**QUALITATIVE VALIDATION
OF
EMERGENCY RESPONSE PROCEDURES**

Prepared by

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PREFACE

Emergency managers have come to recognize that there is a quintessential style of emergency response procedure development that must be guarded against. This style allows the definition of objectives to be decided upon apart from the problems posed by their implementation, and then permits the brushing aside of such obstacles as mere tactical problems to be dealt with once goals have been clarified. If permitted to pervade emergency management policy-making, this "can do" spirit will grow steadily more confused and complex each step of the way. Instead of plowing bravely ahead in the confident belief that a formidable array of talent and resources will overcome any obstacle, intuitive managers periodically pause and take inventory of accumulated liabilities and difficulties associated with their emergency response procedures.

This work suggests use of the extreme value analysis principle in conjunction with time/loss analysis as the inventory tool to gauge the effectiveness of procedures in the response phase, or amelioration process, of an incident.

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INTRODUCTION

Every authority having jurisdiction¹ requires that emergency response procedures be reviewed on some periodic basis. Such procedures are usually reviewed after an incident involving a major loss. To be sure, this is a necessary and sound management practice. However, such reviews are expensive in both time and money and sometimes are of questionable objective benefit.

Procedure review requirements are generally very vague; i.e., "This procedure will be reviewed annually and reissued with a new signature date whether revised or not," or "In addition to an annual review, this procedure shall receive a documented review if the procedure fails during an emergency." "Fails" is of course not defined, and objective review criteria are not identified.

If resources of the organization charged with the periodic review are already being taxed, such a requirement may result in only a cursory review and reissue of the procedure to make the dates match the requirements. As such, the review would be nothing more than a meaningless administrative action.

¹ As used in this document, "authority having jurisdiction" is the organization, office, or individual responsible for establishing the acceptable level of risk within the constraints of codes, standards, and regulations, and approving emergency response procedures.

In the second instance where the review is initiated because the procedure was perceived to have failed, there is an implied threat. Possible finger pointing or efforts to avoid a liability issue will surely limit an objective effort.

As the operations of emergency response organizations become more varied and budgets become tighter, there is a need for objective analytical techniques to assist the authorities having jurisdiction to most effectively allocate limited personnel and material resources.

Extreme value analysis is a technique originally developed by E. J. Gumbel to predict the frequency of natural events. Initial uses of the process included predictions of river flows, highest winds, etc. In addition, extreme value analysis was an effective tool to determine the adequacy of dams and flood control efforts and wind resistance requirements of tall buildings.

This technique is also recognized as a tool for accident investigators to determine event causal factors. Depending upon the type of extreme value graph paper used (linear or logarithmic y-axis), the evaluator can determine if the prevention of large losses are under control.

Time/loss analysis (T/LA) is also an analytical tool of the accident investigator. The principle of T/LA enables one to determine the loss incurred after a response has been

activated. Essentially, T/LA addresses the level of loss after intervenors (emergency responders) come into play. We eliminate from the total loss of an incident that upstream portion which was sustained prior to emergency responder intervention, and include in our extreme value analysis only that portion of the loss upon which emergency responders had a direct impact.

PURPOSE

The purpose of this paper is to discuss the use of extreme value plotting in conjunction with T/LA as a quantitative determinant of the effectiveness of response procedures which are, in essence, the heart of a modern-day emergency response.

Extreme value plotting of incident loss values developed through T/LA will allow the reviewer(s) of emergency response procedures to (a) better understand what range and frequency of losses they should expect and (b) determine what further evaluation is called for in specific areas of the loss protection program under review. Application of these analytical tools to the procedure review effort will respond to the nagging question of objectivity and the very real concern of whether a procedure review/revision materially contributes to a strengthened procedure or is just a paper exercise which produces the same set of instructions with a new signature date.

EXTREME VALUE ANALYSIS

As an analytical tool for evaluating the effectiveness of emergency response procedures, the use of extreme value analysis assumes that the authority having jurisdiction has established an acceptable level of risk within the constraints of codes, standards, and regulations. Within this context, extreme value analysis can be used to predict the frequency of maximum cost incidents.

