APPENDIX G

CRASH RECORDERS AND ALTERNATE METHODS OF DEFINING CRASH SEVERITY

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Precise and representative data on highway crashes in the United States have potential value in enactment of standards, design of new vehicles, and in the evaluation of recent safety improvements. Accident data collected to date have been intended to serve many purposes, and one of the consequences of such a multipurpose activity is that it may not solve any specific problem as well or as economically as would an experiment designed specifically for one purpose.

One of the measures desired by many concerning the U.S. fatal accident population is the cumulative distribution of fatalities by crash severity. This has frequently been put in the form shown in Figure 1 with the abscissa being a barrier equivalent speed. It is clear that if we knew the exact crash speed (defined in an understandable and meaningful way) for each fatal crash in the U.S. for, say, one calendar year, the curve plotted from that data would precisely define the population. If we could sample randomly within the same population we could define this curve with a degree of precision which depended on the sample size.

The crash recorders which have been proposed for installation are, of course, not capable of infinite precision nor do they necessarily report the barrier equivalent speed used in the wording of the standard. The test sequences in controlled crash tests reported indicate a 95% error of less than 2 miles per hour in the derived velocity change (ΔV). The sample size required to achieve a precision in the vertical scale to that in the horizontal scale may be computed from a knowledge of the slope using the Kolmogorov-Smirnof test. For large numbers of cases ($N > 100$) the error in percent (95% bound) may be computed from:

$$\text{Error}_{95\%} = \frac{136\%}{\sqrt{N}}$$

For a 2 mph error in ΔV, and a slope of the distribution of approximately 2.5 (percent/mph) the required sample size would" be 740 cases. There would be some gain, of course, in an infinite sample; but a more usual practice would be to define the sample size as above so as to increase the total error only by the square root of two.

SAMPLING CONS1DERATIONS: "

In order for the data for a sample to truly represent the national population, the sample must be properly drawn. If there is a bias in the sample, the output will not be representative. For example, if the mean age of the fatal occupants in the sample were ten years older than the mean age in the U.S. vehicle fatal population-- and with the assumption that 10 years of age were equivalent to 5 miles per hour in fatality probability, the curve of Figure 1 would exhibit a *bias* Of the order of 12.5% in a downward direction. There are, of course, a number of other possible biasing factors. If all cars in the sampled group were full size (and the total population contained a large proportion of small cars) the distribution would be affected in the opposite direction. The biases given as examples here are estimates for illustration only, but they are not unreasonable. To get the true representation one must either sample in such a way as to eliminate the biases (e.g., random sampling) or collect enough additional information to adjust the data to correct for unwanted bias.

NUMBER OF INSTALLATIONS NECESSARY FOR 740 FATAL CASES

There are a number of ways of computing the number of installations necessary to compile 740 fatal crashes over some period of time. A simple one will be used here. With approximately 100,OOO,OOO passenger cars in the U.S. and about 40,000 in-car fatalities per year, only one in 2500 passenger cars would have a fatality in it in a year. 740 fatalities, then, would require

1,865,000 installations. If a three year period were acceptable this reduces to approximately 622,000 installations. If a larger error were acceptable (say twice as large), we no longer need 740 fatalities but only 1/4 that number--and the sample could be further reduced to 155,000. So in three years with 155,000 installations there is a potential for defining the desired cumulative curve with a precision on the order of ± 10%. The various options are shown in graphical form in Figure 2.

DISCUSSION

The statistical considerations above are based on a precise and complete sample. The mechanics of achieving this are not trivial. Placing a number of recorders in a sample of new cars biases the sample against older cars in the general population. And if these new cars were then distributed to the general population a high percentage of recovery would be difficult if not unlikely.

Placing the devices in a fleet (for example by agreement with an insurance company) should increase the probability of recovery--perhaps to a very high value. But this same action is likely to result in a non-representative sample in terms of age, sex, or car size. Adjusting such data to draw inferences to the national population is a questionable practice.

ALTERNATIVES

A number of crash severity measures can be viewed as alternatives to the crash recorder. None have the advantage of producing a direct acceleration-time trace during impact. But most are applicable in principle to all cars. These include the CDC (Collision Deformation Classification) --a newer version of the VDI (Vehicle Damage Index), the SMAC computer programs developed by the CALSPAN Corporation, comparison of detailed crush measure-ments on accident involved vehicles with results of instrumented crash tests (as described by Campbell in SAE paper 740565) or by Patrick (in an analysis of Volvo crashes). In addition, the TAD scale as applied by several police agencies is a crude measure of crash severity with the potential for relatively universal employment. Each of these will be discussed briefly below.

