STUDY OF THE COMPONENTS OF EVACUATION TIMES

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SUMMARY

The magnitudes of accident dose-risks calculated by the RADTRAN code depend directly on the time span between an accidental release and evacuation of the affected area surrounding potential radionuclide releases. In a previous study of truck and rail transportation accidents, and other incidents requiring evacuations (Mills et. al., 1995), a lognormal distribution of evacuation times (time span from decision to evacuate until complete) was developed, which provided a better model for this parameter than the practice of using a highly conservative value of 24 hours. However, the distribution did not account for time required for responders to arrive on the scene, to evaluate the hazards to surrounding population and to initiate an evacuation. Data from U.S. Department of Transportation (DOT) accident statistics have been collected and their distribution functions determined. The separate distribution functions were combined into a single, comprehensive distribution which may be sampled to supply values of the RADTRAN input parameter, EVACUATION.

A sample RADTRAN calculation illustrating the effect on risks of using the distribution versus the original (24 hour), conservative point-estimate are also presented..

INTRODUCTION

In a previous study (Mills et. al., 1995) it was found that the time required to effect an evacuation from an area threatened by highway, rail or fixed-site accidents fit a lognormal distribution with a mode of approximately 1 hour. Subsequent comments on this study pointed out that the time span from occurrence of an accident until a decision to evacuate is made may be significant compared to 1 hour. In response, available DOT data were searched for possible insight into this aspect of emergency evacuations or other pertinent emergency actions. Data describing response of emergency medical (EMS) personnel were located (DOT, 1992) which were suitable for describing time elapsed from an accident until arrival on the accident scene. The data consist of tabulated distributions of "Time of Crash to EMS Notification" and "EMS Notification to EMS Arrival" for both "Rural Fatal Crashes" and "Urban Fatal Crashes". In order to obtain a distribution function for elapsed time between the time of an accident and completion of the

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evacuation, it was necessary to combine these distributions properly and to combine the result with the original evacuation-time distribution.

COMBINATION OF DISTRIBUTIONS

Since the DOT EMS response data were in the form of distributions, i.e., number of instances for a range of time intervals, and since the time from initial accident until arrival on the scene was divided into two components, random samples from these distributions had to be summed to obtain a distribution of accident-to-arrival times. The Urban distributions of accident-to-notification and notification-to-arrival were sampled 100 times using a structured sampling code, Latin Hypercube Sampling, developed at Sandia (Iman and Shortencarier, 1984). These samples were added in pairs to yield a distribution of Urban accident-to-arrival times. The same procedure was applied to the Rural distributions and the resultant histograms and cumulative distributions are shown in Figure 1. These distributions reveal that average response times are slightly shorter for Urban areas versus Rural areas, in agreement with intuition.

There is a slight loss of detail at each instance of combining two distributions. Therefore, to minimize the number of distributions to be combined for the final result and to obtain a conservative distribution of total time to effect an evacuation, only the Rural accident-to-arrival distribution was combined with the original distribution (Mills et. al., 1995) of evacuation times. The final distribution was computed by the same means described above; the histogram and cumulative distribution are displayed in Figure 2. Note that this distribution is presented with times in days, the units required for input to RADTRAN in calculating radioactive material transport accident risks.

The method of combining distributions by use of Latin Hypercube Sampling is not exact, particularly in defining the far tail (~ 1 day) of the final distribution. Figure 2 displays no times greater than 0.675 day (~16 hours) although the original distribution of evacuation times included one instance of an evacuation requiring 23 hours. In order to include the possibility of such extended evacuations and to simplify input to the Latin Hypercube Sampling code, the experimental cumulative distribution in Figure 2 was fitted by a lognormal distribution as shown in Figure 3. The lognormal distribution defines a probability for a total evacuation time of one day as 0.32%; the comparable value from the original distribution of evacuation times is 0.34%, a minimal difference.

SAMPLE RADTRAN CALCULATION

In order to demonstrate the effect of the modification described above on Accident-Risk estimates as calculated by the RADTRAN code, the lognormal distribution in Figure 3 was used as input for the EVACUATION variable in a RADTRAN calculation applied to a standard, comprehensive route. Total Accident Risk was calculated for 100 samples from this distribution; a histogram and cumulative distribution of the results are shown in Figure 4. This distribution of values has an average of 0.044 person-rem and a standard deviation of 0.019 person-rem which compare very favorably with a value of 0.091 person-rem for a fixed evacuation time of 1 day (24 hours).

