*Automobile Collision Data: An Assessment
of Needs and Methods of Acquisition*

February 1975

NTIS order #PB-244867

OFFICE OF TECHNOLOGY ASSESSMENT

Automobile Collision Data

AN ASSESSMENT OF NEEDS
AND METHODS OF ACQUISITION

FEBRUARY 17, 1975

PREPARED AT THE REQUEST OF

THE HOUSE COMMITTEE ON APPROPRIATIONS
TRANSPORTATION SUBCOMMITTEE

PREPARED UNDER CONTRACT OTA C11 BY

ECONOMICS & SCIENCE PLANNING, INC.
1200 18TH STREET N.W.
WASHINGTON, D. C. 20036

Congress of the United States

OFFICE OF TECHNOLOGY ASSESSMENT

WASHINGTON, D.C. 20510

The Honorable George H. Mahon
Chairman
Committee on Appropriations
U. S. House of Representatives"
Washington, D. C. 20515 .

Dear Mr. Chairman:

On behalf of the Board of The Office of Technology Assessment,
we are pleased to forward to **you the** following report on
Automobile Collision Data. This study was requested as an
evaluation of the automotive crash recorder program proposed
by the National Highway Traffic Safety Administration (NHTSA).
As the assessment progressed, the implications for automobile
collision data as a "whole became apparent and the report has
been so titled to provide a more accurate indication of its
scope.

This report is being made available to your Committee in
accordance with Public Law 92-484.

Respectfully yours,
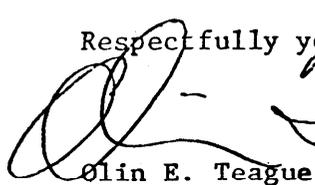
Olin E. Teague
Chairman
Technology Assessment Board

Respectfully yours,
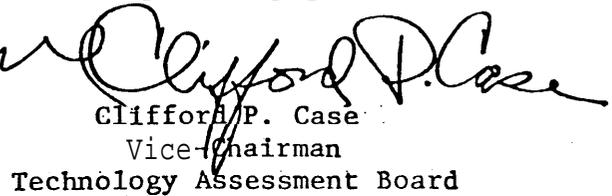
Clifford P. Case
Vice-Chairman
Technology Assessment Board

Highlights of the study findings which are especially relevant to the four questions posed by the House Appropriations Committee in its letter of request are summarized below. (The Committee letter is appended).

1. Cost and Adequacy of Current NHTSA Programs

The National Highway Traffic Safety Administration has spent a total of $15.8 million during the last three years gathering and analyzing automobile crash data. The data collected by NHTSA is inadequate to provide a basis for effective safety standard setting or measurement of the benefits of the standards in force. The inadequacies of the system are: too few reports are gathered too slowly; the file is biased toward severe injury accidents; reports do not include adequate quantitative measures of causal severity; and, the information recorded in accident reports is not that which is essential to answering the specific questions of rulemakers, accident researchers and car designers.

2. Use of Existing Crash Recorders

There are 1800 installed (disk-type) crash recorders. These provide a 3-axis acceleration time history over the actual impact interval. This information would probably be adequate to determine crash severity had a severity index been explicitly defined. After the index is defined, these same recorders might be used as part of a specialized crash severity research program.

Currently these recorders provide a limited independent measure of crash severity in air-bag equipped cars. They are also giving NHTSA practical experience in the retrieval, readout and analysis of crash records, the reliability of recorders themselves, and the reactions of fleet owners to crash recorder installations.

3* Improving the Data Base

NHTSA has not provided a sampling plan to support requested appropriations for crash data acquisition programs in the last three years. In order to rectify the inadequacies of the existing data base and the current crash data acquisition system, a comprehensive sampling plan must be developed.

The rate of acquisition of collision reports should be , increased to 500,000 to 1,000,000 per year at an estimated cost of $3-10 million annually. Causal severity should be measured and reported. This could be done by using disk recorders at a cost per report of about $133. Alternately, vehicle deformation could be measured and analyzed to determine severity at a cost of about $20 per report. However, if a cheap crash severity measuring device could be developed, it would eliminate the tedious measurement and analysis of vehicle deformation.

The consequences of not getting data are, first, sus- taining a continuing societal 10SS of at least $22 billion per year in automobile death, injury and damage without developing adequate tools to correct the problem; and second, imposition of $7 billion to $14 billion in consumer costs for meeting existing, proposed, and planned future motor vehicle safety standards whose benefits **will continue to** be uncertain.

Current NHTSA programs (multidisciplinary accident investigation, air cushion restraint system evaluation, fatal accident reporting, pedestrian-cyclist accident survey) should be continued. They are necessary to answer specific safety questions. . . . _

4. Further Considerations

If sophisticated tape crash recorders were used, there may be secondary benefits to driver training programs. For example driver errors may be more readily determined and the effectiveness of driver training may be better measured.

If crash recorders are installed, there is the possibility that their readings could be used in liability cases. This matter should be examined more fully in the legislative process.

Congress of the United States
House of Representatives
Committee on Appropriations
Washington, D.C. 20515

November 19, 1974

Honorable Edward M. Kennedy
Chairman
Technology Assessment Board
Washington, D. C.   20510

Dear Mr. Chairman:

On behalf of Congressman John J. McFall, Chairman of the
Transportation Subcommitee, and Congressman Silvio O.
Conte, the Subcommittee's Ranking Minority Member, I am
transmitting the attached request for a technology
assessment with regard to automobile crash recorders.

with kindest personal regards.   .

                    Sincerely,

                    Chairman

Congress of the United States
House of Representatives
Committee on Appropriations
Washington, D.C. 20515

November 19, 1974

Honorable George H. Mahon
Chairman
Committee on Appropriations
U.S. House of Representatives
Washington, D. C.

Dear Mr. Chairman:

The Conference Report to H.R. 15405 (Department of
Transportation and Related Agencies Appropriations Bill,
1975) states that: "The conference agreement contains no
funds for the crash recorder program. The Committee
intends to request an evaluation of this program by the
Office of Technology Assessment. "

The purpose of this program, as proposed by the National
Highway Traffic Safety Administration (NHTSA) , is to assemble
detailed data on actual collisions so as to develop realistic
automobile design standards. NHTSA proposed the installation
of 100, 000 crash recorders in vehicles used in ordinary
driving. Total cost of the 5 year program including
installation of the recorders and monitoring and analysis
of the data was estimated at $14.5 million in 1973. An
alternate approach has also been proposed by NHTSA. This
entails the controlled crashing of unoccupied vehicles along
with computer s emulations o f automobile crashes. The cost
of this program has been estimated as approximately the same
as the crash recorder program.

Although the committees of both Houses have heard extensive
testimony on this program over the past three years,
substantial question and differences still exist on the
necessity for gathering additional information through the
installation and monitoring of the requested crash
recorders.

Since this issue remains unresolved, the Conference Committee on H.R. 15405 decided to call upon the Office of Technology Assessment for assistance.

We therefore request that the Technology Assessment Board consider approving an assessment that would address the following issues:

1. How much has NHTSA spent in each of the past three years to gather accident data? Is that data sufficient, or is further data on the characteristics of automobile collisions necessary for effective NHTSA standards-setting? If the existing data base is inadequate; in what ways is it inadequate?

2. An evaluation of the type of data being produced by existing crash recorders and an explanation of how this data is being used by NHTSA should be conducted.

3. If the data base is inadequated, how might an adequate data base be obtained and what are the consequences associated with obtaining the data in different ways (including the possibility of not obtaining the necessary data)? The cost effectiveness of the crash recorder and the crash impact approaches proposed by NHTSA should be examined.

4. Secondary consequences of implementing these or other program should be identified and evaluated. Examples of these secondary consequences include legal questions associated with the existence of actual physical data from an accident and the potential value (to driver training program) of a knowledge base concerning how drivers actually respond in accident situations. For each type of approach investigated, the implementation costs to the Federal Government, industry and consumers should be identified.

We appreciate your assistance in transmitting this request to the Chairman of the Technology Assessment Board.

Sincerely,

(signed)

(signed)

John J. McFall
Chairman, Subcommittee on
  Transportation Appropriations

Silvio O. Conte
Ranking Minority Member
Subcommittee on Transportation
  Appropriations

Contents

In this volume: **Page**

Bound Separately:

    Appendices

1.   <u>INTRODUCTION AND SUMMARY</u>

At the request of the House Appropriations Committee, the
Office of Technology Assessment, through contract OTA-C11,
engaged Economics & Science Planning, Inc. (ESP) to undertake
a study of the need for and means to assemble detailed data on
actual automobile collisions so as to develop realistic automobile
design standards. The study examined the desirability, utility,
design and cost of crash recorders and of the alternate approaches
to gathering collision data, including computer crash simulation,
controlled laboratory crashes and their correlation with observed
vehicle deformations, and methods to improve the accuracy of acci-
dent investigation reporting and to increase the utility of national
crash data files. Specific data collection programs previously
proposed to Congress by the National Highway Traffic Safety
Administration were studied and evaluated. This report contains
the results of this effort.

We have concluded that the current national accident data
base is inadequate to resolve the uncertainties in NHTSA's current
and proposed motor vehicle safety programs. One of the major
deficiencies is data relating collision forces and actual fatalities
and injuries. The need has been clearly expressed by Professor
B. J. Campbell (University of North Carolina):

>   ". . . when one is forced to use nonhuman subjects [in
>   laboratory crashes] then one is left in the situation of
>   knowing a great deal about the physics of the crash but
>   knowing little of the actual injuries that might have
>   occurred in such a crash. On the other hand, in real
>   world automobile crashes one can learn about the actual
>   outcome in terms of survival and injuries, but the
>   input variables mentioned before are unknown.

"The need to link these two systems is apparent.
Engineers who design protective systems need to know
about stopping distances, forces, decelerations, etc.
But knowing these things is of too little help unless
one has a way to relate them to real world injuries."

FINDINGS

1.   The existing national data base is inadequate

   --   only four of 40 existing standards have been shown to
        be beneficial based on statistical evidence.

   --   the nationwide effectiveness of lap belts in mitigating
        fatalities is still unknown after five years; statistical
        evidence is available from only one state.

   --   there is an immediate need for more and better crash
        data

        º   to support rulemaking and to estimate the benefits
            of proposed safety standards

        º   to determine the effectiveness of existing safety
            standards

        º   to determine causes of accident, injury and fatality
            to aid crashworthy vehicle design

        º   to identify new safety problems as they develop

        º   for predicting the impact of trends in motor vehicle
            design on accident incidence and outcome

-- Larger crash data collection expenditures than the
   $5 million to $6 million now programmed annually
   appear to be justified:

   ° Motor Vehicle accidents cost society $22 billion
     to $44 billion annually.

   ° Present safety standards cost consumers $2.5 billion
     annually

   ° proposed and possible safety standards could cost an
     additional $4 to $12 billion annually.

   ° Present and planned safety standards add weight to
     automobiles which increases gasoline consumption.

2. A Comprehensive Accident Data Program

-- must be designed with great care to assure that

   ° it is representative and avoids inadvertent biases

   ° it will answer the outstanding critical safety questions

   ° it is adequate in rate and quantity

   ° it provides uniformity in reporting and format

-- should be reviewed and approved by a broadly based body
   of experts before it is implemented.

-- elements for a comprehensive program could include:

   ° 500,000 to 1,000,000 crash reports per year for a
     mass data file at a cost of $3 to $10 million per year.

⁰ the measurement and reporting of crash severity
either by vehicle deformation measurement or a
cheap and widely installed crash severity recorder,
at a cost of $10 to $20 million per year.

⁰ some measurement of crash dynamics using some mix of
simulated accident reconstruction (SMAC) and
collision history (disk or tape) crash recorders at
a cost of $2 million to $4 million

⁰ supplementary surveys to answer specific questions
and the existing special programs now costing $5 to
$6 million per year

⁰ a cheap crash severity recorder at a development cost
of about $500,000

⁰ field trials of planned safety improvements whose
costs are high and whose benefits are uncertain (as
an example, the cost of a field trial of passive
restraints would be $30 - $60 million)

3. The Federal Government, not States, manufacturers or insurance
companies, should support the central data collision activities.