The CDC (or VDI)

The CDC was developed as a means of recording crash damage in a simple codable form. It consists of 6 elements--the clock direction of impact, four letter codes indicating the location of the damage (vertically and horizontally) and the general nature of the object struck, and a numeric code (1 through 7) indicating the extent of deformation. An experiment conducted by Cromack at Southwest Research Institute, and reported in an SAE paper, indicates that the CDC as presently defined can, in general, be assigned consistently by a trained investigator. The CDC, however, is not directly convertible into a measure of the crash dynamics because it depends in part on the structural characteristics of the particular car under investigation. Further, it was not developed primarily as a substitute for a measurement of the deceleration characteristics of the crashed vehicle, but rather as a simple codable record of crash damage.

The data elements contained in the CDC, however, when related to a knowledge of the vehicle structure (and perhaps other information about the crash circumstances) could permit a computation of some of the crash dynamics. An experiment could be conducted (largely with existing data) to define the ability of the CDC to predict much of the output desired from crash recorders. If an initial experiment looks promising, a large number of crash recorders in vehicles which are also measured with a CDC could lead to either (1) a calibrated CDC, (2) a redefined CDC which is more useful in the context of defining crash dynamics, or (3) both.

The CDC has the advantage that it can be applied to any accident vehicle after the crash without benefit of additional instrumentation, and thereby reducing the problem of sample selection. It has the disadvantage, at present, that its capabilities for providing a measure of crash dynamics are not well known, and that these capabilities must depend on better knowledge of vehicle structure than is generally available in the literature.

The SMAC Programs

The MAC development is intended to provide computer assistance to the reconstruction of a traffic' accident. The method involves inputting certain observational and factual data into the computer, and iterating a solution which best fits the final rest positions of the vehicles involved. The iterative computer programs can be run from data acquired with a special observational tool (the SMAC van) or can be run with data taken by manual methods. In the latter instance, in particular, the technique should be applicable to a large number of collision analyses.

The present SMAC programs are limited to the ground plane, and, as a result, are not able to handle certain odd collision configurations-- such as rollovers, or vehicles running down an embankment. To the best of my knowledge the SMAC program output has hot been compared directly with crash recordings, although from some of the remakers at the recent conference I would assume that NHTSA has either started to make such comparisons or has done some. Crash recordings have been used to compute A V. This output of the SMAC programs has been validated to some extent.

In addition to the ground plane limitation, these programs are also limited by the accuracy of input data on the structural characteristics of the vehicle. However, the capability exists for removing these deficiencies. The problem of this point seems to be one of choosing the optimum tradeoff of input data requirements and modeling sophistication versus the detail and accuracy of the resulting output.

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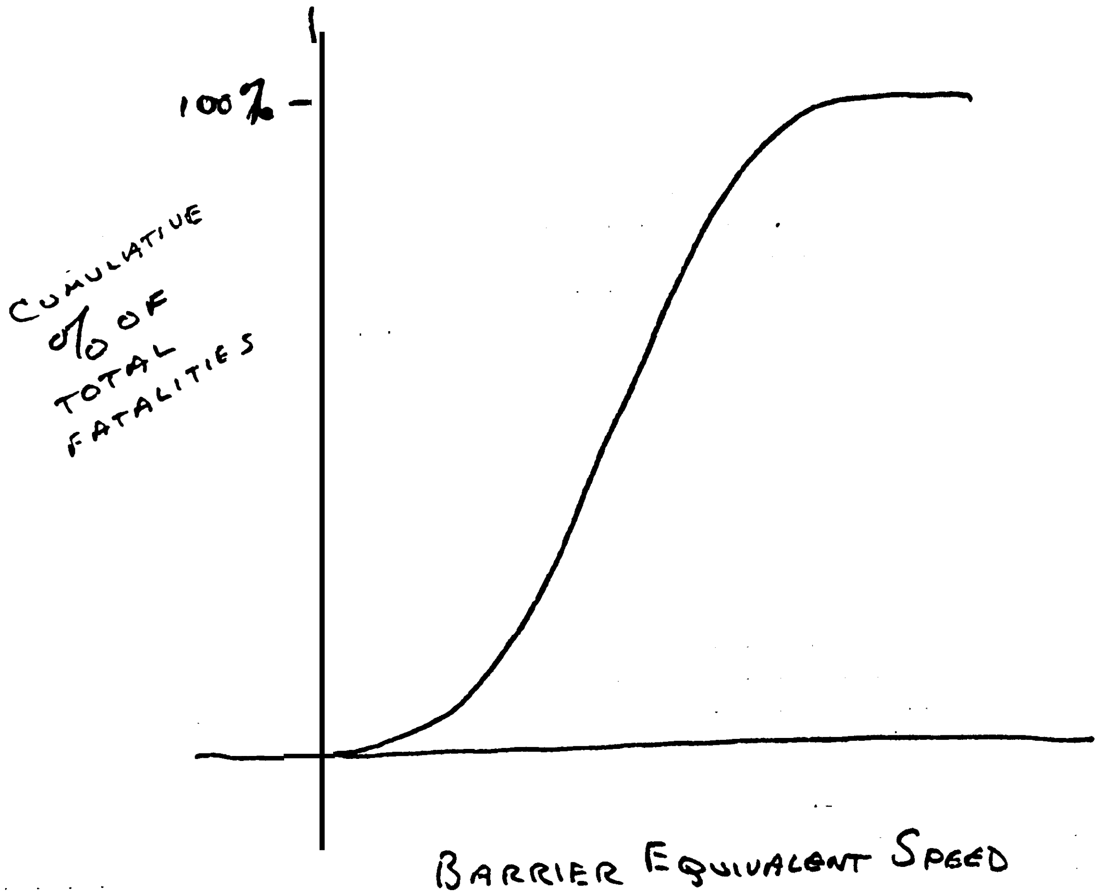