Extreme value plotting is a predictive and analytical method which uses a small quantity of readily available data and is self-testing as to applicability. Extreme value plotting allows us to estimate the average time between recurrences ("return period" of an event with a given value such as a \$1,000,000 fire loss). For instance, if the return period for a \$1,000,000 fire-loss incident is two years, there is a 50-50 chance that a fire loss of \$1,000,000 or more will occur during the next two years.

G. J. Briscoe provides a very clear discussion of the concept of extreme value analysis which is understandable by the nonstatistician. That approach is used here to give the reader a better grasp of the basic concept.

The maximum events taken from each of a large number of time intervals form a special frequency-severity relationship which is somewhat similar to the log-normal distribution pattern. The scale on the extreme value graph paper converts this skewed, bell-shaped curve to a straight line on the x-axis. Also on the x-axis opposite the frequency (cumulative probability) scale, is a scale which converts the frequency to return periods. Return periods are in the same time units as the time intervals from which the maximum events were taken. The y-axis represents the severity or cost. The average time between events (return period) can be read directly from the graph paper for maximum events of any given severity or cost. The value lies in the ability to extrapolate or extend the straight line to include longer time periods, and thus predict the occurrence of very large loss incidents.

There are two kinds of extreme value graph paper. On one paper, the severity or cost scale is linear; on the other, the severity or cost scale is logarithmic (see Figures 1 and 2). The severity or cost scale is depicted two different ways since the cost increases linearly with respect to the cumulative probability scale for events resulting from multiple independent causes. For those events resulting from multiple interdependent causes, the cost increases exponentially or logarithmically. This indicates a possibility of a common cause, such as some factor in the management systems, leading to the several causes of the large loss incident.

The extreme value equation is an empirical derivation of the frequency and severity of maximum events represented on the upper tail of the log-normal curve. The basic difference between extreme value and log-normal analysis is that all events are used in log-normal analysis, but only the maximum events are used in extreme value analysis.

Data points are calculated as follows:

1. Select a time increment or period.
2. Select the maximum loss incident for each time period, and rank the selected events in order of increasing cost.
3. Select a vertical scale which will permit extrapolation to desired consequence levels (generally two or three times the maximum value).

Figure 1. Loss data plotted on linear scale extreme value paper.

Figure 2. Loss data plotted on logarithmic scale extreme value paper.

4. Calculate the cumulative probability by dividing N_i by $N + 1$.
5. Plot the data on both logarithmic and linear extreme value papers, and use the paper that gives the best straight-line fit. If a straight-line relationship does not occur in either case, some type of change has likely occurred; analyze the data for homogeneity.

If the plot approximates a straight line on the graph paper with a linear cost scale, the losses are likely to be independent, and the prevention of extremely large losses is well under control. If the plot approximates a straight line on the graph paper with a logarithmic cost scale, the multiple causes can usually be traced back to a common source, or one cause may influence another. Since a strong systems control program would eliminate common causes, review of the control system may be in order. This is especially true if the slope of the logarithmic curve is steep so that the return period for a large loss is short.

If only a small portion of the more recent data fit the straight-line distribution and examination of the data reveals that the dollar value of property protected, as well as the losses, grew at a high rate during the period under study, this is an indication that the situation changed rapidly. This suggests that loss ratios (cents loss per dollar amount of property protected) be used on the y-axis. If the loss ratio figures are

plotted on extreme value paper, it may be seen that the required linear relationship is achieved and the expected "most probable maximum" loss ratios, over any period of observation, may be obtained from the return period scale on the top of the extreme value paper.

TIME/LOSS ANALYSIS

The concept of T/LA isolates that portion of the total cost of an incident which is directly impacted by emergency responders. T/LA suggests that the only losses that can be controlled after arrival of responders are those which have not yet occurred. Intervention should change the course of events and natural outcome of an incident. Ideally, intervention will reduce the losses that would have occurred naturally, and each intervenor will contribute some net reduction to the loss.

