D.E.C.I.D.E.
In Hazardous Materials Emergencies

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The views expressed in this paper are those of the author and do not necessarily represent the views of the National Transportation Safety Board.

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INTRODUCTION

EVERYONE KNOWS WHAT AN EMERGENCY IS: it is a set of sudden, unforeseen, and urgent circumstances that demands immediate action. When hazardous materials (HM) are involved, the possibility of the emergency escalating into a disaster is always present, and the demand for action even more immediate. But what action? For what purpose? By whom? When?

Some sort of response is usually mounted, either by the individuals involved or by an emergency response team. The mounting of the response requires that discrete decisions be made with respect to the action needed, the outcome to be achieved, the response actions available, the methods and facilities to be employed, the timing of the action, and numerous other factors. Because of the nature of an HM emergency, many of these decisions are made on a "first-time" basis, usually under duress. They involve a form of either "adaptive behavior" or "adaptive learning" in a situation being encountered for the first time. In these circumstances, are there some techniques that will help the decision-maker to produce "better" decisions than those that may have resulted in so many injuries in the past?

This paper explores such techniques. It is based primarily on the analyses of HM emergencies in transportation that have involved injury and loss of life attributable to the behavior of HM present. It assumes that emergencies consist of a series of events that occur in a logical sequence. This "think events" approach is amplified by assembling the events into an "anatomy" of an HM emergency, and by treating the decision making process in an "events" framework.

EMERGENCY RESPONSE PURPOSES

Why mount an emergency response? Answers abound. Save lives! Save the ship! Protect the public! Prevent a disaster! It's our duty! But there is a common purpose, conceptually, and it can be stated simply in terms of events sequences: to favorably influence the outcome of the events sequence that would otherwise occur.

Any emergency will stabilize in time, without any emergency response effort, as the emergency runs its natural course. However, as they run their course, emergency events are often accompanied by injury, and this is objectionable. The purpose of mounting an emergency response effort, therefore, is to change the events sequence constituting the emergency before it has run its course naturally and to minimize harm that would otherwise occur.

In order to make an informed decision on whether to intervene, an attempt must be made to predict what the natural outcome probably will be. If harm is predicted, then intervention will have some purpose, provided the harm to the interveners does not exceed the harm prevented. The "gain" achieved by reducing the naturally occurring harm should not exceed the "cost" (harm) attributable to intervention. The difference between the "gain" and the "cost" provides a measure of the extent to which the emergency response effort favorably influences the outcome in any given emergency. Although such predictions of outcomes are required, they are now usually made intuitively — if they are made at all. Too frequently, the impulse to act immediately overwhelms reason in crisis situations; risk-taking becomes excessive, and losses escalate rather than decline. To forestall these wasteful losses, a structured approach to decision making in HM emergencies seems long overdue. No such structured approach or framework now exists for HM emergencies. Some attention *has* been focused on the need for this type of approach. For example, in a report of an HM accident in which numerous emergency personnel were injured, the National Transportation Safety Board found that available information was inadequate for on-scene identification and assessment of the hazards, potential injury-producing events, and consequent response options. [1] Also, M. E. Grimes described a study of HM emergencies that revealed problems that fire officers encountered in decision making. [2] However, a useful method for guiding decision making throughout the emergency is not yet available. The development of such a method would be facilitated by an understanding of what an HM emergency is.

