (1980) applied Anderson's thesis to the three dimensions discussed above. Thus, Professor Carter developed three predictions concerning how one would expect various civil defense offices to handle coordination problems based on the integration strategy employed by the study site.

First, it was predicted that those sites with separate city and county civil defense offices were likely to face coordination problems arising from the autonomous actions of two parallel sets of agencies. That is, carefully planned coordination between city and county agencies would be necessary to insure that inconsistent actions were not undertaken. A second problem was that of uncertainty of authority which could be expected to be especially critical for those civil defense offices which are components of other governmental agencies. Of relevance here is the expectation that if the civil defense office is under the authority of another governmental agency, then one of its primary roles--overall coordination of the community's response to emergency conditions--will be difficult to perform. The final problem is that of organizational membership and responsibilities which was predicted to affect particularly those civil defense offices with part-time directors.

To a significant extent these predictions have been upheld by our research. Of the 14 post-threat studies in 13 sites, five took place in sites with separate city and county civil defense offices. In all five sites, we found relatively poor coordination between the city and county response efforts. This lack of coordination ranged from mere lack of communication to inconsistent actions and conflict. Further, in none of these five sites did the separate civil defense offices have the capability of communicating by any means other than commercial telephone service.

A total of 18 civil defense offices existed in these 13 sites. Of these, ten were components of other organizations--primarily either the sheriff's department, the police department, or the fire department. In all but three of these cases--all at the city level--the civil defense office played a relatively minor role in the site's response to the natural hazard. In fact, in three of these sites the civil defense office played no role at all in the site's response to the natural hazard threat. While a number of problems existed in sites with part-time civil defense directors, most of these cases also had separate city and county civil defense offices and civil defense offices which were components of other agencies. Thus, it is difficult, with our small number of cases, to attribute these problems to part-time directors.

On the other hand, four of the sites had what had been predicted to be optimal civil defense organizational structures--Council Bluffs, Iowa, Rochester, Minnesota, Atlanta, Georgia, and Mobile, Alabama. With one exception, these sites had the most coordinated response to the natural hazard threat we observed. Two of these were particularly noteworthy--Mobile, Alabama and Rochester, Minnesota.

On the basis of our own research and the research performed at Ohio State University, it is apparent that a majority of local civil defense offices are organized in such a manner as to create coordination problems rather than solve them. Thus, without dramatic changes in the organization of the civil defense or emergency service function at the local level, it seems unlikely that FEMA's efforts to promote comprehensive emergency management will meet with much success.

Coordination of Community Emergency Service Organizations

In this final section, we will combine the topics of the previous two sections and discuss explicitly the problems of coordinating response to natural hazard threats. In the first section we found that serious communication gaps exist throughout the network of organizations which must coordinate their activities during emergency periods. In an attempt to offset the difficulties created by this lack of communication, it has become commonplace to establish Emergency Operation Centers in which representatives of each organization are brought together at a single location. There is little doubt that such a strategy is effective in facilitating coordination among those organizations represented at the EOC. However, given the splintering of civil defense efforts between cities and counties, the EOC's tend to become isolated enclaves which operate to inhibit coordination between different governmental jurisdictions.

That this process has important implications for the coordination of response to natural hazard threats can be seen from a comparison between the response to Hurricane David in Miami, Florida and Hurricane Frederic in Mobile, Alabama. As mentioned earlier, Mobile has a unified civil defense organization. Miami, on the other hand, has separate civil defense offices for the county and the city of Miami, as well as most of the smaller towns in the county. As a result, Mobile had a single EOC in operation during the threat period from Hurricane Frederic, while at least five separate EOC's were in operation throughout Dade County during the threat period from Hurricane David.

In Miami, we found evidence of close coordination among county agencies and among city agencies. However, there was little evidence of close coordination between city and county agencies. Much of this lack of coordination can be attributed to the fact that city and county agencies were isolated in separate EOC's with little or no communication between the two locations. The situation was quite different in Mobile where both city and county agencies were located in the same EOC. As a result, there was close coordination both among and between city and county agencies.

In general, then, we have a situation in which two characteristics of the typical community's civil defense effort--a serious lack of communication facilities and a splintered civil defense function--combine to exaggerate the coordination problems created by each separately.

IV. Household Studies

SUMMARY OF RESULTS

Comprehensive household data on populations at risk to tornadoes, flash floods and hurricanes were gathered prior to the threat of these natural hazards. Post-threat data collection permitted the identification of pre-event household characteristics and orientations which predict the taking of defensive action in response to warnings. Although the character of household response is somewhat different among the three hazard types, a common process of response to natural hazard warnings is discernable.

The initial response of the public to the receipt of hazard warnings is to seek additional confirming information. In all three hazards, the receipt of warnings prompted household heads to seek confirmation of the warning information through discussions with their family, friends, and neighbors, by personally assessing environmental conditions (in tornado and flash flood situations) or by turning to their radios and televisions. An assessment of risk to the current threat resulted from this information-gathering process and prior notions of being at risk to the hazard. It appears that the very general nature of warning messages with their tendency to specify only general geographical referents provides great opportunity for the exclusion of oneself from the "at risk" category.

For those, however, who did define themselves at risk, the next step was serious consideration of alternative defensive actions. Once a family reaches this stage in the decision-making process, they have a high probability of actually evacuating. Another important factor in making this final decision, in all three hazard types, was whether respondents had prior plans for what they would do if a threat like the present one occurred.

In general, the analyses of the household studies have found:

(1) Warning confirmation is a critical first step in the decision-making process.

(2) General warning messages broadcast through the mass media motivate the public to seek additional information, but apparently do not motivate them to take immediate action.

(3) Social contacts with friends, relatives and neighbors are important during the decision-making process.

(4) Many residents who are at risk to natural hazards do not perceive themselves to be at risk.

(5) Risk perception is a critical variable in the continuation of the decision-making process.

(6) Warnings received directly from local authorities facilitate the decision-making process.

(7) Having a plan of what to do and where to go increases the probability of taking defensive actions.

(8) The majority of the public at risk to natural hazards does not take extreme forms of defensive behavior (i.e., evacuation and seeking safe shelter) in response to hazard warnings.

IV. Household Studies

BACKGROUND AND PREVIOUS RESEARCH

There is little doubt as to the potential benefits of advanced warning to populations at risk to natural hazards in reducing their vulnerability to such hazards. Warning of impending natural disasters provides opportunities to protect lives and property, to minimize social disruption, and to put plans for recovery, rehabilitation, and reconstruction into operation. Individual and community response to warnings varies, however, largely as the result of the character of the warnings issued and the preparedness of the threatened population to react appropriately to such warnings. Unfortunately, only a portion of the potential benefits of hazard warnings are realized because of failures in the effective dissemination of warnings and/or inappropriate and inadequate responses once they are issued. One of the most frequent complaints of public officials is that citizens fail to respond adequately to natural hazard warnings once they are issued.

There is widespread agreement among researchers in psychology, economics, geography, and sociology (Slovic, Kunreuther, and White, 1974; Janis and Mann, 1977; Perry, et al., 1980; Drabek, 1969; Clark and Carter, 1979) that the appropriate model to describe public response to natural hazards is a derivative of traditional decision-making models. Using this concept, information relating to the existence or possibility of a natural hazard is viewed as one of a number of inputs into some form of a probabilistic utility function which is based on a payoff matrix. It should be noted that such a model is only one of a number of possible models which could be utilized to describe response to an informational input. Another possible model is the stimulus-response model which forms the basis of much current learning theory. The primary difference between these two models is the extent to which the individual is viewed as an independent actor capable of evaluating and differentially acting upon informational inputs.

The choice of a decision-making model over a stimulus-response model is based, in part, on the fact that a number of the empirically observed behaviors associated with response to information on natural hazards (e.g., seeking confirmation of the information, delays in responding to the information, consideration of alternative actions, etc.) are more consistent with (although not a proof of) a decision-making process. That is, predictions from a decision-making model of how individuals would respond to hazard information are more consistent with the existing empirical data than are predictions from a stimulus-response model.

Two major objectives of the household studies were to identify the key determinants of household decision making in response to natural hazard warnings and to make recommendations for increasing the likelihood of producing desired responses to these warnings. Content, timing, source, and consistency of warning messages all influence how individuals and families respond, which may include taking immediate, defensive action, attempting to verify the warning, "waiting and seeing," or ignoring the warning information. Ideally, warning statements could be constructed so as to elicit prompt appropriate action. To approach this ideal, however, requires careful attention to factors underlying this decision-making process. Both social psychological factors (such as feelings of vulnerability and risk perception) and social factors (such as family relations and neighborhood integration) affect the response of the household to warnings. It is possible that extended family and neighborhood relationships play a major role in household response and that hazard plans and warnings must recognize and capitalize on the informal, interpersonal communication networks found throughout all communities.

METHODOLOGY

Sampling of Households

Flood maps, hurricane storm maps, and city maps were used to determine the area at risk in each site and informants on site were consulted to pinpoint the risk areas more precisely. Two computerized sampling programs, designed specifically for this project, randomly selected samples of 400 persons at risk from either city telephone directories (where the entire site was at risk) or cross-reference city directories (where only a portion of the city was at risk). In tornado sites, the sample was drawn from the entire urban area. In flash flood sites, the sample was drawn from households within the 100 year flood lines and, in the "post-threat without pre-threat" surveys, from households which had been flooded to any degree. In hurricane sites, areas near the coast less than 20 feet above mean sea level which were likely to be flooded during a hurricane were sampled. The 400 households in the original samples were telephoned at random until a final sample of approximately 200 heads of household was obtained for each site.

Data were either entered into the computer directly at the time of the interview via CRT's (cathode ray tube terminals) or recorded on code sheets and later stored via CRT terminals. In three sites (Atlanta, Corpus Christi, and Miami), interviews were conducted in Spanish for Spanish-speaking respondents.

Procedures and Measurement

The pre-threat household studies were designed to measure the extent to which community residents are prepared to respond to tornado, flash flood and hurricane warnings. In addition to standard social and demographic characteristics (such as age, work status and family structure), the household interviews focused on seven substantive areas related to disaster warnings. These include: (1) previous experience with hazards and hazard warnings, (2) exposure to the mass media (questions covering the likelihood and manner of receiving warnings directly and evaluations of past warnings), (3) integration of the household into the neighborhood (variables focusing on the possibility of receiving and transmitting warnings and reactions informally), (4) knowledge about hazards and warning terms (such as the meaning of watches and warnings), (5) feelings of vulnerability to hazard threats, (6) plans for response to tornado, flash flood and hurricane warnings, and (7) judgments about probable response to hypothetical hazard warnings.

The post-threat studies were designed to measure actual household response to tornado, flash flood and hurricane warnings and to compare pre-threat plans, orientations, perceptions and day-to-day behaviors with actual responses during activation of the warning-response systems. The household interviews focused on receipt and evaluations of warning messages as well as decisions made and actions taken during the warning period. In addition to the structured interview schedule, all post-threat interviews included a single open-ended question asking for a narrative of actions taken during the warning period. Responses to the open-ended question were taped and later transcribed. Although various fixed-answer questions were also asked about actions taken, the open-ended responses enabled us to gain greater insight into the sequence of events in the decision-making process. They have also proved helpful in verifying conflicting data within questionnaires as well as being useful for descriptive and illustrative purposes.