-- It is a national problem.

-- The Motor Vehicle Safety Standards are promulgated by the
Federal Government.

-- The data has to be obtained in an unbiased and uniform
manner throughout the nation.

-- The Federal Government has the resources and ready access
to the sources of information.

4.   <u>Crash recorders provide data that may be admissible in
     a court of law</u>.

5.   <u>Program alternatives include the following</u>:

     *   <u>Doing nothing to improve the current crash data
         acquisition system</u>. If this course is followed, $22
         to $44 billion in societal losses will continue to be
         incurred each year without developing adequate tools
         to analyze and correct the problem; $7-14 billion or
         more in consumer costs will be imposed yearly by current,
         proposed and advanced motor vehicle safety rule making
         whose benefits, in most cases, will continue to be
         uncertain.

     *   <u>Upgrading current data collection programs without adding
         a mass data acquisition system</u>. This course will neither
         provide statistically convincing measures of the reduced
         incidence of death or injury resulting from incorporation
         of safety features nor will it give a timely response to
         questions regarding the impact of vehicle design changes.

     *   <u>Providing a mass accident data acquisition program at a
         cost of $3 to $10 million yearly</u>. This course will begin
         to permit timely statistical determination of safety system
         benefits and identification of automotive safety problems.
         However, crash severity measures will be inadequate and
         it will be difficult to associate injury with crash severity.

     *   <u>Upgrading mass accident data acquisition program to provide
         accurate severity reporting at a cost of $10 to $20 million
         annually</u>. This action would finally provide timely
         determination of safety benefits with ascertainable accident
         severity incidence and associated injury and fatality
         exposure bridging the gap between laboratory and field
         experience.

º   Use of acceleration time-history (disk) recorders. A
small (10,000 to 20,000 recorders; $2-4 million)
program   will permit: generating baseline statistical
information such as severity distribution of all collisions;
the calibration of vehicle deformation estimates as a
severity measure; and calibration of computer simulated
crash reconstruction (SMAC). A program as large as
large as 100,000 disk recorders -- $10 million -- would
overdo it from the standpoint of research and be
inadequate from the standpoint of mass data gathering.

Development of a cheap and proliferable causal severity
measurement device at an estimated development cost of
$500,000 and a production cost of approximately $2 per unit
will provide a device capable of widespread installation
that permits ready read out of crash severity magnitude and
direction by an untrained investigator. The need for
careful deformation measurement and transformation of these
measurements to equivalent barrier speed would be
eliminated.

providing a federally sponsored field trial of uncertain
and/or expensive safety aids. This program will permit the
evaluation of safety aids, where normal market forces do
not operate, prior to their being mandated on a national
scale.   (In the case of passive restraints, the one time
cost would be $30 - $60 million.)

This study was accomplished by an extensive literature survey;
by independent analysis by members of the ESP staff; by analysis
of specific assigned topics undertaken by knowledgeable members
of the automobile accident research community; and through an
Automobile Collision Data Workshop, convened January 16 and 17,
1975, at which the requirements for, and various approaches to,
better collision data gathering were presented and discussed in
depth by experts in all aspects of the problem. Individuals who
participated in the Workshop were the following:

Lynn Bradford	National Highway Traffic Safety Administration
Paul Browinski	AVCO Systems Division
B. J. Campbell	Highway Safety Research Center University of North Carolina
Charles Conlon, Jr.	AVCO Systems Division
J. Robert Cromack	Southwest Research Institute
John Edwards	Ford Motor Company
M. D. Eldridge	National Highway Traffic Safety Administration
Vincent J. Esposito	National Highway Traffic Safety Administration
William Fitzgerald	AVCO Systems Division
John Garrett	Calspan Corporation
Howard P. Gates, Jr.	Economics & Science Planning, Inc.
Lawrence A. Goldmuntz	Economics & Science Planning, Inc.
Walton Graham	Economics & Science Planning, Inc.
James Hofferberth	National Highway Traffic Safety Administration
John F. Hubbard, Jr.	Center for Auto Safety
Paul R. Josephson	Center for Auto Safety
Charles Kahane	National Highway Traffic Safety Administration
Edwin A. Kidd	Calspan Corporation
Phil Klasky	Teledyne Geotech
Gene G. Mannella	National Highway Traffic Safety Administration
Don Mela	National Highway Traffic Safety Administration

Charles A. Moffatt	National Highway Traffic Safety Administration
David Morganstein	Center for Auto Safety
James O'Day	Highway Safety Research Institute University of Michigan
Brian O'Neill	Insurance Institute for Highway Safety
L. M. Patrick	Wayne State University
Steven J. Peirce	National Highway Traffic Safety Administration
Louis W. Roberts	Transportation Systems Center, Department of Transportation
A. J. Slechter	Ford Motor Company
John Versace	Ford Motor Company
Richard Wilson	General Motors Safety Research and Development Laboratory

We wish to acknowledge our gratitude to these individuals not only for their participation in the Workshop, but for their continuing assistance during the study effort and preparation of this report.

2.   THE NEED FOR MORE AND BETTER CRASH DATA

The following paragraphs will discuss the general objectives
of crash data collection, identify some specific data needs that
are not now satisfied, and point out serious inadequacies in the
current data file and acquisition systems. It will be shown that
these needs and limitations lead to a requirement for mass
acquisition of crash data, supplemented by special surveys and
large scale real-life experiments.

a.   THE OBJECTIVES OF COLLISION DATA COLLECTION

The cost to society of automobile death and injury is con-
servatively estimated[2/] at $17 billion annually. The vehicle
damage adds at least another $5 billion yearly[3/]. The total,
$22 billion per year, corresponds to an average of $2200 in
losses per each U.S. automobile during its lifetime.

The specialists in auto safety have, as their concerted
objective, the reduction of this enormous waste. A body of
collision data is needed that will provide a substantial part of
the means to determine the causes of accidents, of injuries, and
of damage.

Professor Lawrence Patrick of Wayne State University
expressed the consensus view of the Workshop participants as follows:

  "PREMISE
      1.   The only valid way to establish safety needs
  for automobiles is through examination of field data.
      2.   The only valid way to evaluate the effectiveness
  of safety measures is through analysis of their effect on
  accident data.
  CONCLUSION
      Accident data are essential."

The National Highway Traffic Safety Administration is respon-
sible, under the National Traffic and Motor Vehicle Safety Act of
1966,* for the promulgation of Federal Motor Vehicle Safety
Standards to which vehicles manufactured for sale or use in the
United States must conform. Under the Motor Vehicle Information
and Cost Savings Act (1972)** the Secretary of Transportation is
also responsible for setting standards for damage-limiting
bumpers and for evaluating automobile damageability and
crash-worthiness.

Safety standards put into effect to date cost the consumer
about $2.5 billion annually[4] and standards proposed will cost
another $4 billion or more each year[2, 4]. In addition,
standards suggested in Advance Notice of Proposed Rulemaking
would cost $4 billion per year in first costs plus another
$4 billion in added fuel costs when fully implemented. While the
more than 40 existing standards , which were based on intuition,
judgment and limited experience, are believed to yield in the
aggregate a societal benefit greater than their consumer cost,[2]
only four of them (seat belts, energy absorbing steering column,
HPR glass and head restraints) have been shown by any authority to
be beneficial based on convincing statistical evidence. The
problem is that the body of data is inadequate.

Thus an initial objective of crash data collection and analysis
from the standpoint of the Government rulemaker, is that of evaluat-
ing the efficacies of the existing standards to determine which
should be kept on the books and which should be eliminated.

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*   Public Law 89-563.
**   Public Law 92-513.

A second objective from the standpoint of rulemaking is that
of providing the necessary statistical support to estimates of
benefits of a projected safety or damage-limiting standard. In the
next section there will be discussed a projected rule that is
controversial because of inadequate supporting data.

A third objective is the early identification of problem areas
in automobile damage and injury so as to permit designing effective
motor vehicle and highway safety programs.

The foregoing objectives from the standpoint of rulemaking have
their parallel from the standpoint of the automobile manufacturers.
C. Thomas Terry of General Motors has summarized [8/] the objectives
of gathering accident data in the field:

a.   Evaluation of production safety systems.
b.   Prediction of performance of proposed safety systems.
c.   Identification of problem areas and evaluation of
        proposed solutions on a cost/benefit basis.
d.   Estimation of human tolerance to impact.

Automobile manufacturers are , of course, vitally concerned with
the relative merits of specific alternative designs as well as with
the validation of Safety Standards to which they are required by law
to conform.

A number of universities and institutes, both profit and non-
profit, have been for years involved in research in accident
causation, injury causation and designs of vehicles and roads that
will reduce accidents and injuries. They need accident data to
discover causes of accidents and injuries; armed with this information
they can accomplish and test in their laboratories design modifica-
tions and provide valuable advice to NHTSA and automobile manufacturers.

Finally, there is a need for national planners to predict the impact of new trends in automobile designs. Fuel and resource conservation programs, encouraged if not mandated by the Federal Government, will lead to lighter, lower power-to-weight ratio automobiles. Data on collision frequencies and outcome are needed as a function of these parameters to inform Federal officials.

b.   UNSATISFIED NEEDS FOR CRASH DATA

The body of specialists concerned with automobile collisions -- the rulemakers, safety researchers, accident statisticians, car designers, insurers, and public interest people -- overwhelmingly agrees that there is a grave and compelling need for more and better crash data. The need is expressed by Dr. Edwin A. Kidd of CALSPAN Corporation[1/] in the following way:

> "It is essential that NHTSA have a data bank for surveillance and effectiveness studies related to the impact of standards on accident, injury and fatality frequencies. The relatively small output of the special federal teams and/or the higher quantity, but low content State data banks are inadequate for the purpose. In addition to information on the general accident environment, vehicle damage and occupant injuries, details of the impact environment -- velocity at impact, change in velocity during impact and possibly, vehicle deceleration -- are required for a sample of 100,OOO to 500,000 automobiles annually."

Professor B. J. Campbell, Highway Research Center, University of North Carolina[10/], states:

> "In acquiring automobile accident data several approaches are used in the U.S. : First, are intensively investigated accident crashes of which several thousand have been collected. The advantage of this approach is that the cases are extremely detailed with photographs and good injury data. The most important disadvantage is that by virtue of the changing sampling criteria and the small sample size, the ability to generalize these few cases to the population is restricted heavily.
>
> I believe too much reliance has been made on this type of data for guiding NHTSA decisions. It leads one to situations in which too much is made of a small number of cases."

The critical need for better collision data to support rulemaking can be illustrated by the passive protection provisions of Motor Vehicle Safety Standard 208. Estimates of the cost to consumers of meeting passive protection requirements range from [2/], [~/] $220 to $400 per car, or a gross cost of $1.5 billion to $3 billion per year more than belt restraints now cost. There is also significant uncertainty in the incremental benefits that may be realized from passive protection. Estimates range from 3,000 to 8,900 more deaths prevented, and from 130,000 to 492,000 more injuries prevented.

One crucial lack of data leading to uncertainty can be pin-
pointed: the number of lives saved and injuries prevented by a
restraint system in frontal collisions is estimated by NHTSA from
a graph showing the percentage of injuries and deaths as a
function of "equivalent barrier test speed."* This graph is shown
in Exhibit A (Figure 4). The "equivalent barrier test speed" is
that speed which would produce as much car damage, when the car is
driven into a rigid barrier, as the car suffered in an actual
collision.

The fatality curve of Figure 4 is based on judgment estimates
of barrier equivalent speed of 51 fatal frontal collisions by
General Motors and a small (unstated) number by Ford Motor Company;
in Figure 3 of Exhibit A the NHTSA curve is replotted for comparison
with the companies' judgment data.