THE ANATOMY OF AN HM EMERGENCY

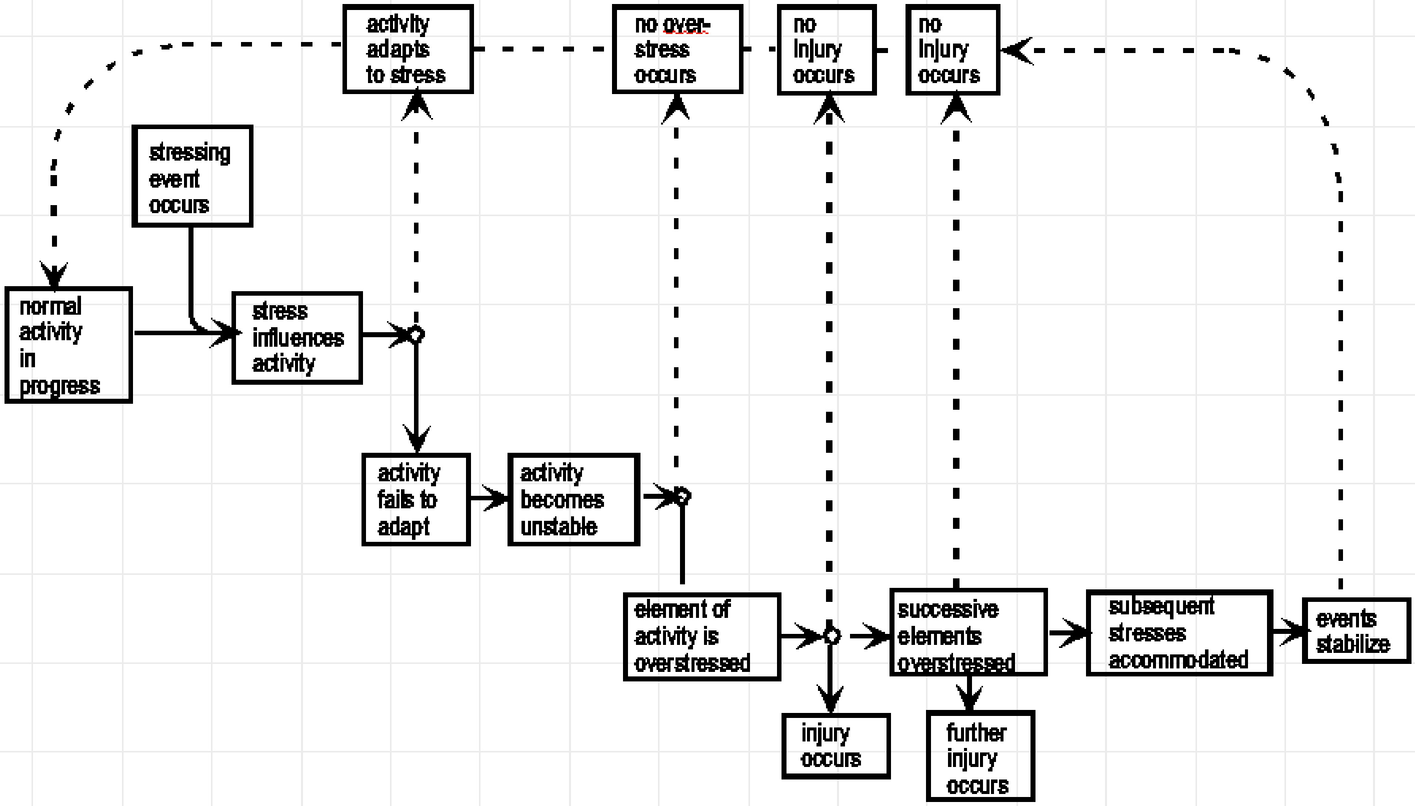
We can make two assumptions in describing a typical HM emergency — first, that the emergency events sequence progresses in an orderly relationship in a given set of circumstances, and second, that the events sequence can be generalized for descriptive and analytical purposes.

What happens in an HM emergency? During the course of a normal activity in which HM are involved, the HM are controlled by some method of containment or confinement or isolation from stressing events. For an emergency to begin, the "holding" system for the HM must be disturbed or stressed in some manner. The system may or may not adapt to the stress. If the stress does not exceed the capability of the "holding" system to resist or adapt to the stress, no disruption of the activity occurs. However, if the "holding" system is overstressed beyond its recoverable limits, some kind of failure occurs. Upon the occasion of such failure, escape of the HM from the "holding" system can occur. This escape can take the form of matter capable of producing harm, or of harmful energy, or some combination of both. Once this occurs, the matter or energy can disperse until it comes into contact with or impinges on a vulnerable exposure. Depending on the intensity and duration, the exposure can harm the impinged resource, and possibly cascade by overstressing and harming additional exposed "holding" systems or resources. The emergency events sequence ends when the cascading stresses are accommodated by the elements next impinged without injury, and the conditions once again stabilize.

This events sequence is illustrated in Figure 1, taking into account the adaptive events discussed earlier. The illustration uses a convention of rectangles to represent events, and arrows to indicate a proceed/follow relationship.