The "preless post" studies attempted to measure the same substantive areas that were included in the pre-threat and post-threat studies. Since these communities were selected because they had experienced a hazard threat, questionnaires examined household characteristics at the time of the threat and responses immediately after the threat. Household preparedness and feelings of vulnerability prior to the hazard event were measured retrospectively.

RESULTS

In our analysis of public response to natural hazard warnings, we have developed multi-stage probability models of the process leading to the decision to take defensive action (i.e., seeking shelter and evacuation) in response to tornado, flash flood and hurricane warnings.

The models are composed of a series of multiple regression equations. Because all of the variables in the models are dichotomies (coded yes = 1, no = 0), the unstandardized regression coefficients can be interpreted as the increment in probability of saying "yes" on the dependent variable that is associated with saying "yes" on the independent variable. For example, if individuals in Mobile responded "yes" to the question: "During the time that you were making up your mind whether to evacuate or not, did you have a pretty good idea of where you might go if you decided to leave?," this increased their probability of evacuating by 19.6 percent over those who did not have an idea of where to go. In other words, 19.6 percent more people who knew where they might go evacuated than did people who did not know where to go.

It is important to point out that while the models do give probability increment values for the variables, the coefficients cannot be directly compared across samples as the values are sensitive to differences in sample variances. We have identified a number of factors which are external to the models and which affect the differences in the values both across hazard types and across sites within hazards. The characteristics of the hazard, including both the speed of onset of the hazard and the severity of the event, affect which variables are important in the decision-making process. For example, in a tornado, where the lead time before the expected touchdown is very short, discussing plans with relatives and neighbors is not a very important variable. In a hurricane situation, where the lead time before the expected landfall may be several days, discussion of plans can be a very important variable. Characteristics of the sample population, including the level of previous experience, the length of residence in the area, the type of family structure and other demographic characteristics (such as age) can affect the values of the coefficients across sites. A final important factor which influences the importance of different variables within the models is the content of the warning messages received by the public. The source, specificity, certainty, and urgency of a warning varies across hazards, across sites, and across messages.

From our studies of public response to natural hazards, we have developed three somewhat different models of response--one for tornadoes, one for flash floods and one for hurricanes. The tornado model is based on our studies of six tornado threats (Tupelo, Tulsa, Council Bluffs, and three suburbs of Minneapolis-St. Paul). The flash flood model is based on studies of flooding events in Rochester, Minnesota and Clarksburg, West Virginia, and the hurricane model is based on response to Hurricane David in Miami and Hurricane Frederic in Mobile. Although there are slight differences in the form of these models due to the available responses in our questionnaires and the timing between receiving a hazard warning and the impact of the hazard, we have concentrated on the same types of variables across all three hazards.

General Overview of the Model

The tornado model has three stages. The first identifies those variables that predict confirmation of the warning messages. The second stage focuses on those variables that predict risk perception during the warning period, and the final stage identifies those variables which predict taking shelter. The flash flood and hurricane models have four stages. The first two focus again on predicting warning confirmation and risk perception during the warning period. The third stage focuses on those factors that predict considering evacuation as a viable alternative response to the hazardous event. The fourth stage looks at additional factors which convince those families that are seriously considering evacuating to leave their homes.

Variables in the Equations

The first variable set that we looked at was "Warning Information." Two different types of warning information were measured in our questionnaires. The first is general warning messages, such as watches and warnings, that are received through the mass media or through mechanical devices, such as sirens. Our studies show that the vast majority of people receive their first warnings through the mass media. These warnings are usually very general in nature, seldom mentioning locales in more detail than counties or cities. The second type of warning information comes from local authorities. This type of information includes the evacuation recommendations issued during hurricane situations, weather information received directly from local officials, and advice received on how to respond to the hazard threat. Warnings from official sources, such as police and fire departments, are more likely to be believed and acted upon. These messages are also usually delivered in a more personal manner, with department members carrying street or door-to-door warnings. Studies have shown that belief in warnings is greater for warnings that are delivered personally than for those communicated through some impersonal medium such as the mass media or sirens (Moore, 1963; Williams, 1964).

While warning messages are part of the formal communication network that operates during a hazard threat, informal communication networks also operate in all communities. To study this phenomenon, we focused on two variable sets. The first of these is called "Social Contacts" and measures whether or not relatives and friends checked on the safety of the respondent during the warning period. While these variables were measured in all three of the models, social contacts do not seem to play a role in the decision-making process during a tornado threat. This is most likely due to the very short time between the issuance of a warning and the impact of the tornado. The second set of variables is labelled "Community Integration," and focuses on whether or not the family discussed their evacuation plans with relatives in the area or their neighbors before making their final decision. Both variable sets are important in the flash flood and hurricane models. In these situations, in addition to checking on the family's safety and discussing plans, friends and relatives may extend an invitation to the family to stay with them upon evacuation. Our studies have shown that the majority of evacuees do not go to public shelters, but rather go to the homes of relatives and friends. The invitation to evacuate may play an important role in the final decision of whether or not to leave.

People can also receive information from the environment. The flash flood and tornado models include a variable labelled "Environmental Clue." In tornado situations this variable measures whether or not the respondent looked to the sky for threatening storm clouds. In the flash flood model, the environmental clue measures whether or not the respondent experienced any flooding near her/his home. We have no measure of clues from the environment for hurricane situations, although we believe that such things as increased winds and heavy rains can play a role in decision making during hurricane threats.

Many officials assume, as least implicitly, that the public will (or should) respond automatically to the warnings that they issue. Most people, however, will not take protective action on the basis of a single warning message. This is particularly true when they have previously received warnings and had no hazard materialize. Upon receipt of a hazard warning, most people will make some attempt to check on the information. "The attempt on the part of a warning recipient to obtain additional information beyond that contained in some original warning" is termed "Warning Confirmation" in the hazards literature (Mileti, Drabek and Haas, 1975) and is the first "stage" or first dependent variable that we are predicting in our models.

Drabek (1969) identified patterns of confirmation behavior in his studies of the 1965 Denver flood. His first method is "appeals to authority." A very small percentage of people attempt to contact local officials directly, usually by telephone. Many families, however, turn to their radios and televisions for additional information as they expect information from officials to be transmitted via the mass media. This is an indirect appeal to authority. Drabek's second method of warning confirmation is called "appeal to peers." This includes either face-to-face or telephone contact with friends, neighbors, and relatives in order to find out more information about the hazardous situation.

Drabek also found that many families did not consult with anyone, but looked to the environment for confirmation of the warning information. Going to the flood site and checking the water level or observing the behaviors of others around you (such as neighbors and local authorities) are all examples of "observational confirmation."

We have found that different methods of confirmation are used for different hazard types. Seeking additional information from the mass media, authorities, or peers are all used to a great extent in hurricane situations. Indirect appeals to authorities via the mass media are the primary sources of additional information in tornado situations. It is hypothesized (although we have no systematic measure of this) that many people receive their first warning of a tornado by hearing sirens and turn to their radios or televisions for additional information about the location of the tornado. In flash flood situations, people appear to rely on "observational confirmation" (specifically, looking out their windows and checking the levels of the creeks) to check on the information they receive in the official flash flood warnings.

The models also focused upon the respondents' perceptions of risk to the hazardous event. If people do not believe that they are at risk to the hazard, it is not very likely that they will take protective actions against the threat. There are two measures of risk perception in our models. The first measures the respondent's perception of risk prior to the event. In flash flood and hurricane situations, the respondents were asked if they considered their immediate neighborhood at risk to flooding. In tornado situations, respondents were asked their perception of the likelihood that a tornado would hit the area where they live. We also have a measure of risk perception during the warning period. "Risk Perception During the Event" is the second "stage" in our decision models. This variable is based upon the official warning information received during the warning period. The respondents were asked their perceptions of the likelihood of a tornado touchdown or flooding occurring in their immediate neighborhood, based on the warning information they received. While this stage of the model is not very important in the decision-making process operating in tornado situations (probably due to the limited scope and erratic pattern of tornadoes), it plays a key role in the process of response to hurricanes and flash floods.

Individuals make assessments of their risk to the hazard based upon all the information they have received from the mass media, peers, authorities, and the environment, and their prior perceptions of risk. If, based on this information, individuals perceive themselves to be at risk to the flash flood or hurricane threat, they consider alternative actions to take in response to the hazard. Our models focus on one of these alternatives--"Consideration of Evacuation"--which is the third "stage" of our hurricane and flash flood models. This stage is not measured in the tornado models, due to the limited time available for decision making in tornado situations.

In the final stage of the hurricane and flash flood models, we attempted to determine what factors are important in reaching the decision to evacuate for those who seriously consider evacuation. Our models indicate that if a family considers evacuation, they have a 40 percent chance of leaving their home, even without receiving further incentives. Additional variables that are entered at this point in the analysis include knowing where to go and what routes to take to a safe place, authorities advising evacuation, and discussing evacuation plans with relatives and neighbors.

The final stage in the tornado model focuses on those factors that predict taking shelter. Two additional variables are important at this stage--having a tornado plan at home and knowing of a safe place within the home in which to take shelter.

Results from the Tornado Model

The summary model of response to tornado threats, based on studies of response in Tupelo, Tulsa, Council Bluffs, and three suburbs of Minneapolis-St. Paul, is shown in Figure 4.1 The first stage of our model examines the effects of four variable sets on behavior aimed at confirming the warning message. The first of the four independent variable sets contains warning information variables including the watch, the warning, information from officials, advice on how to respond to the threat, and the warning sirens. Not all of these variables are relevant in each tornado site; no warning was issued in Tupelo, and no sirens were sounded in Tupelo and one of the Twin Cities' suburbs. In Tulsa, sirens were sounded, but many of them failed to go off. Receiving a tornado warning is a strong predictor of