In making an estimate of the fraction of lives saved by a
restraint system, NHTSA attributes to the system a barrier
equivalent speed below which it is effective and above which it is
not effective (a conceptual convenience). On the basis of laboratory
crashes with dummy and cadaver occupants, lap belts are taken as
effective to 25 mph, lap-shoulder harnesses to 30 mph, and air-bag
passive restraints to 35 mph.[6/] The intersections of these speed
lines with the fatality curve of Exhibit A, Figure 4, then yield
NHTSA's estimate of fraction of lives saved in frontal collisions.
For example, the intrinsic effectiveness of the lap-shoulder harness
in preventing fatalities in frontal collisions is thus deduced[6/] to
be 37%, and for all collisions (of which frontals constitute 50%),
is estimated at 31%. Yet extensive field experience in Sweden shows
lap-shoulder harnesses have an overall fatality prevention effective-
ness of 90%. The lap belt alone is estimated by NHTSA to have
intrinsic fatality prevention effectiveness of 20% in frontal colli-
sions, with 22% for all collisions. Yet extensive field experience
from North Carolina indicates an overall fatality prevention effecti-
veness with lap belts of 75%.

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*   Technically, these curves are cumulative distribution
     functions for barrier equivalent speed for fatal
     collisions and injury collisions.
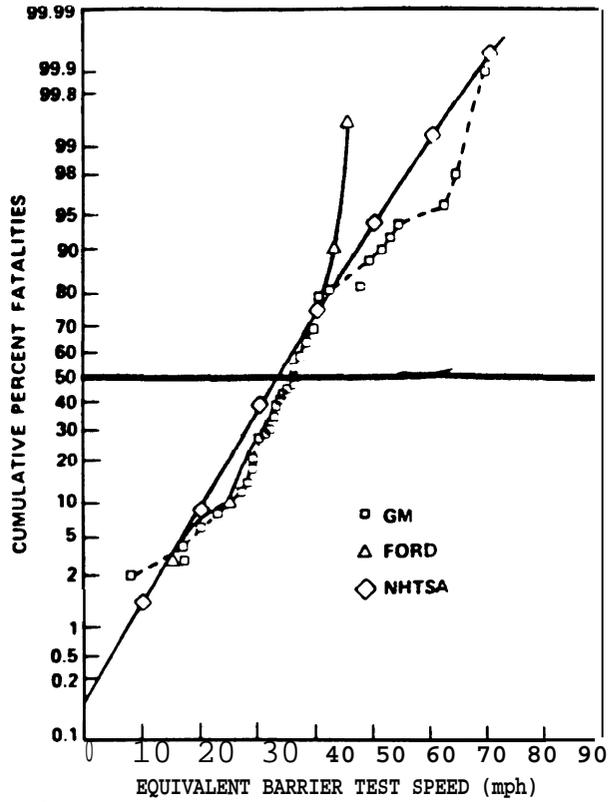
FIGURE 3 - Comparison of Fatality Distribution Data
(Frontal Collisions)
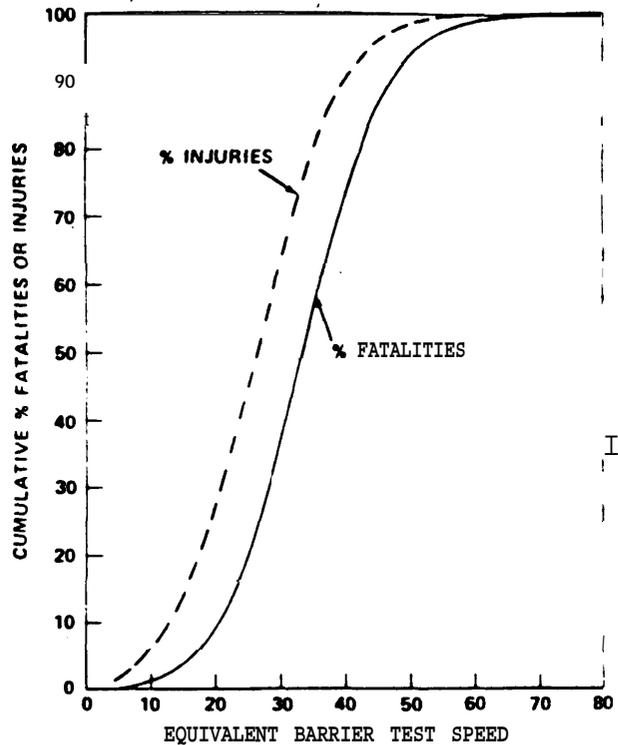
FIGURE 4- Cumulative % Fatalities Injuries within Equiva-
lent Test Speed Range

EXHIBIT A

Curves from NHTSA's "Passive Protection at 50 Miles Per hour"

These discrepancies can be explained in three principal ways, any of which may be correct: 1) The Swedish and North Carolina experience is not representative of the population of u.s. car collisions; 2) The barrier equivalent speeds up to which restraint systems are effective are underestimated by NHTSA; or 3) The barrier equivalent speeds at which fatalities occur were over-estimated in the original material of Ford and General Motors.

All of these questions can be resolved by more and better data.

The uncertainty about these curves as a basis for rulemaking is confirmed by National Highway Traffic Safety Administrator James Gregory in Congressional testimony:

> " . . .we have gone out on an advanced notice of proposed rulemaking at the same time that we went out with the passive restraint notice to say that we are moving in the direction of a standard for occupant crash protection at the level of 45 to 50 miles per hour. We figure when we get there we will have pretty much attained what is cost effective and technologically feasible in today's world.

> "We feel, by the way, that this would still be worthwhile doing. Yet, as we move toward that, without quantitative data, without persuasive data, even in the public interest, without being able to substantiate a standard we feel is reasonable and in the public interest, the challenge would be sufficient to provide that type of occupant protection. . .

> "...The reason I have to be rather vague about this is that most curves that have been derived by experts and from data that have been collected get very fuzzy when you get much above 40 miles an hour as far as what percentage of the fatalities occur at these particular speeds.*

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*   Excerpts from Dr. Gregory's testimony before the Transport-ation Subcommittee of the Committee on Appropriates, House of Representatives, 93rd Congress 2nd Session 1974, Part 3, pp. 41 - 43 [emphasis ours].

...To establish crashworthiness, we need to know what to do to an automobile and what we need to do to the occupants from the standpoint of restraint protection under a given crash condition. <u>These precise data we now lack</u>. . .

"At the present time we cannot make a judgment with accuracy and that makes us guess. And those guesses could cost, unnecessarily as far as the consumer is concerned, untold millions of dollars for protection that we may actually not need. . ."**

The doubts the Administrator expresses about the curves at speeds of 40 mph and above, we believe, as indicated earlier, also should apply to speeds lower than 40 mph.

The kinds of information needed to mitigate much of the uncertainty about the prospective incremental benefits of passive restraints are, first, a file of representative collision data from which it is possible to derive the incidence figures for injury and fatality of belted occupants, in order to establish as a baseline the capabilities for the current belt restraints; second, results of a large-scale field experiment to establish the relative capabilities of passive restraints; and third, representative files of fatal and injury collisions (involving unrestrained and restrained occupants) for which causal severity magnitudes such as BEV have been quantitatively established. With this information the lifesaving and injury prevention potential of restraint systems and the speeds to which the systems are effective can be established.

** Excerpts from Dr. Gregory's testimony before the Senate Committee on Appropriations (Hearings on FY 1974 supplemental appropriations, HR 11576) 93rd Congress, first session, part 2, pp. 1509-1510. [emphasis ours]

Fundamental to the statistics of accidents are the cum ulative probability distribution functions of severity for all accidents, for injury accidents, and for fatal accidents. These, though badly needed, are not now being obtained from large quantities of real-life accident data. In order to establish them, measurement and reporting of causal severity is required.

C. LIMITATIONS OF THE CURRENT DATA SYSTEM

In a later section we address the question of collision data requirements. The basic needs can be summarized as follows:

(1) The data should be representative of the population of u. s. automobile crashes.

(2) The data should be gathered in sufficient quantity to be useful, at a sufficient rate to be timely.

(3) The data should be in adequate detail and precision to permit its analysis to determine causes of accidents, injury and death (and the functional relationships between these causal factors and the probabilities of accidents, injury and death) ; and to permit answering questions that may arise relative to traffic safety and motor vehicle safety standard efficacy.

The inability of the current files to meet each of these needs is expressed by several investigators.

O'Day of the Highway Safety Research Institute, says:[9]

"A random sample is the best way of insuring represen-
nativeness. Unfortunately, no random sample of United
States crashes exists."

Kidd 15/ comments:

> "For too long, those concerned with accident studies
> of the effects of safety standards already in force
> have had to make do with either too small samples of
> reasonably good data or relatively large samples of
> data whose content is inadequate for the purpose. In
> the first category is the data bank (and "bank" is too
> grandiose a term) that has resulted from the individual
> federal teams of multidisciplinary, professional
> investigators. These teams can serve useful purposes in
> special studies, in discovery of problems that would
> otherwise go undetected and, particularly, in the area of
> accident causation. By their very nature, they cannot
> provide a sufficiently large data sample relevant to the
> implementation of standards aimed at injury and fatality
> reduction without excessive expenditure of funds."

MDAI -- Multidisciplinary Accident Investigation[14] -- is
conducted by about 20 teams scattered throughout the country and
sponsored by the National Highway Traffic Safety Administration
and the Motor Vehicle Manufacturers Association. These teams
have been performing clinical in-depth studies (both on-scene and
off-scene) of selected accidents in the United States, primarily
on new cars, since 1969. The accidents selected for data collec-
tion have been strongly influenced by the specific interests of
the individual teams. Although the information gathered is accurate
and detailed, only about 6,000 cases have been investigated and
2,500 of these have entered the computerized file in the five years
since the program started. The MDAI favors accidents in which
there was injury or severe damage or in which there were large
disparities between the degree of damage and the degree of injury;
as a consequence, there is significant bias in the file. B. J.
Campbell states,[10] "I believe too much reliance has been made on
this type of data for guiding NHTSA decision. It leads one to

situations in which too much is made of a small number of cases."
According to Marie Eldridge of NHTSA, "As a system for producing
statistical information needed for supporting our safety standards,
the on-scene in-depth investigations cannot be regarded as cost
effective. The average cost per case is about $2,000. The cost
decreases to about $800 per in-depth case if the on-scene
investigation requirement is eliminated. " Moreover, as indicated
by O'Day, "The present collection of MDAI cases is a sample of an
undefined and relatively undefinable population, thus limiting
severely the capability to draw inferences to the national accident
picture."

A program that has long been established but only recently has
become operational is "FARS" -- the Fatal Accident Reporting
System.[16] This system involves NHTSA collection of state data on
all fatal accidents, with recording into a uniform format that will
permit central storage, retrieval, sorting and analysis. Police
data plus later medical reports are included. Reports are made on
each occupant, each vehicle and each accident, so that about
200,000 reports are expected to enter the file yearly. Since the
file will cover all and only fatal accidents, it will be represen-
tative, but only of fatal accidents. Without supplementary
information from a sample.of all accidents whose intrinsic severity
distribution is the same as that for the fatals, inferences cannot
be drawn as to, for example, whether sobriety or use of belt
restraints affects the incidence of fatalities in crashes.

A much more representative collision data sample, structured to
meet limited objectives, is being collected by NHTSA.[14] From five
selected regions of the country "Level II" data is being obtained on
new cars in tow-away involvements for the purpose of evaluating
active and passive restraint systems. Information is assembled from
the police report, a doctor's report, photographs, a brief vehicle
investigation, and driver interviews. Data is collected on all

occupants, whether injured or not, but information gathered is
limited to that needed for the statistical analysis of restraint
system effectiveness. The design of the sampling process was
accomplished centrally, by NHTSA, so that the process will be
free of the biasing influence of the investigators (a serious
problem in MDAI investigations) . The cost is about $100 per crash.
The sampling plan has been designed in such a way that NHTSA
expects to be able to make national estimates based on post-
stratification.