Figure 1: CRASH SEVERITY VS. CUMULATIVE FATALITY %.

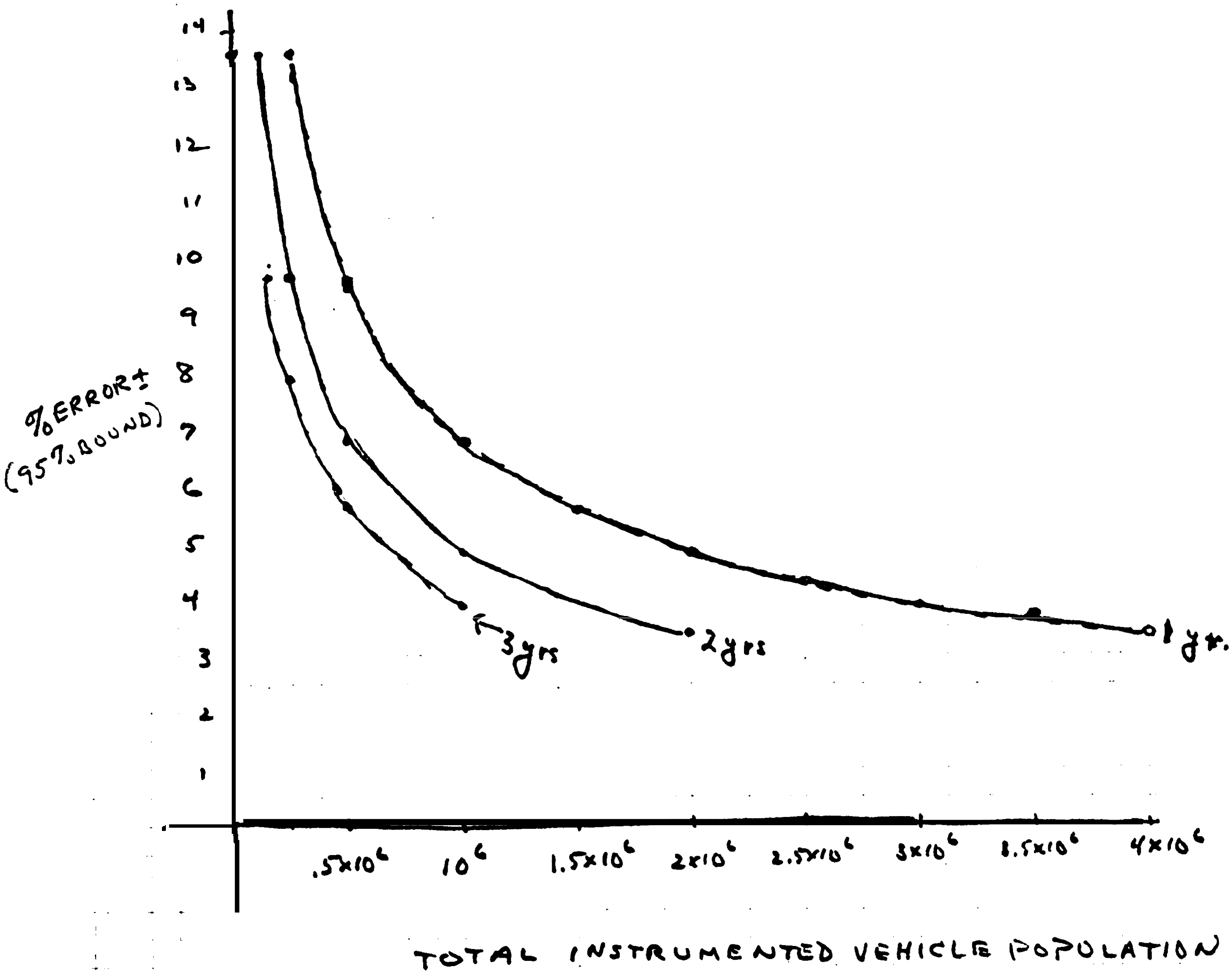

Figure 2: SAMPLE SIZE REQUIRED FOR A GIVEN 95% ERROR BOUND FOR 1, 2, AND 3 YEAR PROGRAMS.