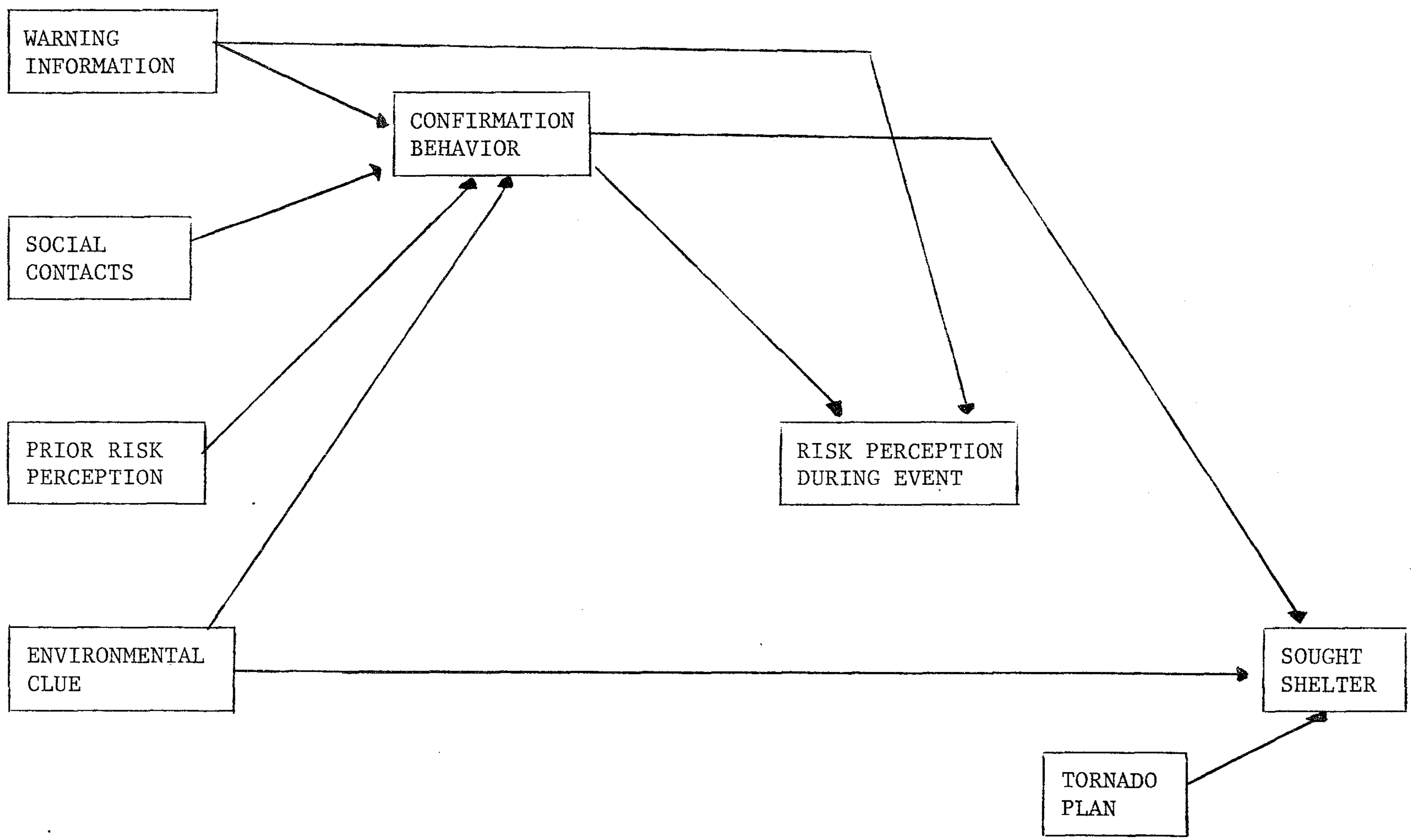

Figure 4.1. Summary Model of Response to Tornado Threats. All paths indicated are significant and positive; the magnitude of the paths, however, is dependent on situational variables, such as the nature of the threat, the warnings issued, and the community's prior disaster experience.

seeking additional information in all sites. In sites in which a tornado warning was issued, about two thirds of the respondents reported seeking such information. In Tupelo, where no warning was issued, receiving the tornado watch had the same effect as the warning did in the other sites. Hearing tornado sirens had a strong effect on confirmation attempts in the Twin Cities. It appears that the primary effect of watches, warnings, and sirens is to motivate the public to seek additional confirming information.

The second variable set in stage one deals with social contacts with relatives and friends during the warning period. The third variable set is a measure of prior risk perception taken from the pre-threat studies. Prior risk perception did have an effect on warning confirmation in the site where official information about the threat was not available. The final variable measures clues from the environment--in this model, we measured the effects of observing threatening storm clouds. All four of these variable sets were important in predicting confirmation behavior.

The second stage of the tornado model focuses on predicting risk perception during the tornado threat. Warning information, specifically the tornado watches and warnings, and warning confirmation are important variables in this stage of the model. It appears that the public assesses their risk to tornado threats based on the official information they receive and their efforts to confirm these initial messages.

The final stage of the tornado model identifies important predictors of seeking shelter in response to tornado threats. Warning confirmation, clues from the environment and plans for response all predict whether or not a person will seek shelter. Observing threatening storm clouds had its largest effect in the situation in which official information was not available. It is important to note that confirmation behavior and environmental clues can have negative effects as well as positive effects on taking shelter, depending on the characteristics of the event. For example, if a person seeks additional information in response to hearing a tornado warning or siren, and finds that the tornado is not headed in his direction, he will not seek shelter. The same is true for clues from the environment; if the individual sees that the skies above him are clear, he will not seek shelter.

Two very important variables which predict whether or not a person will seek shelter during a tornado threat are having a tornado plan at home and knowing of a safe place within the home in which to take shelter. For example, in the Twin Cities, having planned for what to do in case of a tornado warning increased the probability of taking shelter by 20 percent. It is very important to point out that the majority of respondents in every site did not seek safe shelter--a majority of the public remained at risk to the tornadoes.

Results from the Flash Flood Models

The summary model of response to flash flooding events is shown in Figure 4.2. This model is based on responses to flash flooding in two communities--Rochester, Minnesota and Clarksburg, West Virginia. These two sites are quite different from each other; most residents of Clarksburg were experienced with flash flooding while many Rochester residents had never experienced flash flood warnings or flash flooding before this event. Another important difference between the two sites deals with awareness of warnings. Eighty percent of the residents of Clarksburg reported hearing the flash flood warning. In Rochester, where the flooding occurred very late in the evening and where there were major power outages, only 38 percent of the respondents were aware of flood warnings before significant flooding occurred in the area.

The first stage of this model focuses on predicting confirmation behavior. The most important variable in predicting confirmation attempts in both Rochester and Clarksburg was receiving the flash flood warning. In addition, if people in Clarksburg believed that their area was at risk to flooding prior to the flood, they were also more likely to seek additional information during the warning period.

The second stage of the flash flood model identifies those variables that are important in convincing people that they are at risk to the present flooding event. Standard warning messages and information received from officials are both important in increasing peoples' perceptions of risk during the event. Risk perception prior to the event and experiencing flooding near one's home were important in the site with the most previous experience. Social contacts were very important in Rochester. This could

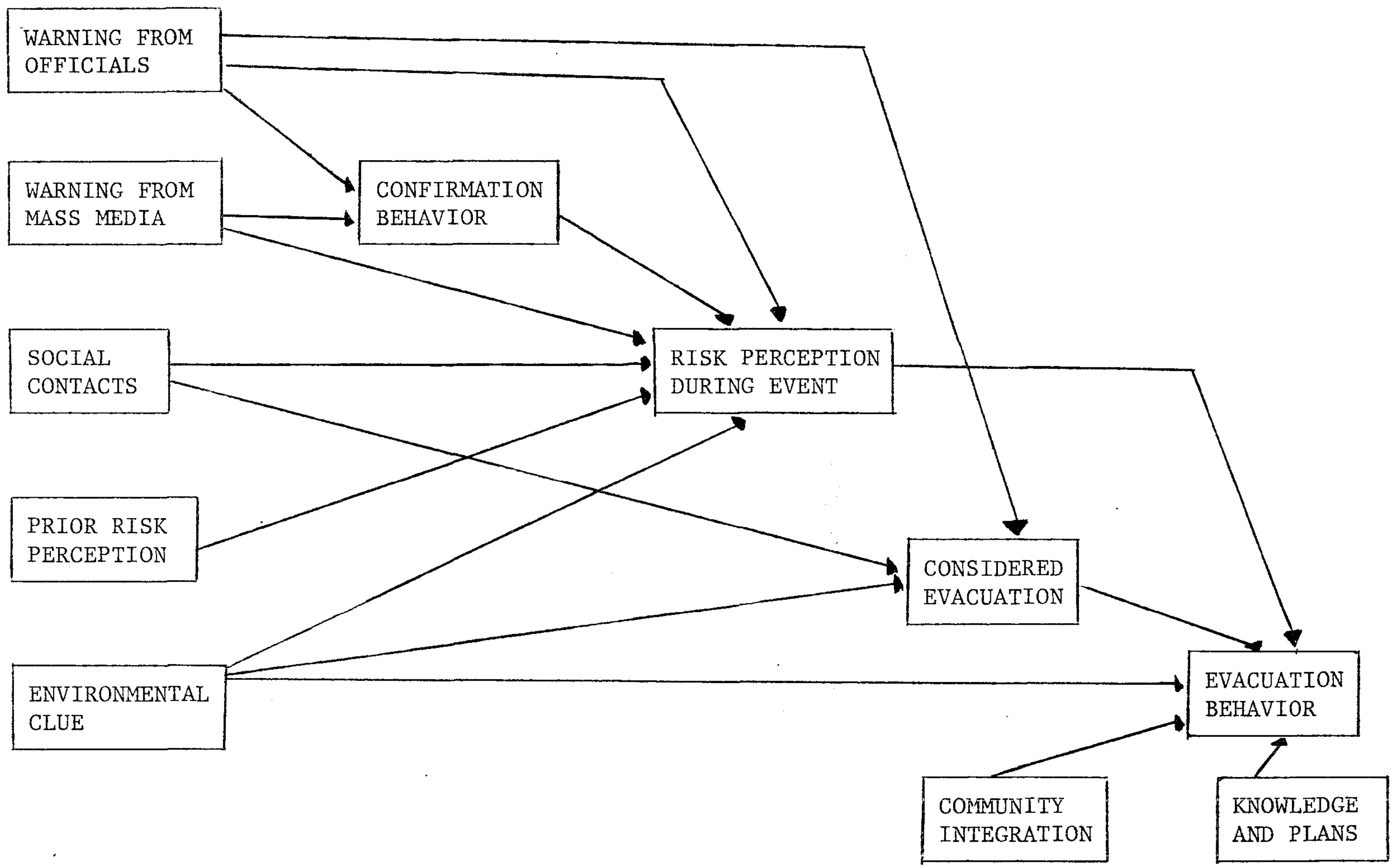

Figure 4.2 Summary Model of Response to Flash Flooding Events. All paths indicated are significant and positive; the magnitude of the paths, however, is dependent on situational variables, such as the nature of the threat, the warnings issued, and the community's prior disaster experience.

be due to the fact that the majority of the respondents in this site were not aware of the flash flood warnings and received their first indication that something might be wrong by having relatives, friends and neighbors check on their safety.

The third stage of the model focuses on those factors that lead individuals to consider evacuation as a possible alternative response to the flooding event. Standard warning messages issued by the mass media had no effect in this stage. Again, it appears that the primary effects of standard warning messages are to get people to seek additional information. They do not motivate people to consider evacuation or to evacuate. Receiving information directly from local officials increased the probability of considering evacuation by over 20 percent in each community. In both sites, however, the most important factor in predicting consideration of evacuation was whether or not the family experienced flooding near their home. This was a major factor in predicting actual evacuation behavior as well.

The final stage of the flash flood model identifies those variables which convince families who have considered evacuating to actually leave their homes. In both sites, over 40 percent of the families that considered evacuation left their homes without receiving any further incentives. An important step in increasing adaptive response is to induce residents to enter into the decision-making process, i.e., to consider evacuation as a possible response to the flooding situation. Receiving advice to evacuate from local authorities and knowing where one might go were important factors for the inexperienced population. It is important to point out that the majority of the respondents living in the flood plains of both sites did not evacuate their homes.

