J5.13 AN EVENT-FRAME MODEL FOR DECOMPOSITION AND RECONSTRUCTION OF LARGE-FIRE DECISION PROCESSES

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1. INTRODUCTION

Each year, thousands of fires occur on public lands. The vast majority of these fires are effectively suppressed in initial attack at a relatively small size, usually an acre or two, or less. Of fires that exceed initial attack, most are suppressed in extended attack and rarely exceed 100 acres or more. However, for a small proportion of all fires, generally less than 1%, unusual environmental, fuel or resource capability conditions can result in particularly large or uncharacteristic fires that have as outcomes high monetary costs, loss of high-valued public or private resources, and (in the extreme case) loss of human life. Though such fires are relatively rare, they tend to lead to a high level of post-incident analysis to determine (a) the possible causes and attributions of the catastrophic outcomes, and (b) actions or steps (e.g., "lessons learned") that can be taken to help prevent or mitigate similar occurrences in the future. In other words, and "accounting" of the incident is required in terms of decisions and decision factors that influenced the outcome.

Several features appear to characterize these extreme incidents such as a relatively long time frame, multiple transitions of management authority, a high level of suppression resource utilization, and critical resource capability and workload conditions at a regional or national level.

This paper reports work in progress on the development of a process for analyzing fire incidents as part of developing a better understand of how fire management practices can be improved. The broader goal of the research is to develop a method for analyzing fire incidents in terms of decision-making principles and to use the language of decision and risk analysis to provide a basis for describing the relationship between fire management decision making and incident outcomes. The essential spirit of the approach is embodied in one of the central concepts from decision analysis, that of decomposition. The essence of decomposition is that large, complex problems can be understood better by breaking them down or "decomposing" them into smaller, more tractable problems that can be solved or characterized in some detail. The individual components of the decomposition are then reconstructed or assembled into a whole. Decomposition is the fundamental principle on which decision and risk analysis are based (Raiffa, 1968; Keeney & Raiffa, 1976; Haimes, 1998; Frohwein & Lambert, 2000), and has been applied in numerous other contexts including judgmental forecasting (e.g., Armstrong, 2001; MacGregor, 2001).

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2. SOCIAL AND ORGANIZATIONAL INFLUENCES ON DECISION OUTCOMES

The process of analyzing fire incidents based on their outcomes is generally one of working backwards or "upstream" to determine the proximal causes of the outcomes. Most generally this is done in terms of one of three general categories of causal factors: environmental conditions (e.g., weather, fire behavior, fuels), technological conditions (e.g., equipment failure), or human error. As relatively clear causal influences emerge, the analysis becomes bounded and the pattern of causation becomes fixed. This approach contains key assumptions about the relationship between incident factors and incident outcomes. First, it assumes that the diagnostic or "causative" value or weight of an incident factor is greater the closer it is in time and space to the outcome. Second, it assumes that a "bottom up" approach will capture the majority of influences that are present in an incident management situation and that account for incident outcomes. Third, it assumes that the links between incident factors and incident outcomes is deterministic or strictly causal, rather than probabilistic and stochastic.

The root influences on incident decisions and decision outcomes can come from factors far removed in space and time from the incident itself. As has been shown in other contexts, such as technological failure, accidents and events that result in monetary and material losses (including loss of human life) may evolve from "normal" operations, and the antecedents of decision outcomes can only be understood by resort to factors that are part of the social and organizational context within which events occur (Perrow, 1984). As an example, Paté-Cornell (1993; Paté-Cornell, 1990) used a combination of influence diagramming and decision analysis to model the failure of an offshore drilling platform (Piper Alpha) in the North Sea oil field. She found that the original failure analysis of the drilling platform accident was heavily driven by technical and engineering factors, which tended to focus the inquiry in such a way as to produce technical solutions to the problem. However, a more careful and extended analysis of the roots of engineering failure identified a number of organizational decisions that influenced failure probabilities in ways that were not readily identifiable by examining details of the incident alone. As a result of the analysis a general model for describing the influence of organizational factors on incident characteristics was developed that decomposed incident outcomes into a combination of social, organizational, and incident-specific factors.