FIGURE 1.

Stage 1 Normal	Stage 2 Stressing	Stage 3 Reactive	Stage 4 Unstable	Stage 5 Overs-tressing	Stage 6 Initial injury	Stage 7 Cascading	Stage 8 Subsiding	Stage 9 Stablized



In order to influence the outcome of the emergency events sequence, it can be seen in Figure 1 that the natural events sequence must be deliberately disrupted by the emergency response efforts. This can be indicated by displaying the "countermeasures" on the same framework, as has been done in Figure 2. To aid in formulating the predicted outcomes, another element has been added to Figure 1: each general event is assigned a "stage" designation, to indicate the stage of the emergency at which a given type of event occurs. These stages can be used to aid in determining the events likely to occur after arrival of the decision-maker at the scene.

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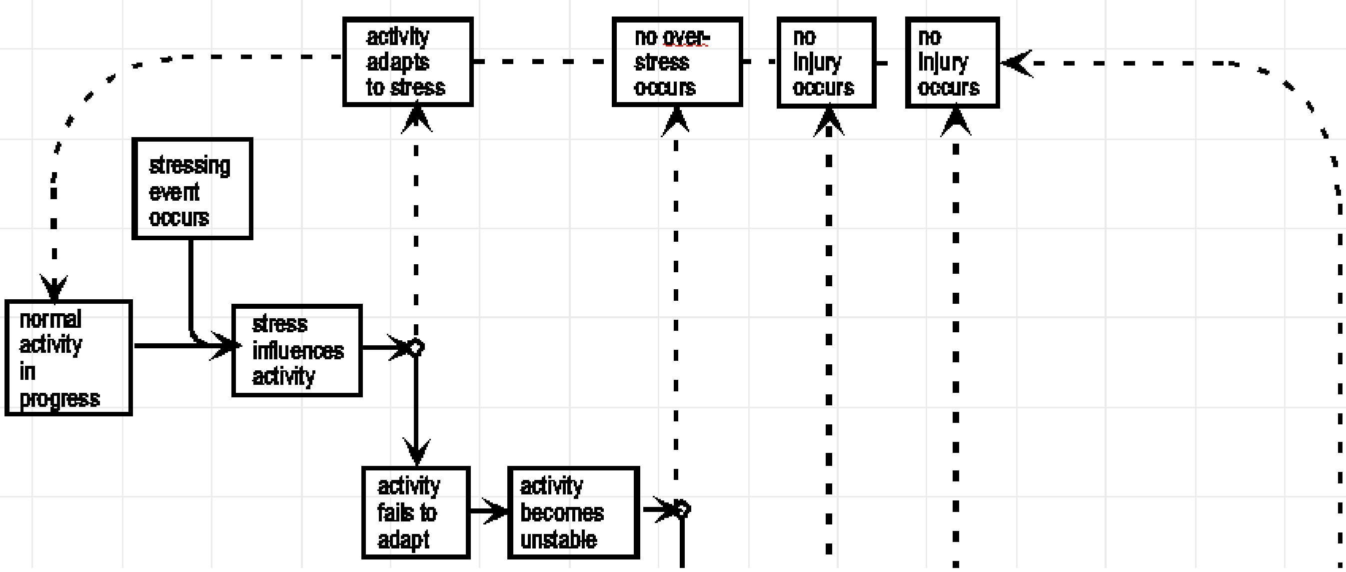
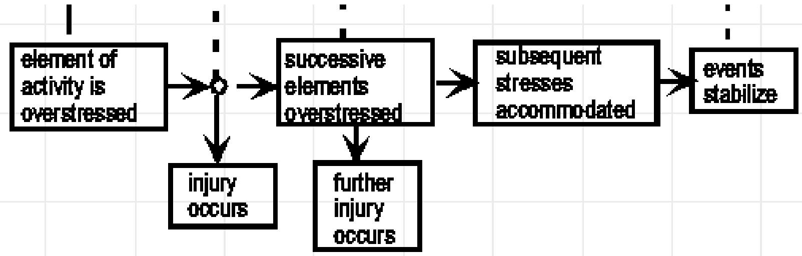




THE "D.E.C.I.D.E." PROCESS

When he becomes aware of the existence of an emergency, the decision-maker is faced with a series of "decision events." To affect or influence the emergency events sequence, decisions must focus on modification of the sequence that would otherwise occur naturally. There are six steps that can provide a framework for decision making in a given HM emergency. These six steps are:

1. Detect HM Presence.
2. Estimate Likely Harm Without Intervention.
3. Choose Response Objectives.
4. Identify Action Options.
5. Do Best Option.
6. Evaluate Progress.