Results from the Hurricane Models

The summary model of response to hurricane threats is shown in Figure 4.3. This model is based on studies of response to Hurricane David in Miami and Hurricane Frederic in Mobile. The first stage of this model again focuses on predicting confirmation behavior. As we found in the other two models, people seek additional information in response to the information they receive from watches and warnings. Persons in Mobile also sought to confirm the information they received from local officials. Discussion of previous

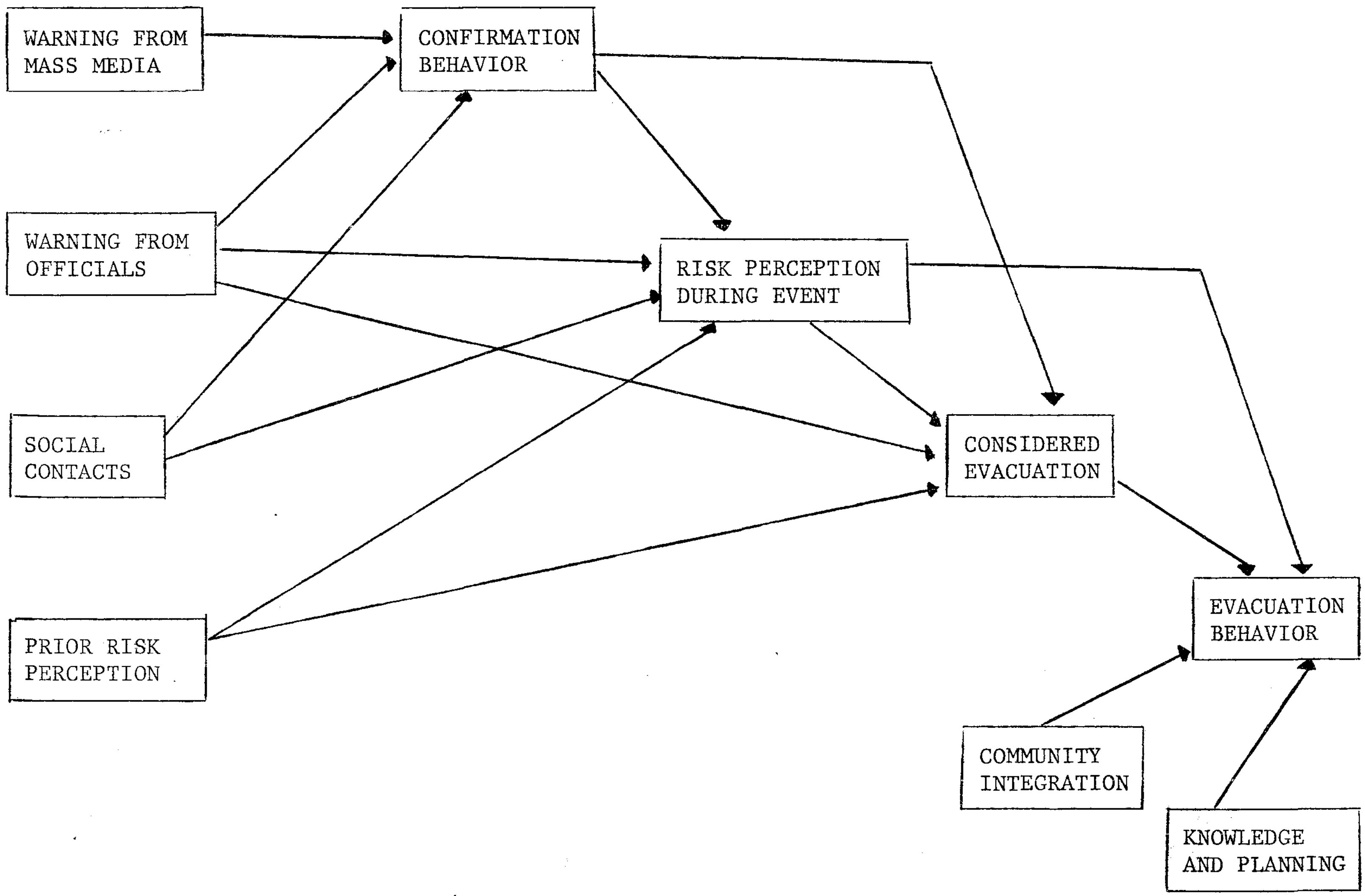

Figure 4.3. Summary Model of Response to Hurricane Threats. All paths indicated are significant and positive; the magnitude of the paths, however, is dependent on situational variables, such as the nature of the threat, the warnings issued, and the community's prior disaster experience.

hurricanes resulted from being checked on by friends in both sites. Prior perceptions of risk were important in determining confirmation attempts in Mobile.

The second stage of the model shows those factors which were important in determining perceptions of risk during the warning period. Receiving an evacuation recommendation was important in this stage for both communities. The most important variable predicting whether or not individuals thought storm surge flooding was likely in their area, however, was whether or not they considered their neighborhood at risk to flooding prior to the hurricane threat. It appears that the hurricane warnings and recommendations issued by officials in these sites did little more than reinforce the public's existing judgment of risk. Persons who thought they were at risk interpreted the statements as confirming this risk. Individuals that did not consider themselves at risk found little in the statements to change their judgments. Residents of Mobile also utilized their social contacts and confirmation attempts in determining their perceptions of risk to storm surge flooding. These variables did not have significant effects in Miami.

Stage three of the model predicts consideration of evacuation as a possible response to the hurricane threat. Standard warning information received through the mass media did not play a direct role in considering evacuation. Again, it appears that the primary effect of the hurricane watches and warnings is to get people to seek additional information; they do not motivate people to leave their homes. Receiving advice on how to prepare for the hurricane and discussion of previous hurricanes were important variables in Mobile. It is apparent from our analysis that little action is taken (in terms of considering evacuation or actual evacuation) if people do not perceive themselves to be at risk to storm surge flooding. In both sites, the most important factor in predicting consideration of evacuation was the respondent's perception of risk during the event.

The final stage of the hurricane model shows the important factors which take the family from considering evacuation to actually leaving their homes. In both communities, over 40 percent of those families that considered evacuation left their homes without receiving any further incentives. Again we point out that an important step toward evacuation is to induce residents to enter into the decision-making process--to get them to consider evacuation as a possible alternative response to the hurricane threat. Authorities advising evacuation had the greatest effect in Miami, while having an idea of where one might go upon evacuation was an important factor for the residents of Mobile. Again, it is important to point out that more than 60 percent of the respondents in both sites did not evacuate their homes during the hurricane threats; the majority of the population in each site remained at risk to possible storm surge floding.

SUMMARY

In general, the models indicate that (1) warning confirmation is a critical first step in the decision-making process, (2) general warning messages broadcast through the mass media motivate the public to seek additional information, but apparently do not motivate people to take defensive actions, (3) social contacts are important during the decision-making process, (4) many residents who are at risk to natural hazards do not perceive themselves to be at risk, (5) risk perception is a critical variable in the continuation of the decision-making process, (6) warnings received directly from local authorities facilitate the decision-making process, and (7) having a plan of what to do and where to go increases the probability of taking defensive action.

V. Experimental Studies

SUMMARY OF RESULTS

The laboratory work demonstrates that human response to warnings of natural disaster depends upon:

1) experience of the responder with prior, similar warning situations,
2) frequency and detail of the warning messages,
3) how important the possible results of an impending decision seem to the person issuing or responding to a warning.

Inexperienced individuals take defensive action sooner when warnings are more frequent and more detailed. As people gain experience in responding, they delay response longer regardless of characteristics of the warning messages. In contrast to the behavior of the inexperienced responder, more frequent and more detailed messages produce even longer delays among experienced individuals than do infrequent or incomplete messages. The inexperienced respond more immediately to first warnings, but their response pattern is quite chaotic. As experience is gained, information is increasingly used in a calculating manner so as to delay response as long as possible or to avoid it altogether. Recommendations for action accompanying warnings will produce quicker response, but the effect is greatest for inexperienced responders.

When two people must respond jointly, as is often the case for families, they appear to take defensive action sooner than do isolated individuals. This shift to a conservative (or "protect each other") strategy is offset in these experiments by having to reach consensus before acting, which requires time not needed by the isolated individual. Although both effects appear in the data, the results are inconclusive: it is not clear from these experiments how delay in response versus lag time in reaching consensus will operate in longer onset situations such as hurricanes. As with individual responders, dyad results show that experience in responding to warnings alters the pattern of response.

Experiments involving both disseminators and responders show that, if disseminators depend on local productivity for their payment, they will be much less likely to issue warnings than will disseminators who are independent of local productivity. Business managers (responders) evaluate disseminators' behavior negatively either if warnings are too frequent, interrupting business needlessly, or if they are inadequate in frequency, detail or type of recommendations for action. As responders gain experience, their actions show progressively less correlation with warnings issued by their disseminators. Both disseminators and responders alter their strategies immediately following a "hit."

V. Experimental Studies

BACKGROUND AND HYPOTHESES

Responding to real hazard warnings is characterized by uncertainties. These may include a somewhat unpredictable course and timing of the hazard, perhaps too little time for calm deliberation, many subjective impressions rather than objective facts, and a need to make the right choice because wrong choices can be very costly. Most people facing such decisions attempt to be rational, i.e., to sort out available information and come to some choice that seems best at that time. That approach is best captured by the Janis and Mann model cited earilier, in conjunction with a Bayesian model of information processing over time.

These formulations lead to a mathematical equation specifying when it is more rational for someone to respond to warnings versus when it is more rational to "wait and see." An informal interpretation of the equation suggests that, in response to a series of warnings about a given hazard, people will be <u>less</u> likely to take early protective action under two circumstances: (1) when messages contain more (as opposed to less) information and (2) when warnings are issued frequently (as opposed to infrequently).

Prior disaster research, simple learning theory and our own field data suggest three other hypotheses concerning action in response to a series of warnings. Specifically, the probability of early protective action (3) will decrease as the amount of prior experience with such decisions and information sources increases, (4) will increase as the proportion of previous warning experiences which resulted in being "hit" increases, and (5) will increase if official recommendations for action are included with warnings.

When two or more individuals must act together (e.g., a family deciding to evacuate their home), their collective action may differ from individual action in two ways. The need to reach a joint decision may result in delayed response. That is, (6) when two or more individuals must reach a joint decision before acting, the lag time between receiving any new information and deciding what to do will be greater than it will for individuals who are acting alone. That lag in reaching a decision may be offset by the reverse of a phenomenon known to social psychology as the "risky shift." Whereas some groups adopt more risky decisions that their members would individually, if people feel responsible for each other's welfare, then a conservative rather than a risky shift should occur. Therefore, (7) the probability of early protective action will be greater for dyads who feel responsible for each other than for isolated individuals.

From the time that appropriate regional or national officials determine that a hazard exists, and that a warning is needed, there often must be intermediate decisions at a local level before action such as evacuation can take place. Since each level creates its own lag in the warning chain, (8) the probability of early protective action will decrease whenever intermediate, local decisions must be made prior to dissemination of warnings or recommendations at the local level. Finally, if a local official experiences no loss from issuing premature and too frequent warnings, then the decision to warn carries no costs. Most officials in fact realize that excessive or premature warnings will jeopardize their credibility and impair their effectiveness. These considerations suggest that, (9) to the extent that people who issue warnings experience costs for issuing too many or too early warnings, there will be a shift toward taking more risk (that is, issuing less frequent and fewer early warnings). These nine propositions provide the rationale for the work reported in this section.

METHODOLOGY

Sampling of Subjects

Volunteer adults were employed in all experiments; 378 in the individual series, 120 in the dyadic series and 90 in the series involving two levels (disseminators and managers). Most were young, unmarried students between the ages of 18 and 32. Fifty one percent were male, 49 percent female. All major treatments showed percent male in the 40-60 percent range, with one exception: business managers in the two level experiments were 70 percent male. Subjects were recruited by advertising in local newspapers. Although those who participated are not necessarily representative of the adult population, the importance of the experiments lies in comparisons between treatments. There is no obvious reason to assume that those comparisons would be invalidated by characteristics of the samples. Subject payments varied between \$5.00 (guaranteed) and \$15, depending upon subject performance and type of experiment.