3. TOWARD A GENERAL MODEL FOR INCIDENT DECOMPOSITION

Decomposing a fire incident requires a guiding structure that identifies the factors influencing incident decisions and outcomes. A preliminary model for such a structure is shown in Figure 1. In this framework, incident decisions and outcomes are the result of factors specific to an incident as well as factors and influences present at higher organizational and social contextual levels. The framework in Figure 1 depicts multiple levels of influence beginning at a broad social level that includes laws, statutes and cultural values (S_i's in the model). These general influences are exterior to the organization but effect organizational meta decisions (O_i's in the model) that include policies, plans and procedures that set an organizational contextual frame for how decisions specific to an incident are structured and represented. These incident-specific decisions are shown in the model as a set of alternatives ($A_{i,j}$'s) associated with decision problems that are linked to a temporal dimension associated with the incident. In the course of a given incident, a

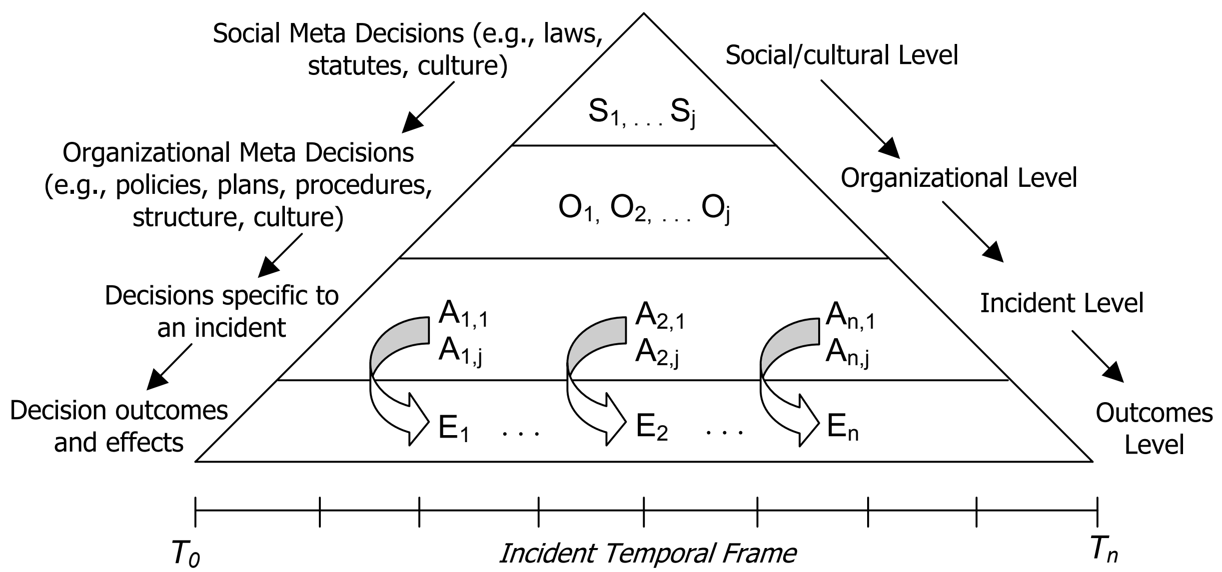

Figure 1. Model Overview.

number of such decision situations arise and can be given a temporal location. Likewise, decision outcomes and effects (E_i's) resulting from incident relationships between levels (as depicted in Figure 2), but also the relationships between concepts at each level as well as the relationship between