T/LA further suggests that during an emergency, each intervenor's goal should be to reduce the losses or time duration of the emergency. If intervenors do not change the "natural" course of events, or if they increase the net losses, intervention practices or assumptions, safeguards, and procedures must be re-examined to find ways to improve the operation's effectiveness and emergency outcomes.

APPLICATION

To use the extreme value T/LA concept as an analytical tool in the emergency response procedure review process, loss data for the organization(s) operating under the provisions of the procedures being reviewed must first be normalized. Cost must be adjusted to reflect only that amount of loss incurred after the responders have arrived.

For example, a natural gas fired furnace in a commercial building malfunctions and an explosion occurs. When responders arrive on the scene, the building is fully involved, but the fire has not yet extended to adjacent exposed structures. If responders are successful and contain the fire to the involved building, the incremental loss incurred after arrival should be within expected limits. However, if exposures become involved after responders arrive on the scene and begin suppression operations, losses will increase and may be beyond the acceptable limits.

The following is an actual application of extreme value analysis to the fire-loss experience of a rural jurisdiction, adjusted by use of T/LA, to reflect only that portion of the loss incurred after responders arrived on the scene. Table 1 reflects the greatest loss in each year under study.

Table 1. Maximum loss in T/LA generated data of each year.

1980 - 1984

YEAR	LOST
1980	\$20,000
1981	2,053
1982	4,625
1983	29,600
1984	95,089

The most attractive aspect of T/LA is that only the largest loss in each of the five years is necessary for the required extreme value plot.

Table 2 depicts the cumulative probability of each event.

Table 2. Cumulative probability using T/LA generated data.

COST	N_i	$(N_i/N + 1) \times 100$
\$2,053	1	16.7
4,625	2	33.3
20,000	3	50.0
29,600	4	66.7
95,089	5	83.3

An extreme value plot of this data on logarithmic paper (see Figure 3) approximates a straight line. As noted earlier, this straight-line plot indicates that the fire loss experience was the result of multiple causes which can usually be traced back to a common control source, or one cause influencing another. Applicable response procedures are probably inadequate, and we can conclude that a review of those procedures should be conducted.

Extreme value analysis alone does not indicate if the cause is upstream to the incident (facility design, method of operation, etc.) or in the response phase of the incident. Had the data for this plot not been arrived at through T/LA, it would have represented the total loss at each plot point, and we would only know that there is the possibility of a common cause. However, since the data represents the loss incurred after responders had arrived on the scene, we can objectively conclude that a review of the applicable response procedures is in order.

The qualitative emergency response procedure validation technique is also useful for evaluating emergency response procedures involving multiple disciplines; e.g., a response procedure providing for a fire and medical response. Historical data for losses experienced for that particular response would be gathered and tabulated as either fire loss or medical loss. On separate graph papers, the highest loss would be plotted against the computed cumulative probability as discussed above.

Figure 3. Logarithmic extreme value plot of fire loss.

CONCLUSION

Frequency-severity distributions as an analytical evaluation tool require use of all data generated by the entity being studied ranging from low-frequency, severe-consequence to high-frequency, low-consequence levels. Since these data may be distributed in a number of ways, sophisticated statistical analysis may be required. This leads to a number of difficulties involved in processing large quantities of data; a lack of low severity data as a result of reporting thresholds; the fact that the great mass of the data will ordinarily lie in the low severity range; and the care that must be exercised in selecting, using, and testing statistical distribution functions in order to avoid invalid conclusions.

Extreme value plotting is a predictive and analytical method which uses a small quantity of readily available data and is self-testing as to applicability. The use of extreme value plotting in conjunction with T/LA as an analytical tool can greatly increase the objectivity of answers to post-incident questions such as the following:

- Was there adequate emergency action to prevent a second incident from occurring?
- Were emergency response procedures executed adequately?
- Were emergency response procedures adequately designed?

Obviously, an application of this technique in the pre-incident review can work to validate procedures based upon historical data and the acceptable level of risk within the constraints of codes, standards, and regulations established by the authority having jurisdiction. Using this technique also provides qualitative, objective material for inclusion in the procedure review documentation package.

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