Procedures and Measurement

To test how people respond to warnings requires that they be involved in something else of sufficient interest or profit such that warnings constitute interruptions of preferred activity. Toward this end, a computerized business management game was developed. Managers began with a small business and a modest bank balance. They could hire or fire personnel, buy supplies and sell products. A complex set of constraints and interdependencies made successful management challenging. All subjects appeared intrigued and motivated by the same.

Warnings of impending tornadoes were introduced by computer control at specified intervals during the experiment, and were varied according to experimental design. Warning rate was either fast or slow (a message every four versus every eight minutes). Amount of information contained in the message was low, medium or high (location of the most recent sighting of the tornado, only; location plus expected time of arrival in downtown Minneapolis, where the business was located; or location, ETA and a Twin Cities metropolitan area map showing current and all prior sightings of the tornado).

For individuals playing alone and for dyads, three separate consecutive tornado scenarios appeared, showing quite different paths. All used reasonable, real time movement of the tornado. The first and third tornadoes (scenarios) began far enough from the Twin Cities that they required 24.5 minutes from first warning to final "hit" or "miss" for the manager's plant. The middle tornado, used primarily to disrupt any possible impression of standardized time scenarios, began much closer to the cities and lasted only 10.5 minutes. The total experiment required slightly over one hour.

After each warning, managers had to decide whether to continue business as usual, to take some protective action with consequent reduction in productivity, or to shut down altogether. If a hit occurred, losses depended upon the state of operation of the plant when the tornado struck. The pattern of hits and misses was also experimentally varied.

These conditions created four variables cited in the hypotheses: rate and amount of information, amount of experience (none, one or two prior scenarios) and proportion of "hits" in prior experience. Subsequently a fifth variable was added to the individual experiments; whether or not warnings were accompanied by official recommendations for action. Dyad experiments were the same as individual ones except that two people played simultaneous but independent management games. Identical warnings appeared simultaneously for the two subjects, and they had to reach consensus on their joint response before the game could continue. The consensus criterion was explained by stating that they managed divisions of a larger company which had to respond as a company, not just by division. That criterion is assumed to be analogous to, for example, families having to respond together. Subjects were in separate rooms, but could communicate via intercom.

Two level experiments consisted of two independent business managers, with different hypothetical locations in Minneapolis, and one disseminator. The disseminator received minute by minute updating on tornado activity and had to decide when to issue warnings, to whom, in what detail and with or without recommendations. These experiments involved five tornado scenarios, and ran for over two hours. After each scenario, managers were able to evaluate disseminator performance. Pay for disseminators was either dependent upon how well the managers' businesses were doing, or was independent of business success.

All messages, decisions and evaluations were automatically handled by and all actions recorded by the computers. Independent variables were those specified in the experimental design. The principal dependent variables were manager decisions, translated into a response index; disseminator actions, translated into a disseminator index; and manager evaluations of disseminator actions, translated into an evaluation index. Details are provided in the full report.

RESULTS

Individual Experiments. Figure 5.1 shows response curves from the individual experiments; by rate, amount of information and amount of experience. Only the first and third tornado scenarios are analyzed, because we need comparable message timing across treatments for statistical comparisons. Scenario 2, as noted, was a much shorter scenario used primarily to provide experience and to eliminate any deductions on the part of the experimental subjects about how long the tornadoes took from first message to conclusion. A response index of zero means that no one took protective action of any kind; an index of one means that all managers shut down their plants completely.

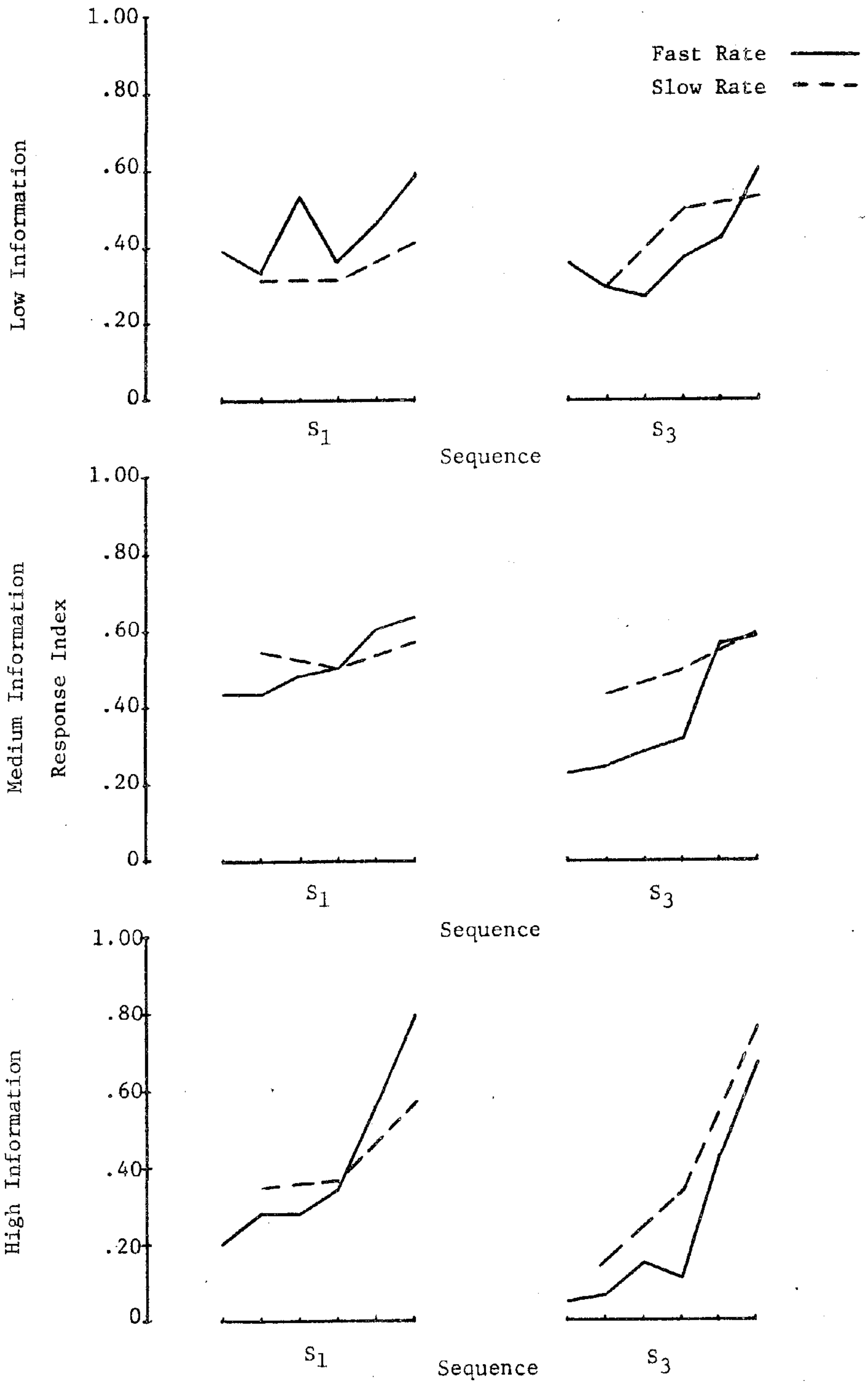

Figure 5.1. Response Rate by Rate of Flow of Information, Controlling Information Level and Experience.

The index is analogous to a probability of taking protective action, though it involves two levels of action: partial or complete shutdown of the company.

A few informal comparisons are helpful. Both medium and low information levels show initial mean responses higher than those for the high information warnings (location, ETA and map). A somewhat erratic trend is evident. With more complete warnings and increased experience, initial response levels decrease. Final responses, just prior to arrival of the tornado, are in the .4 to .6 range except for the high information treatment. The overall impression gained from Figure 5.1 is that inexperienced responders receiving low information warning messages show irregular over-time response, averaging about .5. Managers receiving the most complete messages and the more frequent ones show lower initial response but a clearer, more or less systematic increase in response over time as the tornado approaches. Also, although the fast rate produces a higher response curve than does the slow rate for inexperienced managers receiving low information messages, the same fast rate produces a lower curve of response for experienced managers receiving high information messages.

These impressions are formally tested using Repeated Measures Analysis of Variance. That procedure allows the comparison of mean response curves for different message rates and for different amounts of information as well as the combined (interactive) effect of those two variables. Each scenario must be analyzed separately, however, because the curves return to lower response levels at the beginning of each new scenario. A test of the effect of experience will be discussed shortly.

First, the overall mean response level across all messages in scenario 1 significantly varies with amount of information ($F = 3.36$, $p = .037$). Since high information curves seem to start lower and end higher, that fact is less informative than it might seem at first. Other tests will be more useful. Both rate and amount of information produce significant changes in the rate at which the response index increases across the messages in scenario 1. That is, more frequent and informative messages create a stronger trend toward increased protective action as the tornado approaches. These results appear to contradict our original hypotheses. It will help to examine Scenario 3 data before attempting to reach such conclusions.

For scenario 3 curves, more frequent messages significantly reduce the overall mean of the response curve ($F = 5.61$, $p = .019$). More informative messages produce stronger linear trends of increased response (F = 12.14, p = .000), and amount of information and rate both produce significant quadratic effects, or acceleration of the response as the tornado approaches (F = 6.21, p = .001 and F = 8.53, p = .004, respectively). A simple interpretation of these results does some violence to nuances of the data, but it is clear that, for experienced responders, our first two hypotheses were confirmed. That is, response is reduced by providing frequent, high quality warnings. For inexperienced responders, however, results are less clear.

It would be useful to include both scenario 1 and scenario 3 in the same analysis. To do so requires creating a new dependent variable. If the probability of protective action changes systematically with the independent variables, then so should the average amount of time someone waited before taking any action. This "mean waiting time" was calculated in seconds from the start of each tornado scenario. For any given experimental treatment there is one mean waiting time for scenario 1 and one for scenario 3. Again using Repeated Measures Analysis of Variance, both fast rate and higher amount of information significantly increased mean waiting time as responders gained experienced (F = 7.70, p = .006 and F = 5.99, p = .003, respectively). Such a result parallels the field evidence that longer term residents show lower rates of evacuation under hurricane warnings than do new residents. In contrast, those exposed to slow, uninformative messages actually began to respond sooner as they gained experience.

Returning to the response index, some further clarification is gained if first message (early response) and last message (late response) are separately analyzed across sequences. The amount of information contained in warning messages significantly affects early response as responders gain experience (F = 3.56, p = .031). That is, fewer experienced responders act on the first warning if they have high quality information. Also, being missed by the first tornado results in lower mean early response (F = 3.56, p = .060). Rate does not affect early response. For late response (last message prior to the tornado hitting or missing), amount of information has no significant effect, but fast rate creates a significant reduction in the final response index as responders gain experience.

These results are intuitively reasonable if we assume that responders are trying to reach an optimal course of action. At the beginning of a sequence, there is no evidence of how fast the messages might be coming in. Rate, therefore, should not be able to affect first response. However, as a series of messages comes in at frequent intervals, it becomes increasingly plausible that new information will yet arrive in time to enable delaying action until closer to deadline. Infrequent messages create no such assurance. Consequently, frequent messages lull experienced responders into believing that there is yet time to wait and see before taking action.

Amount of information, on the other hand, is effective primarily at the beginning of a warning sequence. A map, along with other detail, gives a clearer impression of whether immediate action is needed or would be premature. It makes sense, then, that the most detailed early messages allow people to determine for themselves the degree of emergency, hence the need for immediate action versus the opportunity to delay until later. Moreover, the quantity of information indicates immediately how useful information from that source is likely to be in the future.