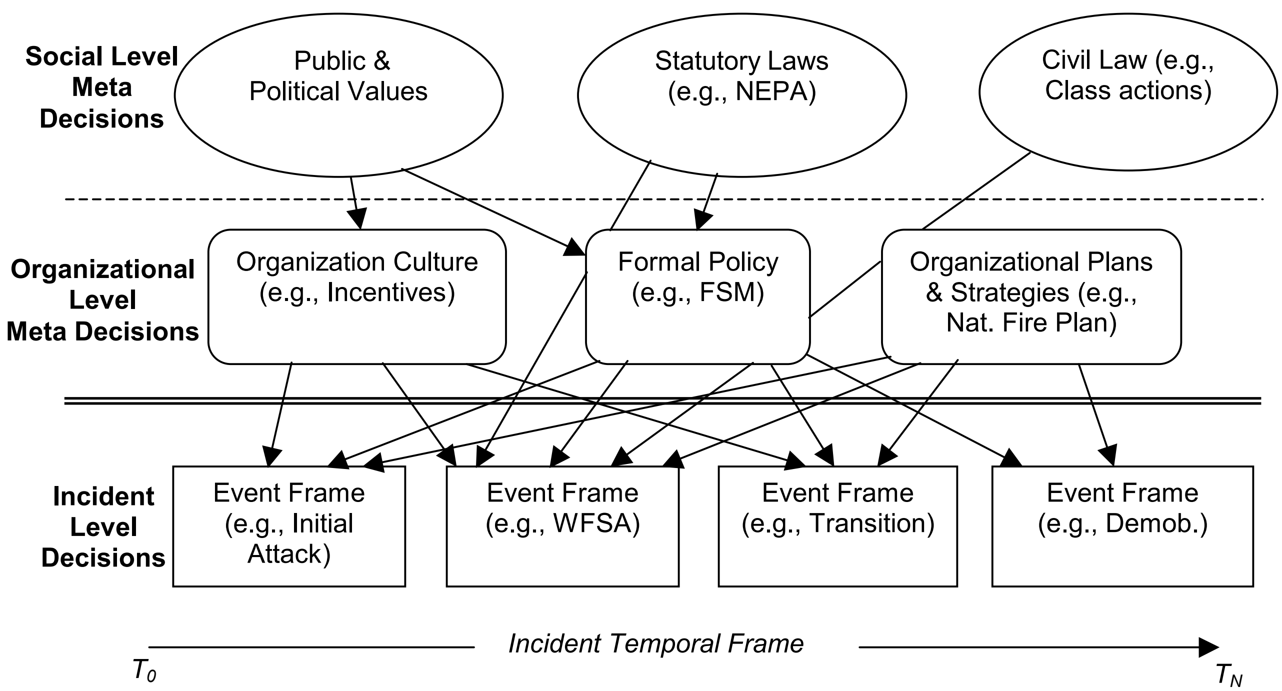

Figure 2. Influence diagram representation of a simplified fire incident

decisions can be given a temporal location as well. In an actual incident analysis, decision outcomes and effects may be linked to subsequent decisions.

3.1 *An Influence Diagram Representation.*

The essential elements of Figure 1 can be shown as an influence diagram that depicts the relationship between components at each of the levels. Influence diagrams are a form of visual representation that depicts relationships between components of a decision problem (e.g. Oliver & Smith, 1990). Arrows between components denote an *influence*, where an influence expresses knowledge about relevance. A causal relationship is not necessarily implied, but an influence exerts a force such that knowing more about A directly affects our belief or expectation about B.

Figure 2 shows a simplified schematic version of how such a diagram might appear. For an actual case, the influence diagram would be much more complex and would show not only the incident outcomes and the societal and organizational levels. This (albeit incomplete) model serves to illustrate how the relationships might be portrayed in terms of influences using some general elements at each level. Starting at the bottom we have a very simple model of an incident shown as a sequence of major events starting at time T_0 and continuing through to the end of the incident at time T_N, where N could vary through a range of days, weeks or even months depending on the length of the incident. At the top level of the figure is the Societal Level, here portrayed as comprised of three components: Political/Public Values, Statutory Law, and Civil Law. In the middle of the figure is the Organizational Level, here represented with three components: Organization Culture, Formal Policy, and Plans & Strategies.

3.2 *Social Meta Decisions.*

These are decisions made a broad social level that are reflective of (and reflected by) general cultural views and values. The decisions themselves are embodied in laws and statutes that govern and guide what organizations can do. Cultural values relevant to these laws can range from the general to the specific with respect to fire and its management. For example, broad sociopolitical values about the appropriate role of government in regulating the lives of organizations and individuals captures, perhaps, the broadest sense of this concept. More specific to fire and its management, social values about the environment, environmental protection, the role of fire in ecosystems and the like also impact social meta-decisions. As an example, the various federal statutes and laws that provide for protection of environmental amenities (e.g., threatened & endangered species, air quality, water quality) are the result of a combination of scientific and political processes that operate at the highest levels in society and that reflect a determination that overarching goals and objectives (many of them protective) be met as part of any actions that impact the environment (e.g., NEPA).