NHTSA has under development a system for sampling pedestrian
and bicyclist accidents in several hundred localities. This is a
"bilevel" investigation effort in which there is a supplementary
investigation carried out by police (with the added costs borne by
NHTSA or others) to establish the nature and location of the
accidents and factors affecting visibility. It will answer questions
at the level of detail needed to determine gross behavior and counter-
measures.

The States, of course, collect accident reports in great
number. The reporting thresholds vary from State to State. Within
a State, sampling may not be representative or uniform. For example,
a city with a high crime rate may devote little effort to investigat-
ing and reporting traffic accidents, while even the slightest crash
may be reported in smaller towns. Efforts by the NHTSA to use
collision data files directly from the States have proved unsuccess-
ful primarily because of the nonuniformity of reports and the
consequent inability to properly combine, analyze and process the
information. A second problem related to the sheer volume of records
that was derived from the States.

On review of the information required on HS Form 214 used
in the Fatal Accident Reporting System (FARS) we observe that
certain information critically required by both rulemakers and
injury researchers is not supplied by the reporters. Specifi-
cally, provision of vehicle crush measurements that could be
converted to Equivalent Barrier Impact Speed (EBS) using the
method of K. L. Campbell[20] would make possible construction of
the cumulative distribution function of EBS in fatality accidents,
a function needed by the rulemakers in analysis and prediction of
the effectiveness of restraint systems. Provision of information
on the vehicle interior points of impact, occupant's height and
weight and more detail on the precise nature of injuries suffered
by injured and killed occupants would provide vital injury cause
information.

It is clear from the foregoing that there is no existing
national crash data collection program that is designed to meet
national needs. As indicated earlier, NHTSA has contracted with
the Highway Safety Research Institute of the University of
Michigan to design a national accident data sampling system based
on a probability sample. NHTSA hopes that through control of the
selection of accidents that a sample can be acquired whose
characteristics can be generalized to the national crash population.

d. MASS ACCIDENT DATA ACQUISITION

In summary, to meet data needs and to overcome the limitations
of the current national data files and collection systems, a
mass accident data acquisition system is needed. In addition,
measurement and reporting of accident causal severity is
important to the classification and analysis of accidents and

often can be important to drawing credible inferences as to
the projected benefits of proposed safety standards. The
following chapter will discuss the problems of design of
the data acquisition system and of measurement of causal
severity in more detail.

The need for more and better data does not mean the
current data collection programs should be abandoned. However,
each of these programs should be reviewed as to its specific
objectives and upgraded as necessary to meet them.   For
example, MDAI team investigations should conform to a
sampling plan rather than being entered into to satisfy
the personal interests of the investigators. An effort
should be made to get causal severity information and
information on injury mechanisms into FARS reports.

An extremely important characteristic of the Fatal
Accident Reporting System that might be overlooked as "just
a detail" is that it provides uniformity in the reporting
from all states, using computerized forms. This uniformity
makes it possible to combine, sort and analyze data.
Extension of this uniformity to general accident reporting
systems used by states would enormously simplify the central
collection and analysis of mass accident data, and should
be encouraged through a system of incentives.

Even with a very good mass accident data acquisition
system in being and operating, it will not be possible to
answer certain questions that were unanticipated at the time
the system was designed. Supplementary data acquisition systems
will be needed to answer such questions; the restraint system

collection system and the pedestrian cyclist system now operating
are examples of systems designed and needed to answer specific
questions at this time.

Mass accident data acquisition may not, by itself, answer
questions with regard to the benefit of a projected safety
standard. When the costs of such a standard are large, or
the benefits uncertain, it may be necessary to undertake a
large scale experimental program to provide the needed
answers.

Section 3, following, is necessarily quite technical.
However, much of the discussion is summarized in the
introduction to Section 4. Readers more interested in
the various alternatives for remedying deficiencies in the
existing data may wish to proceed directly to Section 4.

3.   CHARACTERISTICS OF AN ADEQUATE DATA COLLECTION PROGRAM

   In Section 2 the general needs of an adequate accident data
collection program have been identified and the inadequacies of
the present system have been presented.   In this section, three
characteristics of a satisfactory data collection program are
discussed: the quantities and rate of data acquisition, the
importance of an unbiased sampling plan and the measurement of
causal crush severity.

a.   QUANTITIES AND RATES OF DATA COLLECTION

   It is reasonable to require the data collection system to
provide timely evaluation of the effects of automobile design
changes, whether voluntary or made in compliance with official
safety standards.   This suggests that the national data collection
system should be designed to gather vital information within a
single year.

   As Kidd points out,[15] ~Definition of the total number of
accident cases required annually for an adequate national data
bank can be made if (1) the questions to be asked of the system
can be identified both for the present and future;   (2) the accuracy
with which the particular data elements can be measured is known or
can be appropriately examined; and (3) the statistical analysis
techniques to be employed can be agreed upon."

   But rate depends also on the speed with which results must
be realized.   Rapid feedback from the field is essential to the
evaluation of the effectiveness of changes, so as either to
reinforce the decision made by the designer or rulemaker or to
dissuade him from an erroneous decision.

In the case of general accident statistics, the population of crashes does not represent the statistically stable ideal (stationary time series) because of continually changing mixes of car sizes and weights, changing rules under which cars are operated (for example, the Federal 55 mph speed limit) , changes in the quality and extent of highways, variation from season to season and year to year in total miles driven, and modifications to vehicle designs, both voluntary and in compliance with safety standards.

The allowable lag in production of statistics, based on the foregoing considerations, appears to be about one year. This, in turn, suggests that a sufficient body of data should be gathered within one year to detect differences in injury incidence as a result of actions on the part of the government or the carmakers.

In the following paragraphs we will estimate what this may mean in terms of the number of reports required per year and, if causal severity were to be obtained through the use of crash recorders, the number of crash recorder installations that would be needed. Some less important data might be acquired over longer periods, lessening the amount of data required annually.

We have previously indicated that one objective of collision data gathering is the construction of cumulative distribution functions for severity for all accidents, all injury accidents, and all fatal accidents.   The first of these is needed to provide reference or baseline statistical information from which other important statistics may be derived;   the second and third are needed to validate the rationale used in rulemaking. A statistical technique* permits prediction of the number of

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*   The Kolmogoroff-Smirnov test; see, for example, "Non-parametric Statistical Inference." J.D. Gibbons, McGraw Hill 1971.

observations in a random sample that would be required to construct these distribution functions with a confidence of x percent that the function derived from the sample will be within Y percent of the true distribution. Table 1 tabulates the number of samples required for several levels of confidence and accuracy.

Table 1

Number of Observations Required
To Construct Cumulative Distribution Functions

Deviation From "Truth"	Confidence Level		
	80%	90%	95%
1%	11,449	14,884	18,496
2%	2,862	3,721	4,624
3%	1,272	1,653	2,055
4%	716	913	1,156
5%	458	595	740
8%	179	233	289
10%	115	150	185

The table indicates the number of reports that would be required to construct distribution functions of severity if severity could be measured for each year.

The tabulated numbers represent also the number of reports
needed in a segregated category to construct a severity distribu-
tion function for that category. Taking a typically acceptable
statistical level of 95% confidence, 5% accuracy, 740 fatality
reports would be required to construct a severity distribution
function for fatalities; 740 injury reports would be required to
construct severity distribution function for injury cases.
Suppose it were desired to examine the distribution function for
car weights in injury cases, independent of all other factors;
again, 740 reports would be required in which weight was stated.

The need for a large number of annual reports arises when a
particular set of events to be examined has low probability of
occurrence in the sample. Suppose, for example, one wishes to
determine the distribution of car weight in rollover injury
accidents for two categories of occupants: belted and unbelted,
740 reports in each of the two categories would be required.
Injury accidents constitute 33% of reportable accidents, and the
probability that an injury accident was a rollover [3/] is about 8%.
Perhaps 25% of those injured wore belts. Thus 0.67% of reportable
accidents were rollover-injury-belted, and to find a sample of 740,
an aggregate of 111,000 reports in the 'reportable accident"
category would be required. (This same set of reports would provide
more than enough unbelted-rollover-injury events.) If only injury
accidents were reported, a sample of 37,000 reports would suffice.
If the same analysis were to be done for fatal rollover accidents
drawn from a mass accident file, the file would have to number
3,500,000 to find 740 fatal-rollover-belted events. The reason for
the much larger data file in this case is that there are far fewer
fatalities than injuries.

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* $0.25 \times 0.08 \times 0.333 = 0.0067.$

Analysis of infrequent events requires many input reports. But the fact that events are infrequent does not make them unimportant. The best example of this is traffic fatalities, which, though infrequent, cost society almost as much as automobile injuries and damage combined.

Suppose that a new restraint system modification were implemented, and one wished to confirm, to a confidence level of 95%, that it reduced the incidence of occupant fatalities in the population of all accidents by 10% over the old restraint system.* Assuming the old system had a (perfectly known) fatality rate (when used) of 0.06%. We are seeking to verify that the new restraint system gives a fatality rate of 0.054% or less. The use rate on the new restraint system is expected to be 50%. An upper bound on the number of accident reports required to determine the fatality incidence to the desired accuracy is found to be 768,000. If this were to be accomplished in the first year Of the new installation, reports would be needed on about 30% of all accident involvements of new U.S. automobiles. Clearly, reports on fatal accidents alone would not be useful, as fatality incidence could not be determined.

The foregoing calculation makes use of an expression for the number of samples n required to determine with accuracy σ a proportion p in the population from which the sample is drawn, namely:

$$n = \frac{p \quad (1-p)}{\sigma}$$

Clearly, if the same question were restricted to side impact accidents a sample of 768,000 side impact accidents would be needed, but since side impacts constitute 1/6 of all accidents and were drawn from a sample of all accidents, that sample would have to number 4.6 million.

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*   A practical example of the kind of question NHTSA and
     safety researchers seek answers to.

One can now see, from the examples given, the extent to which
numbers of reports required depend on the questions asked. Efficient
sampling to minimize the number of samples requires a basic set of
questions to provide baseline statistics with supplementary surveys
to obtain the answers to specific questions.

Based on the previous examples of questions that might be asked
of an accident file, we believe that 500,000 to 1,000,000 cases per
year, collected in accordance with a carefully designed sampling plan,
is needed by NHTSA and others.

We determine now the number of crash recorders that would be
needed to determine accident severity distributions if recorders were
the chosen technique to measure accident severity. The number of
recorders required depends on the probability occurrence of the type
of collision. About 7.5% of all cars are involved in reportable
accidents, 2.5% in injury accidents, and 0.04% in occupant-death
accidents each year.

Table 2 indicates the number of recorders required to get the
needed data each year to construct severity distribution function
curves to 5% accuracy (5% corresponds to approximately 2 mph in
estimate of barrier equivalent impact speed) . The figures in the
column headings are the probabilities that a recorder equipped car
will be involved in an accident of the type indicated; 100%
recovery of recorder data is assumed. 30% of involvements are
considered to be of "reportable" severity: that is, that the
damage to the vehicle is of sufficient extent, or that there is an
injury, either of which would require reporting the accident to
police.

Table 2

Number of Recorders Required to Secure in One Year
Data Needed to Construct Severity Distribution Functions
to 5% Accuracy

Confidence Level	Accidents Above a "Reportable" Severity Level $P = 0.075$	Injury Accidents of All Types $P = 0.025$	Fatal-to-Occupant Accidents of All Types $P = 0.0004$
80%	6107	18,320	1,145,000
90%	7933	23,800	1,487,500
95%	9867	29,600	1,850,000

If it were further required to construct these distribution functions for smaller classes of accidents (frontal, side, rear, rollover) the number of recorders required, for 90% confidence and an accuracy of 5%, would be as shown in Table 3. (Based on accident type probabilities given in references 3 and 6.)