An overall view of these findings provides strong evidence that people try to be rational responders. If there is enough data provided and enough confidence in new information arriving in time, experienced responders will make up their own minds just how long they can afford to wait before having to take protective action. This clearly contradicts a stimulus-response notion of the warning/response relationship. Inexperienced responders more nearly approximate such a simplistic model, but as experience is gained, deliberate delay of response until the last moment (and sometimes beyond) will occur.

Will official recommendations alter this pattern? For inexperienced responders (sequence 1), the final response index, just before the tornado arrives, is significantly increased by having recommendations accompany warnings ($F = 9.18$, $p = .003$). For experienced responders, however, that effect disappears, and only rate influences the index. Again, these results support the rational responder model. For those who do not know what to expect, recommendations have an important influence. With experience, responders gain a kind of psychological independence. They choose when to act primarily on the basis of their own deliberations rather than someone's recommendation.

Dyadic Experiments. Before comparing the dyad response curves with those from the individual responders, let us capitalize on a unique feature of the dyadic sessions. In order for managers to reach consensus, they sometimes needed to discuss their preferences, using the laboratory intercom system. It was therefore easy to record those conversations to get a better sense of the reality of the game simulation and the motives of the subjects. Three quotations from those tapes are of particular interest.

Were subjects really paying attention to the messages? One manager explained a desire to close down his/her plant by saying, "The reason is that it doesn't say tornado watch, it says tornado warning. That was the basis for my decision because I thought it was a warning that [means] the funnel has been sighted and it is on its way." Would that all people were so well informed.

Consonant with our interpretation that managers used a strategy of putting off action as long as possible, one defended a desire to continue production by saying, "I am trying to think. Our company is small enough that I think the number of personnel...could be moved fast enough."

Finally, regarding the motivating aspect of the management game, one manager wanted to continue production despite an awareness that personnel might be endangered. With some evident embarrassment, he/she stated, "....my decision is based on a really rotten reason. I am sitting on a bunch of inventory I want to sell." There are many more such comments from the tape transcripts, and virtually no evidence of subjects taking a cavalier approach to the business, the tornado warnings or the need for consensus.

Figure 5.2 compares individual and dyadic response curves for slow and fast rate and for inexperienced versus experienced responders. For all comparisons, dyadic curves look very much like individual curves. The similarity of curve form is striking. Repeated Measures Analysis of Variance shows no significant effects of number (dyad versus individual) on the mean, linear or quadratic components of the curves for either sequence. Rate, of course, has very strong effects on sequence 3 curves, as before.

There are two indications that number may influence response rate. First, there is significant interaction of rate and number during sequence 1. A glance at Figure 5.2 reveals that dyads respond faster than do individuals

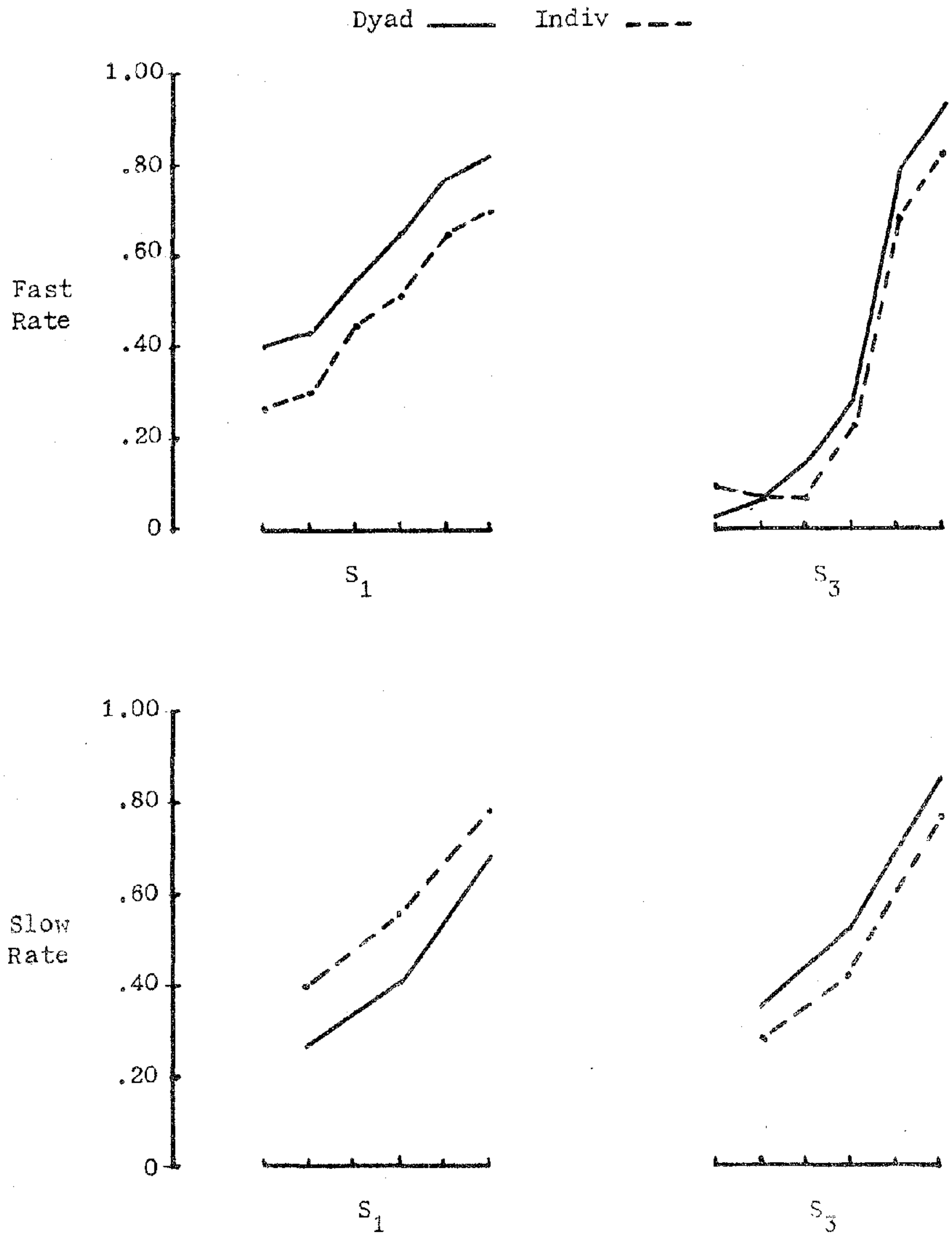

Figure 5.2. Response Rates of Individuals vs Dyads, Controlling for Experience and Rate of Flow of Information.

under the fast rate, but the reverse is true under the slow rate. Secondly, for both rates, experienced dyads show a higher response curve than do experienced individuals. While that effect does not reach traditional significance levels ($F = 7.86$, $p = .090$), there is at least reason to inquire further.

Analyzing mean waiting time provides no new information: there are no significant differences in mean waiting time due to number (dyad versus individual). There is, however, significant interaction of number with rate and experience. Inexperienced dyads respond sooner under the fast rate; experienced ones do so under the slow rate and respond equally soon under the fast rate. Is the notion of a dyadic conservative shift incorrect?

It was suggested that groups (dyads in this case) need more time to make and act on a decision because of the need to reach consensus. Individuals can simply decide and act. To determine whether that dyadic lag hypothesis was valid, the amount of time lag between a given message appearing and a response (consensual, for groups) being entered in the computer was calculated for both individuals and dyads. Results are highly significant for both sequences ($F = 62.26$, $p = .000$, and $F = 30.87$, $p = .000$ for first and third sequences respectively). Rate also influences lag time for the inexperienced.

For sequence 1, individuals average 20 seconds between warning and decision; dyads average 50 seconds. During sequence 3 those averages dropped to nine seconds versus 25 seconds. It should be emphasized that each sequence contained six (fast rate) or three (slow rate) messages, each of which required a decision. Therefore both individuals and dyads had ample opportunity to become experienced at making such decisions. Graphs of lag times indicate a continual decline in how long a decision took, as more experience was accumulated. Two points are important. Regardless of the amount of experience, dyads always show longer lags than do comparably experienced individuals. This is true despite the fact that conversation on the intercom was quick and easy; if either partner requested orally that they be able to speak together, the intercom was turned on immediately. In real life, partners are not so readily reached.

The second point pertains to the conservative shift hypothesis. Even though the differences in decision lags are small in comparison to mean waiting time (the latter average 13 minutes from start of either sequence), dyads always have the longest lags. If the lag in reaching a decision is subtracted from the waiting time until first protective action, dyads appear to start a decision to take action sooner than do individuals with comparable experience, in most cases. These comparisons are speculative, since significance tests on data adjusted in this manner could be questionable. Such effects may not hold up in situations involving long onset times (e.g., hurricanes). Yet an hour or two to reach a spouse or child and make a family decision to evacuate, if family members have difficulty reaching each other, could seriously erode the already too short time remaining after local officials decide that evacuation orders must be issued.

Disseminator-Manager Experiments. The two level experiments were designed to examine how a disseminator's relationship to local productivity would affect the rate at which warnings were issued, and how different disseminator patterns would be evaluated by managers. Two disseminator roles were created by varying the method of calculating their lab payments. Role 1 disseminators were paid \$15, less \$3 for each instance of a "hit" for which no adequate warning was issued. This role is comparable to that of civil defense officials who earn a salary but might be penalized for not fulfilling the warning role. Role 2 disseminators were paid \$2 for each \$40,000 earned by the managers' companies by the end of the experiment, to a maximum of \$15, less \$3 per unwarned "hit." Thus, although the same penalties obtained, these disseminators depended directly on local productivity. Such a role is more akin to the in-house employee or the elected local official who is charged with issuing warnings as an adjunct to company or community business.

A warning index was created which reflected frequency, amount of information and the presence of recommendations. The index could range between zero and 15. For analytic purposes, it was averaged by four minute intervals to provide graphs and statistical analyses comparable to the earlier experiments. Of course, disseminators were able to issue warnings at any time throughout a tornado sequence. Figure 5.3 presents the two roles' warning index curves over the five sequences.