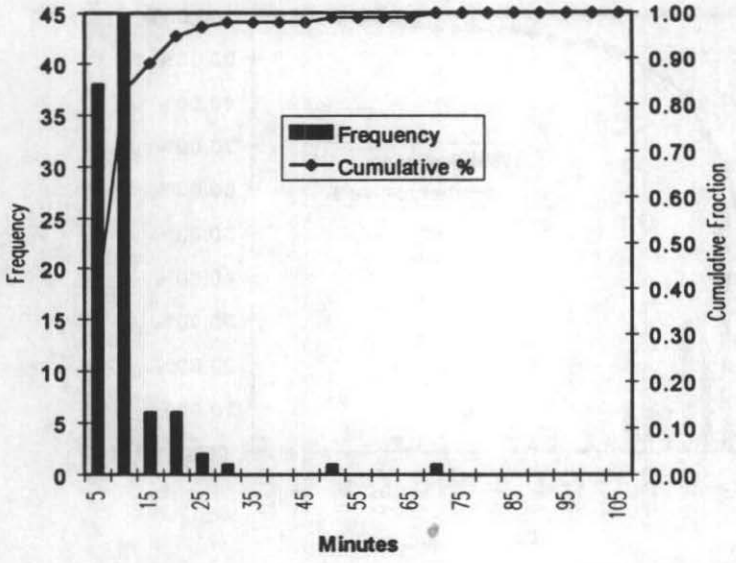

Figure 1a. Histogram and Cumulative Distribution of Urban Accident-to-Arrival Time

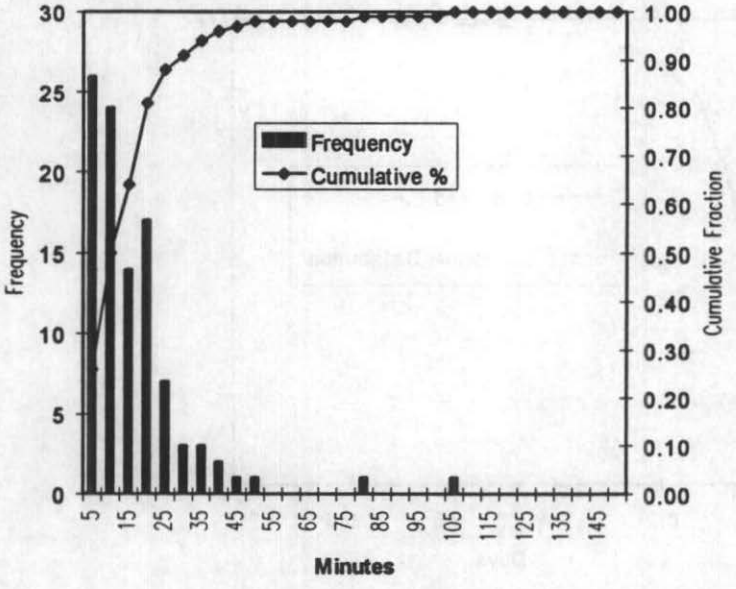

Figure 1b. Histogram and Cumulative Distribution of Rural Accident-to-Arrival Time