Table 3

Number of Recorders Required to Secure in One Year
Data Needed to Construct Severity Distribution Functions
With 90% Confidence of 5% Accuracy

	Accidents Above a "Reportable" Severity Level	Injury Accidents	Fatal Accidents
Frontal	16,190	64,324	2,917,000
Side	46,665	58,048	5,313,000
Rear	27,355	170,000	29,750,000
Rollover	198,000	297,500	9 ,297,000

As the cell size becomes smaller -- that is, as the data is subdivided into more and more classes of interest -- the number of reports needed in each cell for the construction of the particular distribution function of severity remains the same; but the number of recorders required to assure that required number of reports in each cell increases rapidly. Clearly, either a very large number of recorders would need to be installed in the U.S. automobile fleet, perhaps one in each car, or alternate methods of obtaining a measure of severity, such as measuring structural deformation of the automobile, should be used.

If a very cheap (say, $2) crash recorder does not become available, then it is clear that crash recorders become impractical because of costs as a means of measuring severity for mass accident data files, which are needed to evaluate events of low probability yet events of great importance.

b.   THE NEED FOR DEFINITION, MEASUREMENT AND
     REPORTING OF CAUSAL CRASH SEVERITY

Throughout earlier sections of this report, reference has been made to accident severity. It is important to note that what is meant is intrinsic or causal severity, as opposed to the severity of the outcome of crash, such as the degree of injury or damage. As indicated earlier, selection of a sample based on outcome inherently biases the sample and masks the effects of design changes. What is needed, instead, is a bank of data that will permit determining, for a given causal severity or range of causal severities, the outcome as a function of other factors -- car weight, occupant age, passenger compartment design, etc.

For example, in establishing bumper standards, it would be
useful to know, first, the probability distribution for causal
crash severity and second, the relationship between costs to repair
car damage and the severity of the collision in the absence of
damage limiting bumpers. From this information could then be
predicted the gross benefits of new bumpers that prevented damage
in accidents up to a specified severity level.

In determining the efficacy of an existing motor vehicle safety
standard for occupant protection, it is important to be able to
establish how the probability of injury (or degree of injury) is
affected by meeting the standard. This implies a need to develop
a file of crash reports whose inclusion is based on causal severity
level (as opposed to outcome) , so that the incidence of injuries
can be compared for cars that meet the standard and those that do
not. Stratification of the data by causal severity levels would
make it possible to draw inferences about benefit of the standard
as a function of severity. Without the severity measure, the
levels of exposure of uninjured occupants cannot be determined, and
the basis for finding and comparing injury incidence is lacking.

It has been pointed out in an earlier section that there are
doubts about the validity of the NHTSA curves of the cumulative
distribution functions of barrier equivalent impact speed (BEV or
EBS) for injury accidents and fatality accidents. Validating
these curves from real-life accident data would require measure-
ment and reporting of the causal severity of fatal and injury
accidents.

The measurement and reporting of causal severity in crashes
provides a relatively unbiased method of screening crashes for
investigation and introduction into a file. Once the severity
distribution function for all crashes is established with sufficient

accuracy, reports can be identified by severity level, and only the number of reports needed in each stratum can be selected for admission to the file. Knowledge of the severity distribution functions both for the population and for the file permits analysis of the constrained file and extending inferences to the universe of crashes. At the same time, the size of the file can be reduced by preventing the entry of 'the voluminous reports of low severity crashes whose frequency is high.

B. J. Campbell[10]/ feels that a crucial need in the field of crash injury is the means to forge a meaningful link between laboratory test crash data and events as they occur in the field:

"In the staged crashes in the laboratory, telemetric procedures are used for recording data and one can justify in considerable detail the physical system in which the crash occurs -- the 'g' -forces, the rate of onset, delta 'v' etc. But when one is forced to use nonhuman subjects then one is left in the situation of knowing a great deal about the physics of the crash but knowing little of the actual injuries that might have occured in such a crash. On the other hand, in real world automobile crashes one can learn about the actual outcomes in terms of survival and injuries, but the input variables mentioned before are unknown.

"The need to link these two systems is apparent. Engineers who design protective systems need to know about stopping distances, forces, decelerations, etc. But knowing these things is of too little help unless one has a way to relate them to real world injuries."

Clearly, a measure of real-world crash severity would help provide such a link.

The question remains as to what constitutes a proper causal severity measure, or "Vehicle Crash Severity Index (VCSI)"[19,22] This question is independent, of course, of what parameters are being or can be measured, such as vehicle deformation, acceleration time history, speed at impact, etc.

The severity measure that has been used in tests, some crash reports from the field, and in motor vehicle safety standards is Barrier Equivalent Impact Velocity (BEV or EBS). It is of interest to examine whether this is a reasonable measure of causal severity, both as regards occupant injury and vehicle damage.

What injures unrestrained and loosely restrained occupants is the so-called "second collision" of the occupant with the interior of the automobile, such as the windshield, dashboard, B-pillar, etc., or with the restraining belts or air bag. The speed with which an occupant impacts an interior element has fair correlation with the injuries he suffers. The speed of impact is determined by the average car acceleration component in the direction from the object to the occupant and the distance between the two:

$$V = \sqrt{2 \, a \, d}$$

The commonly used head injury criterion is:

$$HIC = \left[\frac{\Delta V}{\Delta t}\right]^{2.5} \frac{\Delta t}{g^{2.5}}$$

Where $\triangle t$ is the time duration and $\triangle V$ is the head speed change during the hardest bump. If the final head speed is zero and there is only one bump, this becomes

$$H\ I\ C = V^{2.5}/\ (\triangle t)^{1.5}g^{2.5}$$

or, in terms of car average acceleration during the crash, is:

$$H\ I\ C = 2.38\ a^{1.25}\ d^{1.25}/\ (\triangle t)^{1.5}\ g^{2.5}$$

Thus, we observe that the criterion for head injury severity increases with car acceleration during the crash interval, but at a slightly greater rate.

If the occupant is tightly restrained, he is subjected to the same acceleration as the occupant compartment of the automobile. The forces he experiences are in proportion to this acceleration and the weight of his own body. It has been determined by investigators[23] that human tolerance limits can be best expressed in terms of the acceleration to which a person is subjected during the crash interval. It is important to note that rapid variations of acceleration with time are not felt by the unrestrained occupant in crashes in which his motion has a forward component relative to the car, as he is in "free flight" until he impacts the interior. The fully restrained occupant feels these changes (called "jerk") but there is no evidence to indicate that they inflict more than minor punishment; the damage to the restrained occupant appears to result from the average level of acceleration he is subjected to during the crash.

Thus we observe that the two most important measures of injury tolerance can be related directly to vehicle acceleration during the crash. The next question is whether and how barrier impact velocity is related to this acceleration.

Running a car into a barrier causes deformation of the car ("crush"). It has been found in the laboratory that there is a linear relationship observed between impact speed and residual crush. The average acceleration during the crash[3] is:

$$a = -\frac{V_o k}{2}$$

where V_o is the barrier impact speed and k is a measure of the "stiffness" of the car. Thus we observe that the car acceleration is directly proportional to the barrier impact speed, but also t. the stiffness, which is higher in small cars than it is in full size vehicles.

We conclude, therefore, that barrier impact speed is a reasonable indicator of injury-related causal severity provided that car stiffness is taken into account.

K. L. Campbell[20] has evolved a sophisticated approach to relating vehicle damage to collision severity. In this approach the dynamic force-deflection characteristics are used to estimate the energy absorbed in plastic deformation of the vehicle. A linear force-deflection characteristic is the simplest (but not necessarily the most accurate) model leading to the observed linear relationship between impact speed and crush distance, and is used by Campbell. The energy can then be expressed as an equivalent barrier speed (EBS or BEV). The approach has been partly validated for frontal impacts in angle and offset barrier tests: The BEV estimates based on vehicle damage differed from the true impact speeds in the angle barrier case, over impact speeds ranging from 18 to 31 mph, by an average of -0.35 mph, with a standard deviation of 2.85 mph; and in the offset barrier case, over a narrow range of impact speeds around 30 mph, by an average of -0.01 mph, with a standard deviation of 1.64 mph. The input

information items required to make the estimate were the crush
coefficients as determined from pure frontal barrier tests for each
of the various automobiles, together with the actual detailed crush
measurements in the test impacts. K. L. Campbell believes that the
technique can be extended to side and rear impacts; such a$_n$ extension
would, of course, require determination of side and rear crush
coefficients. The crush coefficients, as defined by K. L. Campbell,
are the slope and intercept of the curve of impact speed as a
function of crush distance. The slope is identical to the reciprocal
of the "stiffness" constant we used in the previous paragraphs.

     A. B. Volvo employed a series of eleven full-scale frontal
barrier, car-to-car and car-to-pole impact tests[24/] to obtain
data on crush characteristics of the Volvo model 140 automobile.
This information was used in conjunction with detailed measure-
ments of deformation incurred in real-life impacts to estimate
barrier equivalent speeds for 128 collisions.

     In uncomplicated collisions, we believe that similarity
between real-life collision-caused vehicle deformation and that
produced in a laboratory staged crash having the same point and
direction of impact, implies correspondence between the forces
and rates of application. Thus measurements of vehicle deforma-
tion can be analyzed, compared with the outcome of staged crashes,
and used to estimate barrier equivalent impact speed. However,
it is not possible to say that equivalence of deformation always
implies equivalent dynamic forces.

     Average acceleration during the crash interval appears to be
a reasonable measure of causal crash severity. There are several
methods by which it can be measured:

(1) By a crash recorder that records acceleration time history
     (later to be time-averaged over the crash interval to get
    a severity measure)   absent a cheap crash recoder, that
    directly averages accelerations over the crash interval.
    The limitation of this approach relates to the large number
    of recorders required for mass accident files designed to
    illuminate rare events and the substantial expense associated
    therefore with this technique.   For special measurements such
    as severity distribution functions, the number of recorders
    required becomes much smaller, and then this technique of
    severity measurement becomes appropriate.

(2) By measurement of vehicle deformation (the vehicle is its own
     crash recorder) and conversion to barrier equivalent speed or
     average acceleration.   The limitation of this approach relates
     to the limited availability of calibrated deformation informa-
     tion derived from laboratory crashes.   Another limitation for
     mass accident files is the limited ability of police, at the
     scene of an accident, to judge deformation either using the
     calibrated crash deformation information, or some other
     technique, in a consistent reliable manner.

(3) By computer reconstruction of the collision[15/] (SMAC) in an
     iterative simulation process that is driven to match the
     reconstructed accident to real-life observations of skid
     marks, vehicle positions, etc. Momentum changes, in
     conjunction with known vehicle stiffness characteristics,
     can be used to estimate crash accelerations.   The limitation
     of this technique is that it requires trained investigators
     who can estimate the initial conditions of the crash so as to
     initiate the computer simulation.   If the simulation does not
     converge to the actual disposition of vehicles after the crash,
     the estimated initial conditions must be revised.

It must be recognized that the crash severity index is a
vector, and has magnitude and direction. Two linear accelero-
meters are necessary to measure its components in the horizontal
plane. A third (vertical) component is measured with
experimental crash recorders, but does not appear to be very useful.

A problem arises in using vehicle deformation to measure
damage-related crash severity; obviously, the cause and the
outcome are related. If the outcome is defined as physical
deformation, the relationship is one to one. If the outcome is
defined as cost to repair, the cause and the outcome are not
identical. There is also a flaw in the use of acceleration during
the crash interval as a measure of causal severity: if vehicle
exteriors were softened, so that average collision accelerations
were lowered, average severity would decrease even if the average
impact speeds remained the same. So the injury mitigating effects
of vehicle softening would be obscured in the collected data.
Similarly, where vehicle crush is used to determine severity, if
vehicles are designed using resilient materials that do not
permanently deform, the average severity would decline despite
unchanged average impact speed.

Thus we believe it is important that the National Highway Traffic
Safety Administration undertake the job of defining causal crash
severity in the most useful and realistic way.

There are several measures of severity currently in use that
are quite crude and inaccurate and should be supplanted by better
methods.