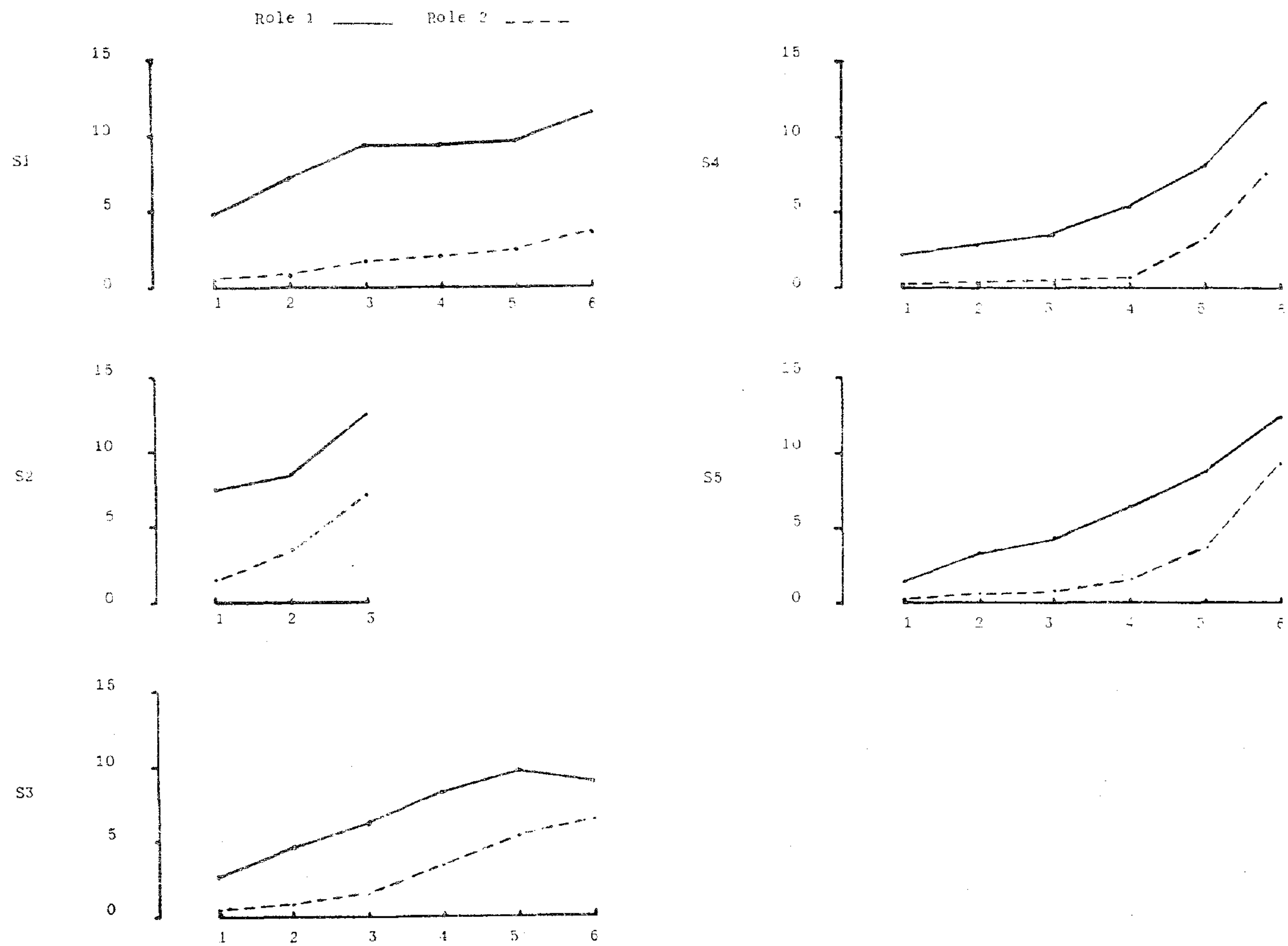

Figure 5.3. Disseminator Index by Role and Sequence.

The most obvious feature of Figure 5.3 is that payment policy (role) made a drastic and continuing difference in how disseminators performed. During sequence 1, role 1 disseminators' indexes averaged 8.6, compared to 1.9 for role 2 disseminators ($F = 41.97$, $p = .000$). After initial feedback from managers (feedback was provided at the end of each sequence), the difference between roles diminished somewhat, but remained quite large. F tests show probability values of .000 for all sequences. This result speaks directly to local delays in deciding to issue evacuation orders. Local officials experience the costs of evacuating in a way that regional or national officials do not.

A second feature of Figure 5.3 is that, parallel to individual and dyad patterns, as disseminators gain experience, they wait longer to issue warnings. Initial index values decline steadily across the five tornado sequences. Indeed, for sequences 4 and 5, role 2 disseminators issued virtually no warnings until about eight minutes prior to hit or miss, even though they had been receiving information about the approach of the tornado for 16 minutes previously.

The two businesses, company 1 and company 2, were shown on the metropolitan area map to be about five miles apart. Each tornado path was calculated to appear more or less equally threatening to the two company locations. However, company 1 was hit by the first tornado, and company 2 was hit by the third. Both were hit by the fifth, but then the experiment ended. Did the differential hit experience affect disseminator behavior?

Graphic evidence, without statistical tests, suggests that the first hit caused no differential warning. However, for a portion of sequence 3, company 1 appeared to be more threatened than company 2. During that portion, disseminators issued more and stronger warnings to company 1. For most of sequence 4, after company 2 had been hit, that company received somewhat more warning than did company 1. It would appear, therefore, that both the developing path of the tornado and the fact that a location had been recently hit influenced how warnings were disseminated, but the effect was not consistent.

Were managers' responses affected by the differential warnings, especially the difference between role 1 and role 2 disseminators? Figure 5.4 displays response indexes by company and disseminator role. A number of important facts are evident.

First, during sequence 1, the much greater warning from role 1 disseminators did produce higher responses. For company 1 managers, that difference continued throughout the second sequence, but virtually disappeared by sequence 3 even though the warning indexes continued to be markedly different. Repeated Measures Analysis of Variance shows significant effects of role only for the first sequence ($F = 7.48$, $p = .008$), with a significant role-company interaction during sequence 2 ($F = 4.91$, $p = .031$). Again during sequence 4, when company 2 was being warned more than company 1, disseminator role approaches significance ($F = 3.56$, $p = .064$). In short, there are discernable effects of disseminator performance on manager response curves. Yet by sequence 3, those effects are minor despite large differences in warning indexes.

In contrast to the effects of role, company managers do not respond significantly differently during the first two sequences, except for the role-company interaction in sequence 2. However, for sequences 3 and 4, there are highly significant differences between companies ($F = 28.01$, $p = .000$ and $F = 20.06$, $p = .000$, respectively). Sequence 3 is the point at which company 1 was being warned much more than company 2, up to the last message. Consequently, although a role effect is not evident, it is clear that how disseminators act influences how managers respond.

Sequence 4, on the other hand, follows the hit on company 2. Note the much greater response from company 2 managers as the fourth tornado appears, compared to company 1 managers. By this time all managers had essentially eliminated early response, but company 2 managers were clearly "gun shy" from their recent experience. This result parallels our field evidence that feeling at risk is basic to being motivated to take defensive action.

The final aspect of Figure 5.4 that deserves attention is that manager response curves progressively shift to long delays in response, with rapid acceleration of defensive action as the tornado approaches. By sequence 5, there is no significant effect of either disseminator role or company. Regardless of differences in experience or the amount of information received in warnings, these managers have evolved a common response pattern. Examination

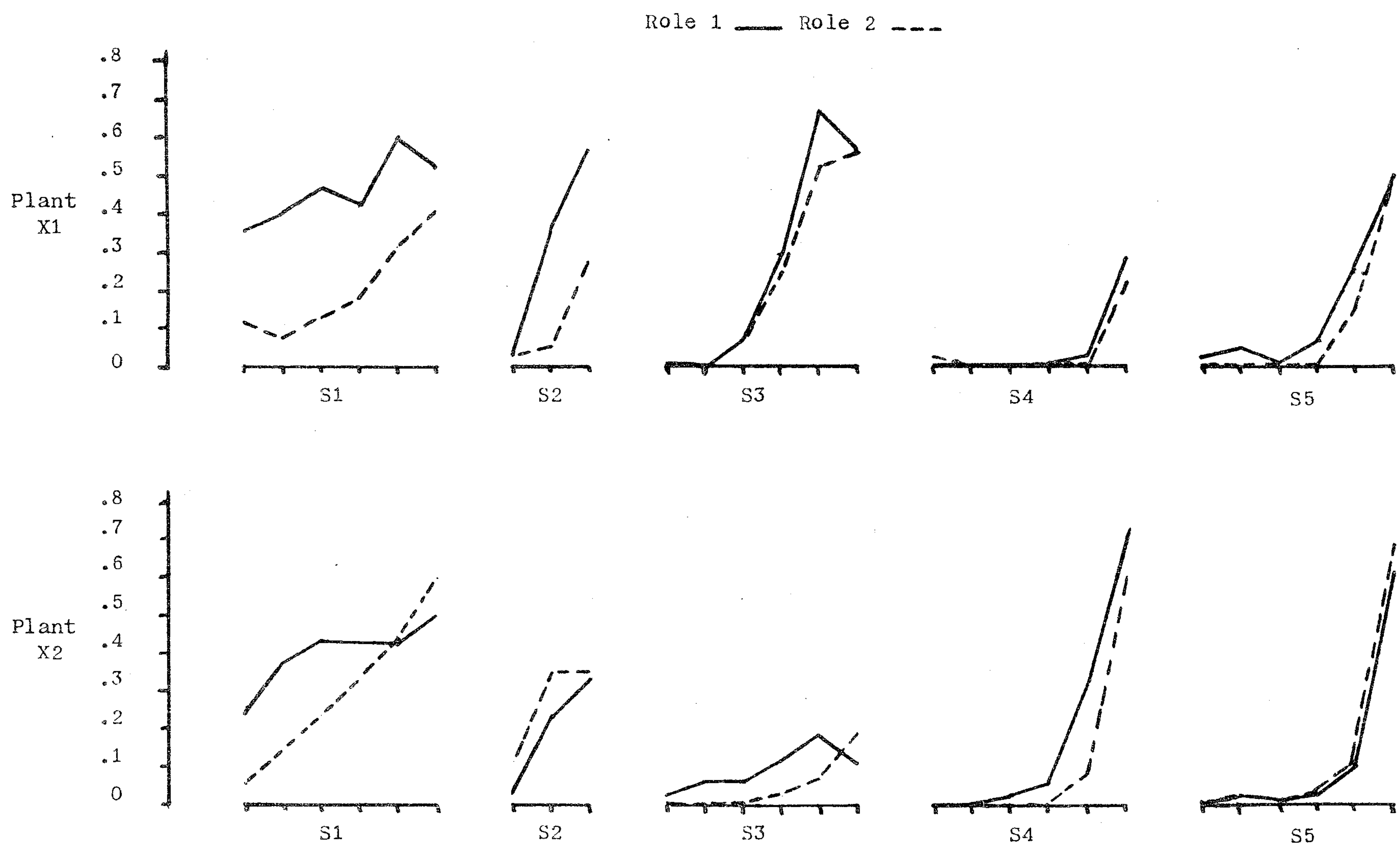

Figure 5.4 Manager Response Curves by Plant and Disseminator Role

of sums of squares from sequence 1 through sequence 5 shows steady decline in within-group variation of response curves. It appears that, with increased experience, managers pay less attention to warnings, adopting a maximal delay policy regardless of information received.

The next question concerns managers' evaluations of the warnings they received. A most notable effect appears for sequence 1. Managers subject to role 1 disseminators said that they were overwarned. General dissatisfaction differed significantly by role ($F = 19.44$, $p = .001$). Dissatisfaction with how often warnings were issued also differed significantly ($F = 16.63$, $p = .001$), as did dissatisfaction with quality of warnings ($F = 13.09$, $p = .001$). However, managers under role 2 were least satisfied with quality of warnings (too little detail) while those under role 1 disseminators were least satisfied with quantity of warnings (too many).

After sequence 1, differences in disseminator role did not result in differential evaluations except in sequence 3, where managers under role 1 still felt overwarned. Since disseminators continued to warn at different rates, the lack of differential manager dissatisfaction for sequences 4 and 5 implies that an accommodation to whatever was received was worked out by the managers. Again, the evidence indicates that, as experience is gained, warnings have progressively less effect.