This is the D.E.C.I.D.E. process framework for HM emergency decision making.

1. Detecting HM Presence

An essential first step in any emergency is to decide whether HM are present or not. Numerous clues usually exist when HM are present, but they must be sought out by the decision-maker. Inductive reasoning may be required when the HM has not been activated before the decision-maker's arrival on the scene. This can be accomplished by using containment principles, activity characterizations, structural or appearance principles, etc. Numerous methods for identifying the presence of HM are described in the literature or regulations governing the transportation or handling of HM.

2. Estimating Likely Harm Without Intervention

The next logical step, if HM are present, is to decide what the most likely progression of events and their outcome will be, if no intervention is attempted. This estimate of the likely harm is the most difficult step in the process, because emergency response information now available about HM does not focus on the data needed to support this predictive effort. Some systems claim to provide "hazard information" indicating adverse behavior of HM, but none provide the decision maker with information about all the variables that determine the events sequence in a specific emergency. [3],[4] [5] [6] [7] These variables include the quantity and quality of their predictive estimates and their resultant decisions. The communication of such information through automated systems is envisioned.

Applying these techniques to emergency response decisions can be expected to have additional benefits. As the events sequences are made visible by the charting methods, pre-accident safety control opportunities will also become obvious. Thus, losses could be reduced even further by this "preplanning" approach.

Further study of the decision processes in HM emergencies in both past accidents and postulated emergencies is required in order to refine the concepts described, but the benefits of the D.E.C.I.D.E. approach seem to have sufficient promise to justify the effort. No other approaches yet proposed appear capable of resolving the problems discussed. form of HM present, the "holding system" failure behavior, dispersion mechanisms, dispersion rates and patterns, damage or injury mechanisms, lethality, and other factors needed for timely on-scene events predictions. Without such data, timely on-scene predictions of the most likely events sequence — the timing of these events, the directions, ranges or distances of concern, and the expected injury estimates — may contain gross uncertainties that raise the risk level in any response.

This step requires the decision-maker to make a "mental movie" of the most likely course of events after his arrival on the scene. This "movie" begins with the setting observed upon arrival and ends with the last harmful event in the emergency. The expected behavior of the HM in the circumstances and the kind of harm that will probably occur constitute the plot of this "movie." The scenario must include the principal "actors" such as stressing agents, the HM and its packaging, and the people or properties exposed to harm, and all the significant actions involving each actor.

For HM emergencies in transportation, two documents that partially address this decision step are an emergency guide and a chemical hazard response information system .[8] [10] The Environmental Protection Agency has also explored this need. [11] None of the documents indicate the full range of events predictions and the comprehensive decision process for which the data are supplied. Substantial study and simplification, of the type being conducted by the US Coast Guard, [12] is needed before timely predictions can be made with reasonable confidence in specific emergencies aboard vessels or at the scene of accidents and spills.

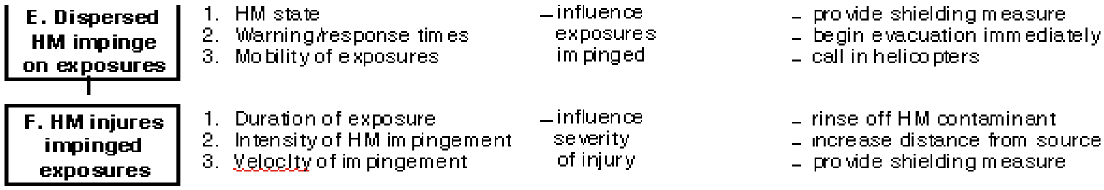
3. Choosing Response Objectives

The third step, choosing the emergency response objectives, proceeds from the predicted injury and damage estimated in step two. This decision indicates what the emergency response effort will attempt to save. It examines the exposed elements and attempts to distinguish between that which is irretrievably lost, that which is in jeopardy but might be "saved" by appropriate action, and that which is not in any jeopardy during the likely events sequence. The result of this step is an identification of the "gain" desired, and, with the result of step two, provides valuable information for step five. Little guidance exists for making this step.