These influences can be thought of as "upstream" factors that exert their effects in a number of ways. They may take the form of specific standards and guides that organizations are required by law to abide by as part of their operations. Air quality standards, for example, fall into this category as do water quality, species protection laws and occupational safety standards. In some cases, these standards and guides will be directly passed through to the organizational level, and in other cases they may be interpreted and incorporated into an organization's culture. Also, they may have an impact by sociopolitical pressures they exert on organizational decision making. For example, an imperative to reduce large-fire costs may be reflective of a relatively non-specific sociopolitical goal of cost reduction but without a specific rule or guide to identify either the means to use to achieve cost reduction or the specific cost-reduction end to achieve.

Another category of influence at the social level is in the form of broad public views about factors relating to fire management decision making. Public attitudes about fire and fire management, including activities that have an impact on fire management such as the use of prescribed fire for fuels management, can exert powerful effects on how organizations frame decision problems and set priorities for fire management actions. For example, the "precautionary principle" as applied to risk management decision making is generally reflective of a broad public attitude that favors a conservative interpretation of risk and that corresponds to a generally risk-averse public attitude with respect to outcomes that are perceived as particularly severe (e.g., Sandin, 1999; Graham, 2001). In essence, the precautionary principle is a "better safe than sorry" view that prescribes protective action even when no harm is certain to occur. One consequence of this principle is a conservative interpretation of science by organizations charged with risk management: in the absence of science confirming the presence of harm, protective action should be taken until such time as science confirms the opposite.

3.3 *Organizational Meta Decisions*.

Decisions at this level are reflected in a number of influences. Figure 2 shows three general categories: Formal Policies of the organization, Organization Culture, and Organizational Plans and Strategies. Organization culture is comprised of many components not shown here, such as the history of the organization and its organizational values, as well as the incentive structure (both explicit and implicit) that exists within the organization and that influences individual preferences and decisions. Formal policies include specific policies and manuals (e.g., Forest Service Manual; Interagency Standards for Fire and Fire Aviation Operations) that provide the general standards and guides that serve as the "business" framework for day-to-day activities. Included here as well are periodic directives that may highlight, modify, or expand on a particular element of policy. Finally, there is a relatively large body of organizational plans and strategies (e.g., National Fire Plan; Cohesive Strategy) that serve to provide more general management direction and strategy.

3.4 *Incident-specific Decisions*.

At the incident level are decisions specific to the particular fire management action on the ground. In Figure 2, these are depicted as a series of events, each of which could be further decomposed to reveal underlying decisions specific to the event. We use the term "event" in this context to refer to a relatively rich component of a fire incident that include at least some elements of judgment and decision making, or that relies upon expert (e.g., management) judgment. To express events having multidimensional or multi-attribute characteristics, we use the concept of an "Event Frame" (discussed below). For example, an Event Frame containing a WFSA (Wildland Fire Situation Analysis) can be collecting a set of initializing information, including the fire situation early in the incident, preliminary information about values at risk, and other land