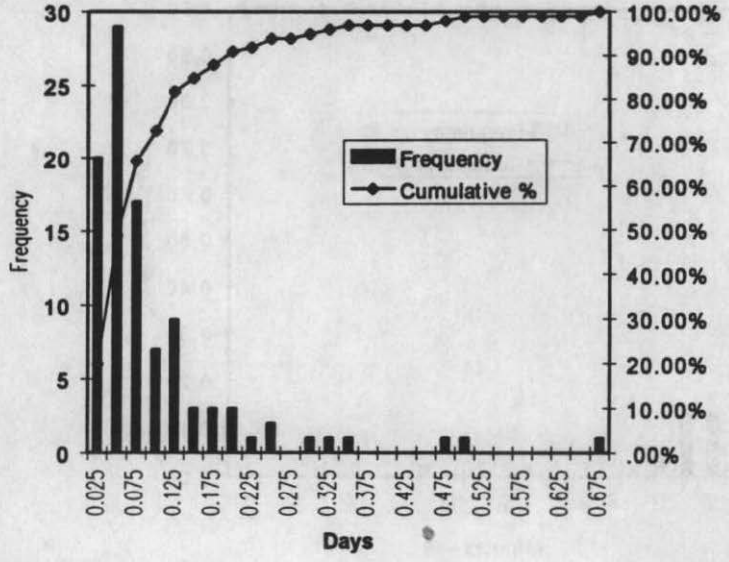

Figure 2. Histogram and Cumulative Distribution of Total Evacuation Times

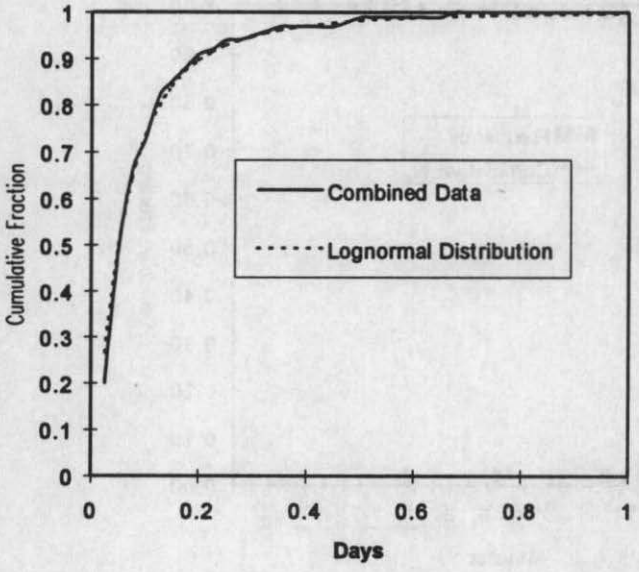

Figure 3. Lognormal Distribution Fitted to Data of Figure 2

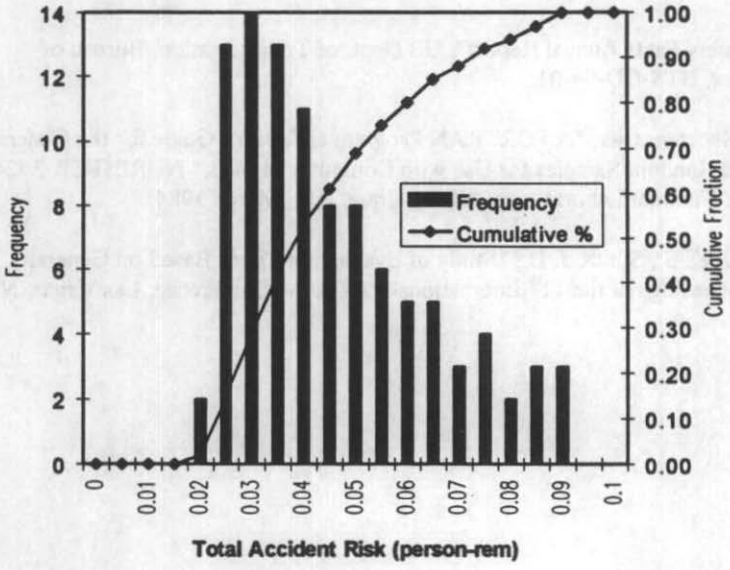

Figure 4. Histogram and Cumulative Distribution of Total Accident-Risk

DISCUSSION AND CONCLUSIONS

Although the distribution derived here does not explicitly include the time between arrival and the decision to evacuate, anecdotal evidence obtained during the original data elicitation by telephone indicated that in cases of obvious danger (e.g., major, spreading fires) decisions to carry out evacuations were very prompt. Incidents involving radioactive material are typically regarded as major threats and may be expected to involve minimal time after arrival on the scene for authorities to initiate an evacuation. Therefore, we conclude that the lognormal distribution represented in Figure 3 is an accurate, statistical description of the time span from occurrence of an accident until affected members of the public are evacuated.

A sample Accident-Risk calculation using the derived distribution of evacuation times indicates that risk estimates may be reduced by a factor of approximately 2 if the mean is compared to that for a fixed evacuation time of 1 day. The reduction is even more significant if the mode (0.025 to 0.030) of the risk distribution is used for comparison. We conclude that use of the distribution of evacuation times provides a meaningful if not radical reduction in calculated accident risk estimates.

REFERENCES

DOT, "1992 Traffic Safety Facts Annual Report", US Dept. of Transportation, Bureau of Transportation Statistics, BTS-CD-04-01.

Iman, R. L. and M. J. Shortencarier, "A FORTRAN Program and User's Guide for the Generation of Latin Hypercube and Random Samples for Use with Computer Models," NUREG/CR-3624, SAND83-2365, Sandia National Laboratories, Albuquerque, NM, March 1984.

Mills, G. S., Neuhauser, K. S., Smith, J. D., "Study of Evacuation Times Based on General Accident History," Proceedings of the 11th International PATRAM Conference, Las Vegas, NV, 1995.