4. Identifying Action Options

The fourth step consists of analyzing the action options plus the "gains" and "costs" that are associated with each option. Usually more than one action option is available that will control the emergency at hand. These options depend on the stage beyond which the emergency is to be influenced, the predicted events selected for the "mental movie," the gains desired, the gains that the option is likely to achieve, the resources available to carry out the option, and the costs of the option. The actions that can be taken may range from a full-scale attack to an immediate withdrawal beyond the range of effects. This step is designed to develop and select those options that are feasible in the specific circumstances of the emergency, and will change the outcome of the "mental movie" from step two. To arrive at these options requires knowledge of the predicted events sequence and of methods that are available for intervening in that sequence, if any. Fire fighting principles might provide sources for such methods. [13] [14] [15] Additional options might be developed by considering the stage of the emergency and the events sequence involved in the predicted outcome. Events sequence charting and analysis of differing types of releases or reactions for a given activity would help the decision-maker discover other response principles. For an example of this events charting technique, see Figure 3.

General Events Sequence No. xxx	Examples of factors determining occurrence of event	Examples of emergency response strategies	Examples of possible response options
A Overstressing event occurs	1. Type of stress applied 2. Intensity of stress 3. Duration of stress	– influence applied stresses	– redirect impingement – shield stressed system – move stressed system
B. Containment system breach occurs	1. HM characteristics 2. Nature of stresses 3. System failure mode	– influence breach size	– chill contents – limit stress levels – activate venting devices
C. HM moves through breach	1. Location of breach 2. HM driving forces 3. HM flow characteristics	– influence quantity escaping	– change container position – minimize pressure differential – cap off breach
D. Escaping HM engulfs danger zone	1. HM quantity present 2. HM dispersion characteristics 3. Meteorological conditions	– influence size of danger zone	– initiate controlled ignition – erect dikes or barriers – dilute with fog sprays



(G) restorative events might be initiated at any time after the initial injury occurs.

Figure 3. Hazardous materials emergency response options.

These response principles could probably be broken down in a manner conducive to automated data storage, retrieval, or display methods to assure their timely availability in given emergencies, in a manner like that contemplated by the CHRIS system. [16] The results of this decision must be expressed in terms compatible with the outputs of steps two and three. This means that each option must be expressed in terms of "gains" that each will probably achieve, and the "costs" necessary to achieve the gains. In addition, each option must be described in terms of the events to be influenced and the new events sequence that is anticipated. Both these descriptions are essential for the next step.

5. "Doing" The Best Option

When the estimated harm and events sequence predictions for each option become available, a decision to do whatever is best must now be made. This fifth decision step will involve the weighing of factors beyond the "net gain" for each option, such as legal requirements to respond, reputations, public expectations, personal risk-taking propensities, etc. This is the action step — the culmination of the preparatory steps described above by which the "mental movies" are transformed into reality. It is in this step that technical judgments are melded with value judgments, and the crucial decisions are made. Since the quality of the technical data influencing this decision will affect the quality of the outcome, the degree of confidence that the decision maker has in the prior estimates will thus have a strong influence on the decision made and the actions taken. Therefore, measures to improve the technical quality of the estimates will directly improve the quality of this decision. Again, documentation of this decision step is not available for NM.

6. Evaluating Progress

Having made the action choice, the next step involves continuous observations and decisions of a yes/no type; either the events sequence is progressing as envisioned in the "mental movies," based on observations, or it is not. If it is not, much of the above process must be repeated — estimates must be revised, options reexamined, and decisions revised. This "feedback" decision step continues until the emergency has been stabilized. The importance of the earlier events predictions is obvious here; the predictions provide the basis for comparing and measuring the success of the response selected during the D.E.C.I.D.E. process. Without these predictions, an emergency response effort has no standards for successful intervention, and the outcome will be more a matter of luck than of sound, structured decisions. Again, documentation of practical methods is lacking.