The deformation extent, a quantity somewhat related to
severity, is often reported in Level II (greater depth than the
police report) and Level III (in-depth) investigations. The
deformation extent is one element of the collision deformation
classification (CDC) code assigned in accordance with the Society
of Automotive Engineers recommended practice SAE J224a. However,
SAE recommended practice J224a warns "The extent number should not
be used as a tool for determining severity or energy required to
duplicate the damage. For vehicles of the same basic type, it
does serve as a tool for gathering together vehicles which have
similar damage characteristics. "

Some reports give the full CDC (sometimes known as "VDI") code,*
which describes the direction of force, general area of deformation,
specific horizontal area, specific vertical area, type of damage
distribution, and extent. The Fatal Accident Reporting System reports
only impact points and an abbreviated damage extent number.

Pollee reports often include estimates of traveling speed
prior to impact, a very poor indication of severity because of
the uncertainty of the effects of braking just prior to impact.
Sometimes "impact speed" is estimated and reported; again this
is a very dubious measure of severity because it is neither
uniformly defined nor readily estimated. It may be, depending on
the investigator, either speed relative to the ground at the
instant of impact of speed relative to the struck or striking
object. Ford Motor Company[21] in an analysis of the differences
between investigators' reports of impact speed and the speed

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*   See, for example, reports on crash recorder equipped cars,
reference 19.

changes indicated by crash recorders, found differences as great
as 40 mph and a standard deviation of 11.9 mph in 20 collisions
involving crash recorder equipped cars. The average was a speed
overestimate of 14.7 mph by the investigators.

     MDAI teams and other in-depth investigators may report their
judgment estimates of equivalent barrier speed (EBS) based on
their background of understanding of the relationship between EBS
and vehicle deformation in laboratory crashes.

     To summarize,

(1) Average acceleration during the crash interval is a reasonable
     measure of the intensity component of a causal crash severity
     index, but has some deficiencies as such.

(2) NHTSA should, with the approval of the accident research and
     statistical community, settle on and begin to use an acceptable
     definition of crash severity index.

(3) If average acceleration during the crash interval is the
     appropriate measure, there are several ways of measuring or
     estimating it with reasonable accuracy.

(4) Several indices of severity currently in use are so erroneous,
     misleading, or ill-defined, as to be valueless, and should be
     either upgraded or discarded.

c.   THE CRITICAL IMPORTANCE OF AN UNBIASED, RELEVANT, AND
     ADEQUATE SAMPLING PLAN THAT IS APPROVED BY EXPERTS

In order to meet requirements for collision data collection,
it is necessary to generate a plan for sampling and to implement
it. The plan should call for collection of a representative
sample of crash data in quantity sufficient to be useful at a
rate sufficient that the data is timely, and in enough detail and
with enough accuracy to permit answering outstanding essential
questions.

Thus there are three separable issues:

   (1) The methods of assuring that the sample
        is representative.

   (2) The quantities and rates of data gathering.

   (3) The information content, detail, and
        accuracy of reporting.

The problem of securing a representative sample is a difficult
and subtle one. To quote Versace (Ford Motor Company)[16/] on the
need for scientific sampling:

   "Not only is an increased quantity of data required but
   the sampling of the accident universe must be by sophisti-
   cated protocol. The last of the three reasons given above
   implies the need for a disciplined approach to the data, to
   avoid ending up with data which are biased in the factors
   underlying them. That requires a scientific approach to
   data collection, not just pouring more dollars into it and

cranking up the administrative machine to get a bigger
program going but doing it in the same old way, Data
gathering programs must be designed by the same people
as will design the analyses that will be applied to the
data. No less expertise than the Census Bureau applies,
or the Gallup Poll, will suffice. Fortunately,NHTSA has
been bringing in very competent people of late, people
who know that a data collection scheme must be designed
from the start with the method of analysis of the
resulting data a key determiner of how the data should be
gathered."

The importance of representativeness of the sample is hard
to overstate.[8], [9]. The sample should be representative of the
entire population of automobile collisions or have an accurately
known relationship to that population. If the sample is selected
in some way -- that is to say, if the sample is biased --
inferences drawn from the sample may be faulty. For example,
consider a sample in which only injury accidents are represented.
If, say, wearing' belts reduces the risk of injury 50%, belted
occupants will be underrepresented by 50% in the sample. Two
incorrect inferences might be drawn by a naive observer:
1) occupants in accidents don't wear their belts; 2) most of the
belted occupants in the sample were injured; obviously belts are
not very effective.

Despite the importance of avoiding sample bias, much of the
material in the existing national files is heavily biased and,
until recently, little thought was given to rectifying this
deficiency. NHTSA has contracted with the Highway Safety Research
Institute of the University of Michigan to evolve a national crash
data sampling plan which, presumably, will be based on sound
statistical principles.

The questions to be asked of the data file determine the
sampling plan: that is, the selection of regions to be sampled
and, within those regions, the collisions on which information
is to be collected; the quantity and rate of acquisition of case
reports; and the information -- kind and reporting precision --
required in each report.

Examples of such questions are:

(1) How effective have the requirements of MVSS 206 (which
specifies crash load requirements on locks, latches, and
hinge systems) been in preventing occupant ejections? In
preventing occupant injury? Are there significant
differences in capability between makes and models of
automobiles?

(2) How effective are belt restraint systems (specified by
MVSS 208) in preventing injury and death? How does the
effectiveness vary with accident severity? Car weight?
Occupant age?

(3) At what collision severity level should the bumper system
prevent damage to the automobile? Should the requirements
be different for front and rear bumpers? For different car
sizes and weights?

(4) How important is car visibility in preventing collisions?
Are the requirements of MVSS 108 (for lighting) effective in
satisfying the needs for nighttime visibility?

(5) What are the factors in passenger compartment design
    that are of significance in contributing to or preventing
    occupant injury? To what extent do the characteristics of
    the occupant himself influence the injury picture? What
    are the interactions of these factors?

As an example, the last question suggests a number of items
of information required for inclusion in reported crash data.
According to Lawrence Patrick of Wayne State University[10]/,
"complete injury data must be included in the accident data.
Sex, age, weight, height, and general physical condition are all
important factors . . .   The type and degree of injury of each
occupant including the minor bruises and abrasions and going
through the severe bone and soft tissue damage are required. It
is important to have complete data on the restraint systems used
and the interior components of the vehicle that caused the injury."
Also needed, according to Professor Patrick, are impact velocity
 (as a measure of severity) and direction, location of the impact,
seating positions of the occupants, vehicle rigidity, and vehicle
interior design.

The design of the sampling plan is critical to the utility of
the bank of data that will be acquired through the sampling
process. If the reported information is inadequate, crucial
questions that one wishes to ask of the file will be unanswerable.
If the sample fails to represent the U.S. crash universe, or
contains biases, the answers to questions may be quite wrong. And
if the quantities of cases on which answers are based are inadequate,
the confidence one can assign to the answers is low.

Thus we believe that the National Highway Traffic Safety
Administration should proceed urgently with the development of a
sampling plan (hopefully, the contract with HSRI will provide the
necessary result; if not, it should be augmented).

When completed, but before the plan is implemented, it should be submitted to, reviewed by and approved by a jury of nationally known experts representing the disciplines of accident and injury research, motor vehicle design, rulemaking, and statistical sampling and analysis.

4.   ALTERNATIVES FOR AN ADEQUATE DATA ACQUISITION PROGRAM

The elements of an adequate data acquisition program have
been previously described as comprising a mass data acquisition
system with acceptable crash severity capability, a precision
crash dynamics measurement system and special investigatory proce-
dures such as multidisciplinary accident investigating teams
(MDAI) and fatal accident reports (FAR).

Section 3 has described the quantitative requirements for
mass accident data collection. It has been indicated that approxi-
mately 500,000 to 1,000,000 accident reports per year are needed
to obtain early warning of motor vehicle hazards and to obtain
confirmation of the effectiveness of various safety programs
in a timely way to a reasonable level of significance. The exact
number of annual accident reports needed depends on the level of
detail of the desired results, the   frequency of the event being
investigated, the desired accuracy and confidence level of the
information being obtained and the time by which the information
is desired.

For example, if one wishes to determine the fatality rate
in rollovers of belted drivers in one year to an accuracy so
that the standard deviation is 30% of the mean, 130,000 accident
reports would be needed. However, if one wished to determine
the probability distribution function of car weight in cases where
belted drivers are killed in rollovers to an accuracy of 5% with
a confidence of 95%, 3,500,000 accident reports would be needed.

The kind of data needed for this mass acquisition system is
generally agreed to be a causal severity index, vehicle identi-
fication number, road and visibility data, injury scale, restraint

system and usage, driver and occupant descriptions and seating positions, with many other items required, perhaps on a special survey basis, to answer specific questions.

There are a number of ways to obtain a causal severity index. If a cheap ($2) two axis crash recorder can be developed --and there are some concepts worthy of exploration--their installation on production cars is justified. This possibility is more fully discussed later in this section.

In the absence of a cheap crash recorder, vehicle deformation should be used as a causal severity index. There are at least two major approaches, one following the lead of Professor B.J. Campbell at the University of North Carolina, and the other following the approach of Professor Lawrence Patrick at Wayne State University, the Biomechanics Research Center and practiced in a recent Volvo-Wayne State University study.[24]/

The State of North Carolina uses police reports of severity reported by the TAD system.* Police training has evidently been sufficiently good to obtain useful reports[7]/ although the data base has been small and the severity reporting system quite simple. The disadvantage of this approach is summarized by Griffin:[7]/

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* A police officer using the TAD system rates severity on a 1 to 7 scale by matching the damaged vehicle with a manual of photographs of typical accidents.

"Rural accidents tend to be more severe than urban
accidents, therefore, police level data for a given
state must be generalized with caution, even within
that state.

"It is not simple to generalize police level data from
one state to other states.   States differ with respect
to traffic density, number of interstate highways, and
weather conditions. All of these factors interact with
accident types and configurations, and thereby affect the
benefits to be derived from a safety device.

"Finally, police level data are not recorded in detail.
Levels of vehicle damage and occupant injury are evaluated
by an officer who may be trying simultaneously to summon
medical aid, direct traffic, and determine whether or not a

law has been broken. Under these circumstances, the
data yielded by these investigators is very good, but
necessarily the collection of data should not be
considered the officer's area of expertise or his major
area of responsibility."

    Professor Campbell 10/ feels the cost of improved police
reporting could be nominal and that it would be important to
extend the North Carolina system, or some improvement of it, to
a number of states that might together provide 600,000 - 1,000,000
reports which would be less biased than those from rural North
Carolina alone.

    It is difficult to accurately determine the cost of this
system, but $3-10 per report is approximately correct, or a total
of $10 million for one million reports. However, there is some
question of the adequacy of police data for many needs.

professor Patrick's approach to the recent Volvo experiment[24/] might be utilized to improve the reporting of causal severity by police.   Staged crashes of major U.S. models, front, side and rear into poles, barriers and cars at three speeds could be used to obtain calibrated deformation data.   The one-time cost of such a program is estimated* to be $3-5 million.   There are a number of possible ways to use these data.   Police could be trained to photo-graph** the damaged vehicle from a few aspects after having placed appropriate identification placards and scales on the damaged vehicle.   The film could be subsequently processed at various centers

to derive the severity data by analysis Of the photographs and by comparison with the calibrated deformation data.   The total accident report including police and medical data, if any, could be assembled at the photographic analysis center.

Alternatively, it might be possible to train police equipped with appropriate templates to measure the collision deformation in conformance with a handbook based on the calibrated deformation data from the staged crashes.   Appropriate supplies, compensation and incentive would have to be provided to local police.   A cost of $10-20 per accident report might be sustained by more detailed analysis of this reporting system.   Therefore this type of mass accident data system might cost a total of $25-30 million for the first year including non-recurring capital as well as operating costs.

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* Conversations with Professor Patrick.

** M_r. John Garrett of Calspan reports some success in Western N. Y. comparing estimates of severity from police photographs with estimates of professional accident investigation teams.