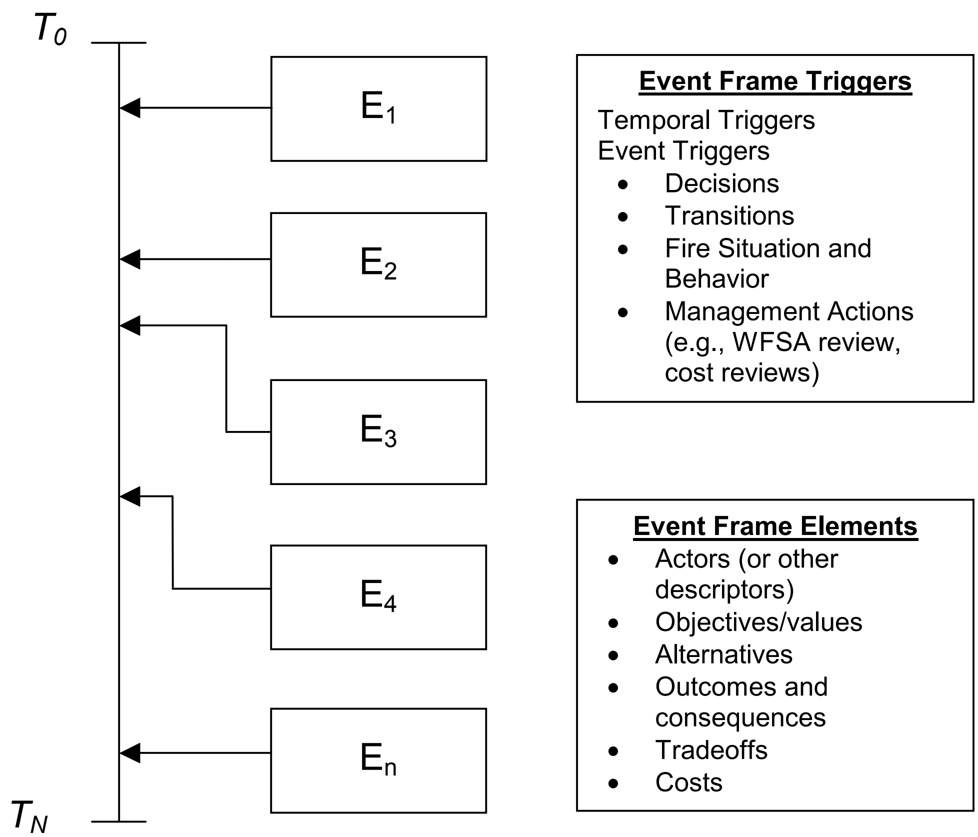

Figure 3. Event-frame model

decomposed into a number of specific WFSA elements, each of which may be influenced by higher-level social and organizational meta-decisions, such as Air Quality Standards (Social Level, Statutory Law), Public Values (Social Level), and Organization Culture.

4.0 STRUCTURE OF AN INCIDENT ANALYSIS

The process of structuring an incident analysis begins by placing a series of Event Frames along an incident temporal dimension. Most fire incidents worthy of such analysis are those having significant consequences and outcomes, such as loss of life or unusual suppression costs. This category of incident is generally document in part through the Wildland Fire Situation Analysis and other procedural documents (e.g., Delegation of Authority) that provide a convenient and authoritative basis for management issues that reflect decision priorities. Figure 3 shows a general structure for linking Event Frames to an incident time frame.

In Figure 3 a set of schematic event frames are shown as located along a temporal dimension that ranges from the beginning of an incident (Time = T_0) to the end of an incident (Time = T_N). The number of discrete event frames is, in principle. Unlimited. In practice, however, the number would be determined by the desired granularity of the analysis and by pragmatic factors such as (a) characteristics of the incident, with longer and/or more complex incidents requiring a greater number of event frames, and (b) availability of information.

Each event frame is characterized by a set of event frame elements that include (a) objectives and values, (b) alternatives, (c) outcomes or consequences, (d) sources of uncertainty, (e) tradeoffs, (f) risks, and (g) costs. Convenient methods for representing these elements include multi-attribute value trees, and decision trees. Risks associated with each event tree can be represented in terms of a basic risk assessment model that characterizes risk in terms of (a) things that can happen, (b) the likelihood that each would happen, and (c) the consequences associated with their occurrence. Further elaboration on this approach could extend to utilizing the Kaplan and Garrick Theory of Scenario Structuring (TSS) Model (e.g., Kaplan, Haimes, & Garrick, 2001). In practice, the extent to which more sophisticated methods for analyzing each event frame can be used are dictated somewhat by the value of greater analytic detail and rigor.

Event frames can also take advantage of information sources routinely generated by a fire incident. One example is the Wildland Fire Situation Analysis (WFSA) that is developed early in a fire incident and continually updated (and in some cases refined) as part of incident management. The WFSA provides primary information about land management objectives and values at risk as well as preliminary estimates of fire suppression costs. These cost elements are periodically reviewed and updated, and provide the basis for a set of periodic event frames relating directly to cost. A second source of information comes from periodic plans and documents developed as part of incident management, such as shift plans. While shift plans do not directly depict incident decision problems, their contents include current incident objects and reflect resource allocation decisions. Shift plans can be used to structure a protocol process whereby incident decisions are reconstructed on the basis of resource allocations.

5.0 ACKNOWLEDGEMENTS

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