CONCLUSIONS

An approach and method for structuring the HM emergency response decision-making process has been presented here, and the needs for developing data to support this process are described. Weaknesses in present HM emergency information systems can be seen, and an approach is suggested for resolving these weaknesses by the use of events charting methods. Within the "think events" framework presented, information to support a structured decision-making process in HM emergencies can be developed and made available to on-scene decision makers to improve the quality of their predictive estimates and their resultant decisions. The communication of such information through automated systems is envisioned.

Applying these techniques to emergency response decisions can be expected to have additional benefits. As the events sequences are made visible by the charting methods, pre-accident safety control opportunities will also become obvious. Thus, losses could be reduced even further by this preplanning" approach.

Further study of the decision processes in HM emergencies in both past accidents and postulated emergencies is required in order to refine the concepts described, but the benefits of the D.E.C.I.D.E. approach seem to have sufficient promise to justify the effort. No other approaches yet proposed appear capable of resolving the problems discussed .

Source: Fire Journal Vol. 69 No. 4 July 1975

Footnotes

[1] *Derailment of Missouri Pacific Railroad Company's Train 94 at Houston, Texas, October 19, 1971* , Accident Report RAR 72—6, (Washington, DC: National Transportation Safety Board).

[2] M. E. Grimes, "Hazardous Materials Transportation Accidents," Fire Command!, Vol. 41, No. 4 (April 1974), p. 11.

[3] ChemCard Manual (Washington, DC: Manufacturing Chemists' Association, 1965).

[4] Fire Protection Guide on Hazardous Materials, Fifth Ed. (Boston: NEPA, 1973).

[5] *Notice of Proposed Rulemaking* No. 73—10, Federal Register 39 FR 3164 (Washington, DC: United States Department of Transportation, Hazardous Materials Regulations Board, 1974).

[6] *B E Pamphlet No. I Hazardous Materials Emergency Guide* (Washington, DC: Bureau of Explosives, Association of American Railroads, 1973).

[7] *Handling Guide for Potentially Hazardous Materials* (Chicago, Ill.: Railway Systems Management Association, 1972).

[89] *Emergency Services Guide for Selected Hazardous Materials* (Washington, DC: United States Department of Transportation, Office of Hazardous Materials, 1972).

[10] A. D. Little, Inc. ., *Preliminary System Development, Chemical Hazard Response In formation System (CHRIS)* (Washington, DC: US Coast Guard, 1972).

[11] *Episode Manual* , Contract No. 68—02—0029 (Research Triangle Park, NC: United States Environmental Protection Agency, 1972).

[12] US Department of Transportation, "Vulnerability Model," Contact DOT CG33377A (Washington, DC: US Coast Guard, 1974).

[13] **C. V.** Walsh, *Modern Guidelines for Fire Control* (Brooklyn, NY: Theo. Gaus' Sons, Inc., 1972).

[14] F. L. Brannigan and C. 5. Miles, *Living with Radiation, No. 2 Fire Service Problems* (Washington, DC) United States Atomic Energy Commission, 1963)

[15] **C. W.** Bahme, *Fire Officer's Guide to Dangerous Chemicals* (Boston: NEPA, 1972).

[16] See Footnote 10.

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Historical note

The paper, first published in the July 1975 "Fire Journal" summarized the results of a 3 year effort to develop training for hazmat responders that would produce better results than were then being achieved. It began one day in 1972 when Frank Brannigan, who was in charge of a fire service curriculum at Montgomery College Maryland, expressed his consternation at the criticisms of fire service performance by the NTSB, for which I was largely responsible. His challenge: "If you are so damn smart, why don't you tell us how to do it better." My response to his challenge was to agree to develop and teach a course for him, and with the help of the students, a better program evolved. The first description of the D.E.C.I.D.E. process concepts and approach was in the publication "HAZARDOUS MATERIALS EMERGENCIES, developed for the course and posted elsewhere. This article was the first dissemination of the program in the fire service media.

The D.E.C.I.D.E. process seems to have withstood the test of time, having been applied in other fields as well. This is the original paper.

Reprints should be requested from the NFPA. If not available there, Click here to order a reprint of this paper (Item R071)