In Section 2 there was also described the need for some
precision reference data. This need was stressed by almost every
participant in the Workshop.$\underline{1}$/, $\underline{10}$, $\underline{11}$,$\underline{13}$, $\underline{14}$/.   In particular
sume 10,000 sophisticated recorders with an accuracy of 1-2 mph*,
are needed to obtain in one year's time a representation of the
probability distribution of severity of accidents (above the police
reporting threshold) with severity (barrier impact speed), to an
accuracy of 5% and at a confidence level of 95%. If this represen-
tation of the distribution of severity were limited to frontals only,
the confidence level would be only 80% with an accuracy of 5%.
Alternatively, 20,000 recorders could be used to obtain this
distribution for frontal collisions to an accuracy of 5% at a

confidence level of 95%. The cost of sophisticated crash
recorders in these quantities is approximately $200. Therefore
the total cost of this basic program is between $2 and $4 million
plus the cost of data retrieval and analysis.

The cost per accident report from the sophisticated crash
recorder** would be approximately $2,000 the first year, declining
to $1,000 over the first two years, $500 over the first four
years, $200 over the first ten years. This is the normal
characteristic of the flow of benefits over a period of time from
an initial capital expense.

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*   This corresponds to a 3.8 - 7.6% change in the cumulative
      distribution of fatalities or an annual dollar cost
      equivalence of approximately $250-500 million in estimating
      the effectiveness of occupant restraint systems.

**   Described later in this section.

The SMAC system of computer-aided accident reconstruction could also be used to obtain precision reference data, and is competitive with the sophisticated crash recorder. It is our opinion that the SMAC system, while extremely clever and promising, has not completed its development cycle, and must be operated by full time professionals. These might be specially trained police. However, some means would have to be found to compensate state and city police for performing NHTSA work. If a SMAC van is to operate around the clock, a crew of eight per vehicle would be required. If as many as 100,000 accidents were to be investigated per year with 500 vans, a total crew of approximately 4000 men would be required at an annual cost of $60 million. Thus, the manpower cost seems to limit the SMAC system to obtaining relatively small numbers of reports, say 10,000 per year or lower. The SMAC system like the sophisticated crash recorder, seems most useful for special data gathering programs requiring precision severity data. If 2500-5000 accidents are to be investigated per year, perhaps 15-20 vans would be required at a total manpower cost of $1.8 - 2.4 million plus the cost of equipped vans and processing centers, or roughly $500 per case.

These costs should be compared to the current costs of MDAI investigations at $2000 per case on scene and $800 per case off scene , FAR reports at $15 per case, Level II reports at $100 per report.

Some safety devices, particularly those with uncertain performance and high cost to the consumer, could be subjected to a field test prior to general introduction. Some Federal agencies, The Food and Drug Administration, for example, do require extensive tests of products before general use. These tests, if properly designed and monitored, could yield invaluable data on the benefits from such devices.

However, a safety feature like the 5mph bumper or passive
restraints can probably not be sold on a trial basis depending
on market forces alone. Therefore, Federal sponsorship would be
necessary to design the field trial, pay the cost of installation
and monitor the results. This process would be expensive but, when
viewed against huge consumer costs, may be worthwhile.

Such a test has been suggested for passive restraint systems
by the National Motor Vehicle Safety Advisory Council, a body
advisory to the Secretary of Transportation, by a Resolution
adopted by an 11 - 5 vote on November 19, 1974.*

It is the feeling of a number of both the academic and
automotive participants in the Workshop, and the authors of this
report, that a field trial of 100,000 - 200,000 passive restraint
systems is necessary.

The size of the field trial of passive restraints arises from
the following considerations. If one assumes that the passive
restraint is effective in reducing fatalities by 50%, then it would
require three years of field trial of 200,000 equipped cars to
determine the probability density of severity given a fatality to
an accuracy of 10% with 80% confidence. On the other hand, if one
wished to determine whether the fatality rate in all passive restraint
equipped cars had decreased by 50% to an accuracy of 20%, 125,000
installations would be required to obtain an answer in one year.
If on the other hand, one wished to determine the performance to
the same accuracy in light cars as compared to heavy cars, one
would have to wait two years, assuming the 125,000 car sample was
split equally between heavy and light cars.

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*   See Appendix L.

For this field trial to be unbiased, these systems would
have to be installed in small and large vehicles in representative
parts of the country with a representative set of drivers. Since
market forces cannot be depended upon to provide this, it is
probably in order for the Federal mandator of the proposed regulation
to support the trial. The cost of such a program could be $30 - $60
million.

In summary, an extensive mass accident data system of one
million reports annually may cost

(1) $3-10 million annually using the North Carolina approach of
      upgrading police reporting, plus the cost of improvements in
      severity estimation;

(2) $10-20 million annually using the Wayne State - Volvo approach
      to obtaining accident severity, plus the costs of reporting
      factors other than severity, plus a one-time cost of $5
      million for calibrated vehicle crash data and other capital
      expenditures:

(3) $10 million annually to obtain severity information alone if
      a cheap ($2) crash recorder could be developed and installed
      on 50% of all new production. One would have to add. to this
      cost the cost of collecting the records, analyzing the
      data and coalescing this information with other accident
      information in a mass data file.

These several approaches are potentially mutually supportive
rather than competitive. There is presently no such thing as a
cheap recorder, so one cannot depend on it for severity data.
Should one be developed, it would be extremely useful for mass
accident data. A serious effort toward this objective should be
undertaken. If the Wayne State - Volvo approach to obtaining
accident severity could be developed to apply to the U. S.
problem, then it might be used in conjunction with the North
Carolina approach as a better method of estimating severity.

A needed tool for precision research on the crash dynamics
of a few thousand accidents annually may be obtained by either
SMAC simulation or precision crash recorders.

(1) $2-4 million first cost for 10,000 to 20,000 sophisticated
crash recorders plus the cost of the facilities and personnel
needed to analyze and correlate the data produced as an
annual expense.

(2) $2-2.5 million annually for personnel on vans plus the vans
themselves and analytical equipment.

It would seem possible to put emphasis on one or another of
these programs. In doing this NHTSA should take into account
the somewhat higher first costs of the crash recorder program as
compared to the somewhat higher annual operating costs of the SMAC
program. Obviously this cost analysis must be viewed against the
differences in the kind of data obtained from the two approaches.
The SMAC vans do get trained investigators to the scene. NHTSA
can best evaluate if this capability is justified in view of the
multidisciplinary accident investigating teams. Since MDAI teams
report on 1500-2000 cases per year from a perspective that is
broader than crash dynamics, it seems advisable to maintain this
capability.

The field trial of 100,000 - 200,000 passive restraint equipped cars in a representative sample would cost 30 - 60 million dollars first cost plus annual analysis expense.

Thus in addition to the current accident program of approximately $5 million covering such activities as MDAI, FAR, Level II reports, NHTSA and the Congress should consider adding a mass accident data system that might cost $5 - 20 million annually, a precision crash dynamics system (probably sophisticated crash recorders) at a first cost of $2 - 4 million, and finally a field evaluation of passive restraints costing $30 - 60 million. Table 4 summarizes the existing programs and the recommended alternatives for the additional data that we deem to be required.

The genesis of this OTA study was an issue concerning sophisticated crash recorders and their proper use in accident data retrieval.

Two types of crash recorders have been developed under NHTSA sponsorship.

one of these, commonly known as the "tape recorder," was developed by AVCO Systems Division, Wilmington, Massachusetts. It is designed to measure and record vehicle parameters before, during and after a crash. The time history of the following quantities is recorded prior to the crash:

TABLE 4

EXISTING AND PROPOSED PROGRAMS

DATA NEEDS ALTERNATIVES AND COSTS	MASS ACCIDENT FILE (500,000-1,000,000 REPORTS ANNUALLY)	PRECISION CRASH DYNAMICS (2,500-5,000 REPORTS ANNUALLY)	SPECIAL STUDIES
Medical and Police Reports Using TAD	$3- $10 Per Report, North Carolina Prototype		
Medical and Police Reports Using VDI or CDC	Upgraded Severity Capability as Compared to system Above		
Medical and Police Reports Taking Photos to be Compared to Calibrated Crashes	$10-$20 Per Report Wayne State - Volvo Prototype, Probably the Best Severity been Demonstrated for this file		
Medical and Police Report Using Cheap Crash Recorders if Available	$10 Per Report for Severity Plus $3-$10Per Report for all other information		
Computer Simulation (SMAC) (15-20 Vans)		$2 - $2.5 Million Annual Personnel Charge Plus $1.5-$2 Million First cost	

Table 4 - continued

DATA NEEDS / ALTERNATIVES AND COSTS	MASS ACCIDENT FILE	PRECISION CRASH DYNAMICS	SPECIAL STUDIES
Sophisticated Crash Records (10,000-20,000)		$2- $4 Million First costs Plus Annual Analysis & Maintenance costs of $0.5 - $1 Million	
Multidisciplinary Accident Investigation reams (MDAI)			1500 Reports/year At $2000 Per Report on Scene, $800 Per Report Off Scene
Fatal Accident Reporting System			55,000 Death Reports Per Year Contemplated At a Cost of $1 Million, Uncertain Severity Indica-tions
Level II Restraint System Investigation			Analysis of Restraint System Effectiveness From Police and Medical Reports, $100 Per Case
Field Trial of Uncertain and/or Expensive Safety Aids			100,000 - 200,000 Car Field Trial of Passive Restraints $30-$60 Million One Time Cost

Brake pressure (200-2000 psi, accuracy ± 7%

Steering wheel motion (1260°, accuracy ± 3%)

Speed (as derived from the speedometer cable)

     (o - 120 mph, speedometer accuracy)

Longitudinal and lateral vehicle acceleration

    $\pm$ 1 g, accuracy ± 5%

During the crash is recorded the time history of:

Longitudinal acceleration ($\pm$ 50 g, accuracy ± 3%)

Lateral acceleration ($\pm$ 50 g, accuracy ± 3%)

Vertical acceleration (in vehicle coordinates)

    (± 50 g, accuracy ± 3%)

Prior to the crash, the recorded data are sampled at a 20 per second rate. During the crash, the recorded data are sampled at a 200 per second rate. The duration of the tape record is from 6 minutes prior to the crash to 10 seconds after the crash. A garden variety endless-loop 8-track cartridge is used as the storage element.

Recording is done in digital (PCM) format. The total system includes each of the several sensors, a crush sensor and a recorder, packaged separately.

The other recorder, commonly known as the "disk recorder," was developed by Teledyne Geotek, Garland, Texas. It is a single unit that records, only during the crash interval, the time history of lateral, longitudinal accelerations. The range of accelerations measured is $\pm$ 50 g, with an accuracy of ± 8%.

The disk recorder is much simpler and less expensive than the tape recorder, and has been purchased and installed in experimental quantities by NHTSA. 1050 have been installed in fleets throughout the country, including air bag equipped cars.

The tape recorder is intended to provide data that could give useful information on the handling, braking, speed and forces experienced by the vehicle prior to the crash. Both recorders provide a crash-acceleration time history, which yields information on the forces to which the vehicle was subjected during the crash, and which, if properly interpreted, can give magnitude and direction of crash severity.

In Fiscal Year 1975 testimony, a total cost estimate of $10 million for a crash recorder program was presented. This program would have procured 100,000 disk recorders as compared to the previous 85,000 disk recorders (at $75 per unit) and 15,000 of the more expensive tape recorders for a total cost of $15 million. The program costs include support for initial purchase and funds allocated for analysis of the data provided by the recorders.

The Transportation Systems Center of the Department of Transportation (Mr. Louis Roberts) has examined the feasibility of a somewhat cheaper, all solid state, more accurate alternative to the Teledyne Geotek disk recorder, and have concluded that such a unit could be built at a unit cost of $125 in quantities of 100,000. With this recorder, three-axis accelerations would be measured to 1%.