Those last two sequences do show a significant difference in how company 1 versus company 2 managers evaluated warnings. For both sequences, company 2 managers said that they received too many messages, while company 1 managers seemed to be about satisfied with frequency of warnings ($F = 5.08$, $p = .029$ and $F = 6.83$, $p = .011$, respectively). Apparently the higher rate of warning directed to company 2, which followed the hit at the end of sequence 3, seemed excessive to the company 2 managers.

Summary. Altogether, the experiments demonstrate that both those who issue and those who respond to warnings are subject to predictable patterns of behavior. Warnings do produce effects, but those effects are quite different from the stimulus-response type of result typically assumed by officials who are responsible for warnings. People are deliberate and reasonably rational users of information. Given good quality warnings at frequent enough intervals, the experienced responder will sift, evaluate and choose his/her own optimal time to take action. That time may or may not agree with official preferences. Also, too much warning creates negative reaction from those being warned.

The data suggest the possibility of a larger theoretical model linking successive steps in the disseminations-response chain. Such a model would depend on factors like the ties of local disseminators to local productivity or response cost concerns, the overall extent of experience in the population with such warnings and hazards, recent hits or misses locally, and the capability of issuing warnings of the quantity and quality which local responders find useful without being excessive.

VI. Review and Recommendations

The organizational component of this project has demonstrated that a number of problems exist in current structures and procedures for disseminating warnings. Those problems include large gaps in communication systems linking the National Weather Service, local civil defense offices, local law enforcement and emergency service agencies, and local broadcast media. Such gaps are particularly evident when two-way communication is examined. Despite the widely accepted concept of an integrated warning system, actual capability and practice at the local level represent a fragmented, poorly linked and frequently ineffective communication system.

Communication problems are made worse by overlapping, sometimes contradictory and often uncoordinated civil defense structures. When local civil defense is organizationally a part of other governmental agencies with different priorities and responsibilities, efficient warning procedures are particularly unlikely. A majority of local civil defense offices are organized in such a manner as to create problems of coordination during emergencies. The ultimate indicator of inadequate warning procedures comes from the household data: in those sites where warnings were issued, an average of one third of the general public did not receive warnings.

The household interview data demonstrate the extent of the warning problem. A majority of households interviewed did not take protective action after warnings were issued. For tornado warnings, a majority did not seek shelter; for hurricane or flash flood warnings, a majority did not evacuate. It is clear that receiving a warning only initiates a process of seeking confirming evidence before deciding to act.

If residents are convinced in advance of the warning that their homes are at risk to tornadoes or hurricanes or flash floods, then a warning is likely to induce attempts to confirm the impending risk. Given confirming evidence, protective action is likely. On the other hand, if there is no prior perception of risk, and if warnings are unable to convince residents of impending risk, then protective action is very unlikely.

Local validating evidence is particularly helpful in inducing response. Actually seeing signs of threat (e.g., nearby flooding) is one type of evidence. However, personal contact is also a powerful incentive to protective action, especially if police or other local authorities are involved.

Broadcast media and official warnings cannot pinpoint each residence under threat. Telephone calls or knocks at the door can touch each residence personally. The difference in effect on protective action is sizeable.

Finally, if residents have a prior plan for emergency action, they are much more likely to heed warnings. No doubt feeling at risk induces residents to prepare emergency plans. The most effective warning is one issued to people who are convinced in advance that they could be at risk, who have given thought to how to take protective action, and who are now given evidence to validate the existence of a current threat to them personally, not just to the community as a whole.

From experimental work, it is evident that those who are experienced in responding to warnings react differently from the inexperienced. As experience is gained, people wait longer before taking protective action, pushing as close to the uncertain deadline as they feel they can with some safety. More and better quality warnings only increase this tendency. It is apparent from the disseminator-manager experiments that too many warnings can be disruptive and irritating, causing negative evaluations of those disseminating the warnings. Although we did not provide contradictory messages, it is reasonable to expect even more negative reaction to a barrage of conflicting warnings if different sources of information do not concur on the nature of the threat. Protective action is more likely if official recommendations accompany warnings, but that effect is reduced as experience is gained.

People without experience in responding to warnings act sooner when warnings are more frequent and of better quality, and especially when there are official recommendations for action. These results would seem to require contradictory warning strategies, when the inexperienced are compared with how experienced people respond. However, the early response of the inexperienced is due largely to a lack of familiarity with, and of practice in responding to, the warnings.

Both patterns of response are understandable in light of the household data. Also, the experiments aid our understanding of household results. People new to an area subject to a specific type of hazard (or new to simulation experiments about such a hazard) lack a well established basis for evaluating and responding to warnings. A typical reaction is fear of the unknown threat. For example, new Atlantic or Gulf Coast residents are likely to have heard stories of disastrous hurricanes and to feel very nervous about them. That means that they have a prior feeling of being at risk, have probably considered evacuating at the first sign of danger, and treat a warning or even a watch as such a sign. Our experimental subjects acted in this way.

The primary difficulty with the quicker reactions of inexperienced responders in the experiments was that the pattern of reaction was somewhat chaotic, hence not very trustworthy. It is certainly preferable to induce orderly response patterns that can be predicted and at least in part controlled. Experienced people, with warnings that are frequent and of sufficient detail, can judge their own degree of risk and choose an optimal time to take action. The maps included in the highest quality of warning in the experiments apparently provided confirmatory evidence of risk in the responder's immediate locality, a major factor according to the household data.

The plotted trajectory of the storm and the continuously updated ETA provided a basis for estimating a deadline for action as well as giving convincing evidence of imminent threat. Previous experience generated confidence in how to react and how long effective reaction required. That would be parallel to households having developed a plan of action and tried it out on one or more occasions. Official recommendations helped to confirm the threat, both in the lab and the field, and that confirmation helped induce protective action.

The household and laboratory evidence appear highly consistent. In addition, experimental data on the decisions of disseminators help underscore the extent to which the dissemination network is subject to considerations that have nothing to do with warnings. In particular, disseminators linked to local productivity sent fewer and less detailed warnings. Until managers became experienced with how their source of warnings operated, that difference in dissemination made a notable difference in eventual rates of protective action.

RECOMMENDATIONS

All portions of this project contribute to the conclusion that the entire warning process must be improved if adequate numbers of residents in a threatened area are to be induced to take protective action. Rather than indulge in a lengthy discussion of alternative interpretations and strategies, this summary will conclude with a series of specific recommendations based on the results described in the preceding chapters. It is hoped that the logic behind the recommendations follows readily from the evidence reviewed here. A more detailed examination of rationales will be presented in the full report.

In our discussion of findings from the organizational field studies, we have pointed out a variety of problems in the civil defense efforts of the local community. A number of those problems are severe enough to make local communities largely ineffective in facing natural hazard threats. In this section we present a series of recommendations which, if put into action, could significantly improve local response capabilities.

National Weather Service Communication Facilities

Among the problems covered by our research is the general lack of reliable communication facilities by which the National Weather Service can disseminate warnings to both the broadcast media and the local emergency service agencies.

(1) Since the broadcast media serves as the primary disseminator of severe weather warnings to the general public and the primary means of disseminating warnings from the NWS to the broadcast media is the NOAA Weather Wire Service, the National Weather Service should undertake a major program to upgrade the NOAA Weather Wire Service to state of the art technology in order for it to be compatible with the multitude of existing computer-driven teletype systems.

(2) Since NOAA Weather Radio has the potential to disseminate warnings of severe weather directly to both individual households and a large range of local community organizations, the National Weather Service should institute an aggressive public service advertising campaign to bring NOAA Weather Radio to the public's attention. Further, legislation or executive orders should be enacted to require all public and private organizations receiving federal funds--e.g., schools, universities, hospitals, nursing homes, etc.--to purchase and maintain NOAA Weather Radio receivers with tone alert capability.

(3) Because reliable two-way communication between local NWS offices responsible for issuing severe weather warnings and local law enforcement and civil defense offices is crucial to the operation

of both the evaluation and dissemination components of warning systems, the Federal Communications Commission, in cooperation with the National Weather Service, FEMA, LEAA, and other relevant federal agencies should establish a nationwide weather warning radio frequency to facilitate two-way communication among all local agencies involved in severe weather warning systems.

Emergency Service Communication Facilities

A second problem uncovered by our research involves the general lack of shared communication facilities among the wide variety of emergency service agencies at the state, county, and municipal levels of government.

(4) Increased emphasis should be placed on existing programs which are designed to upgrade emergency communication facilities of local governmental agencies. Such programs include the "911" emergency telephone system and the integrated communications center for law enforcement, fire protection, and civil defense agencies.

A third problem which limits the effectiveness of community warning systems is the almost total absence of communication facilities for the relay of emergency information from emergency service agencies to the broadcast media.

(5) The Emergency Broadcast System, like the National Warning System, was originally designed to provide a means of disseminating warnings of a national emergency from a national warning point to local communities. Unlike the National Warning System, however, the Emergency Broadcast System has not been implemented in such a way as to encourage its use as a locally activated warning system. Thus, the Federal Communications Commission should shift the major emphasis of its Emergency Broadcast System program from a nationwide warning system to an integrated network of local warning systems.

Organizational Structure of Civil Defense Offices

A problem of a different nature from those discussed above involves a number of undesirable organizational characteristics of most local civil defense offices at the county and municipal levels of government.

(6) The Federal Emergency Management Agency should place increased emphasis on its program to aid local communities in implementing a comprehensive emergency management plan. Integral to such a program would be incentives for the rational integration of civil defense functions into the routine governmental agency structure.

(7) The Federal Emergency Management Agency should initiate a program to review and evaluate the coordination problems created by multiple emergency operation centers independently staffed by governmental agencies with overlapping jurisdictions. The findings of this program should then be integrated into the comprehensive emergency management program.

Warning Procedures and Message Content

Warning messages are generally not formulated in a manner which motivates optimal response. Standard messages presented by the broadcast media motivate people to seek additional information, but do not induce protective action. In fact, a standard statement may actually reduce response, unless information is also given which convinces residents in susceptible areas that they are at risk.

Warning messages need to be upgraded in the following ways:

(8) Specific local areas at risk should be identified in warnings. Whenever possible, graphic information (i.e., maps) as well as the names of the areas should be used in television broadcasts. Just giving general warnings or names of entire communities does not provide sufficiently specific information to convince people that they are at risk.

(9) Details of appropriate response should be included in warnings. According to the type of hazard, such details might pertain to evacuation routes, location of shelters, probable travel times, or procedures for taking shelter at home. For such detail to be accurate and timely would require extensive upgrading of the knowledge of local broadcast personnel.

(10) Warning procedures should be expanded to include as much personal, local contact as possible. Where local law enforcement and emergency service agencies cannot provide sufficient personnel, efforts should be made to organize and be prepared to activate neighborhood, friendship and family networks in the larger area as part

of the warning system. A modest trial demonstration program for such an informal network warning system could be established with moderate cost in one or two communities before attempting to institute comparable programs on a national scale.

(11) Efforts should be made to assure that warnings are consistent in content.

(12) Awareness programs should be instituted which focus on increasing the public's perception that they live in areas at risk, and on inducing development of response plans in the home. For hurricane or flash flood prone areas, such plans should include where to go if evacuating, how to get there, and what to take. For tornado prone areas, awareness programs should emphasize how and when to seek safe shelter. It is plausible that schools and other local public facilities could adopt simulation training for interested families, similar to that used in our experiments, which would make them better acquainted with how to interpret warnings, what actions to take, and how serious the consequences could be if hazard threats are ignored. Again, one or two demonstration projects would provide low cost testing of such a procedure.

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