C. Y. Warner and Joseph Free of Brigham Young University,
and Brian Wilcox and Donald Friedman of Minicars, Inc.* have
proposed as a severity measuring device a very simple two-axis
integrating accelerometer whose outputs are change in velocity
during the crash interval. The Breed Corporation is also
developing two cheap crash recorders. One will provide information
indicating that the crash resulted in a velocity change of more
than 30 mph. This is accomplished by a latching system. The
other system provides a direct reading of crash severity. A
combination of Coulomb and viscous forces acting on a mass provide
a system that is insensitive below a threshold, responds to the
vehicle change in velocity during the crash, and latches after
the crash indicating the change in velocity experienced.

We believe that development of a cheap and simple severity
measuring and recording device is highly desirable. There
appear to be many feasible design alternatives to the Warner
device, and they should be examined. A recorder that is
designed to measure average acceleration during the crash
interval, as opposed to velocity change alone, should be
considered. Lynn Bradford, NHTSA crash recorder program manager,
concurs that only the two horizontal components of acceleration
need be sensed, and that the third axis can be omitted.

5.   FEDERAL RESPONSIBILITY AND EXPENDITURES FOR COLLISION DATA
     GATHERING

     The Federal Government through the Department of
Transportation, has undertaken the responsibility for setting
safety and damage-limiting standards for motor vehicles.   The
costs of standards put into effect thus far is more than $2.5
billion annually.   It would appear that prudent   and respon-
sible rulemaking would imply that each such standard should be
promulgated only after acquiring through data collection and
large scale experiment a thorough understanding of the frequency
of occurrence of the hazards to which the standard was addressed,
the extent to which a design to the standard would mitigate the
outcome in terms of damage or injury,   and the   consequent benefits
as related to the estimated costs.   But because of the dearth of
data, rulemaking has been based instead on guesswork and judgment.
Fortunately, two standards (energy absorbing steering column and
belt restraints) appear on the basis of limited evidence to be
highly successful.   TWO others, HPR glass and head restraints,
appear to be beneficial;   but the others remain to be evaluated,
and in the meantime, their costs continue to be borne by the public.

     Motor vehicle collision loss is an enormous national problem
that requires centrally coordinated solutions, both in terms of
motor vehicle standards and highway designs.   Implicit are both
the need and the responsibility for centrally supported collection
of collision data, representative of all the States, from which may
be drawn inferences regarding the need for and benefit of vehicle
and highway design changes.   The establishing of a central collision
data file further implies a need and responsibility for standard-
ization of reporting systems and formats so that input data from

many sources can be combined.   The federal government should
undertake these responsibilities as the central and coordinating
activity for collection of crash data.

In addition to the question of responsibility, there is the
question of capability.   On this question, John Versace of Ford
Motor Company[16]/ has the following comment.

> "Mass accident data acquisition, processing, analysis,
> and broad scale distribution requires great effort and
> much resource.   Only the federal government has the
> necessary resource and easy access to the agencies which
> can supply information.   Furthermore, it seems that it is
> the responsibility of the federal government to assemble
> data which will allow an accurate public review of the
> real dimensions of the crash and injury problem on our
> highways."

The current level of Federal expenditure for the collection
and analysis of automobile collision data is $5-6 million yearly.
A few examples will be presented to illustrate that the justifiable
levels of expenditure may be much higher than the current amounts.

1.   Each traffic fatality is a catastrophe that costs society
     approximately $200,000.[2]/ current Federal expenditures 'or
     collision data gathering average less than 0.06% of the cost
     of traffic deaths.

2.   28 million automobile accidents cost the United States
     $22 billion annually.   Federal expenditures to collect data
     average less than 22¢ per accident-involved automobile, and less
     than 0.03 % of total losses (see Figure 1).

INJURY

$7 BILLION

DEATH

$10 BILLION

PROPERTY DAMAGE
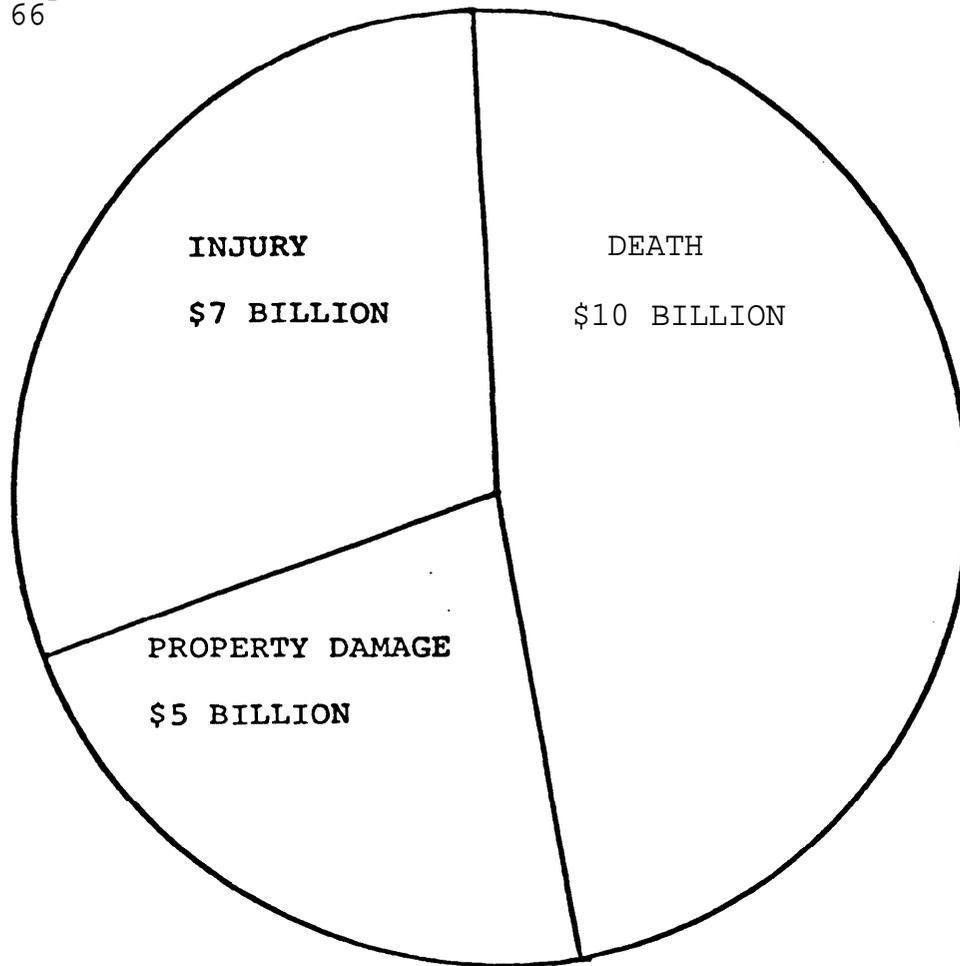
$5 BILLION

ANNUAL COST OF MOTOR VEHICLE ACCIDENTS

●

$6 Million

NHTSA EXPENDITURES ON CRASH DATA COLLECTION

FIGURE 1.   Comparison of the cost of motor vehicle
            accidents with Federal expenditures to
            acquire and analyze crash data.

3. The cost of 5 mph no-damage bumpers front and rear has
    been estimated as $119 per car (first cost) plus about
    $100 in added lifetime fuel costs. The total consumer
    expenditure required to equip all cars is about $2.2
    billion per year. Because of the paucity of hard statistics
    or the frequency distribution and cost of low-severity
    accidents whose damage the bumpers tend to mitigate, there
    is an uncertainty of at least 10% or about $200 million,
    in the estimate of the benefits; this uncertainty alone
    is more than 30 times the current Federal data collection
    expenditures.

4. Continuing uncertainties about the effectiveness of
    seat belts lead to differences in estimates of numbers of
    lives saved (at 50% belt usage) of at least 8000 annually
    representing a societal gain or loss of $1.6 billion. This
    uncertainty is more than 250 times the current Federal
    expenditures on data collection and analysis.

    Thus high levels of expenditure appear justified by the
magnitude of the motor vehicle collision loss program and its
uncertainties. They are not necessarily required to do the
job. The actual amounts needed must be determined after the
development of a comprehensive plan that specifies in detail
the information needed, the quantities of data and rates at
which it is to be gathered, and how the plan is to be implemented.

    The benefits of a data collection and analysis effort can be
easily seen when it is used to resolve a choice between two approaches
to solving a problem. The benefits are less obvious, just as in any
research effort, when the outcome is unpredictable in terms of
establishing the measures and costs of reducing damage, injury and
death.

6.   LEGAL ASPECTS OF CRASH RECORDERS

     Questions that are often brought up with regard to automobile
crash recorders are (1) whether crash recorder evidence is admins-
sible in a court of law;   (2) should it be admitted?;   (3) can it
be prevented from being admitted?

     There is a useful parallel in the inflight recorders installed
in commercial airplanes. In the event of a crash, the data in
these recorders is read out and interpreted by the Federal Aviation
Administration or National Transportation Safety Board staff
personnel. Section 701 (e) of the Federal Aviation Act forbids the
use of the NTSB report in any suit or action for damages arising
out of an accident. The original policy considerations were that
if such possibly legally damaging reports could be used in court,
it would inhibit possible sources of information important to the
cause of NTSB in promoting safety. But it is possible to get the
FAA or NTSB staff member who read out the recorder to testify
as to the facts and thus the "facts", data read or heard from the
recorders can be received as evidence toward the proof or defense
of an allegation of negligence. Neither the airlines nor the
government has any privilege to exclude or restrict such evidence.*

     Similarly one could expect that automobile crash recorder data
could be admitted in evidence in a court of law; but there would be
the usual problem of qualifying the evidence. In the absence of
a stipulation of the opposing party as to the authenticity of the
data and the reliability and accuracy of the recorder, the moving
party would successfully have to demonstrate to the court the
reliability and accuracy of the recorder and the expertise of the
person who read out the data.

----

*   From a private legal opinion.

On the question of whether crash recorder data should be
admitted, the main point again is whether the recorder is reliable,
accurate, properly read out, and provides a record of the particu-
lar event in question. The data of itself is not dispositive of
liability, but merely serves as certain evidence of the event. As
indicated earlier in this report, there is good correlation between
the crash severity a recorder might measure and the extent of crash
deformation to the vehicle in which it is installed; and it would
be difficult to refuse evidence on the crash severity magnitude as
interpreted from vehicle deformation. Thus if the recorder provides
good evidence of the event, it seems appropriate that that evidence
should be admitted.

It may be possible to restrict through legislation the
admissibility of crash recorder evidence, particularly if the
recorders are government-owned and the records are retrieved and
interpreted by government employees. Consider, however, the
objective of a very simple and widely used integrating accelerometer
that is conveniently and reasily read by any police accident
investigator without special training. It would appear difficult to
prevent testimony by a layman -- say a tow-truck operator or an
auto mechanic -- as to what he saw immediately after the accident.

In summary, we believe that (1) the data from a crash recorder
would be admissible, if it meets necessary qualifications, in a court
of law; (2) the data should be admitted if it is good evidence;
 (3) it will be difficult to prevent admitting crash recorder data,
even by Federal law, if the record can be easily read by an untrained
person.

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OFFICE OF TECHNOLOGY ASSESSMENT

Automobile Collision Data

AN ASSESSMENT OF NEEDS AND METHODS OF ACQUISITION

FEBRUARY 17, 1975

PREPARED **AT THE REQUEST OF**

THE HOUSE COMMITTEE ON APPROPRIATIONS

VOLUME II

APPENDICES

APPENDIX A

MORE SOPHISTICATED DATA COLLECTIONS
FOR
AN IMPROVED ACCIDENT DATA SYSTEM

Edwin A. Kidd
CALSPAN CORPORATION

January 27, 1975

MORE SOPHISTICATED DATA COLLECTION FOR AN
IMPROVED ACCIDENT DATA SYSTEM

EDWIN A. KIDD
CALSPAN CORPORATION

January 27, 1975

<u>NEED</u>

It is essential that NHTSA have a national data bank for
surveillance and effectiveness studies related to the impact of standards
on accident, injury and fatality frequencies. The relatively small output
of the special federal teams and/or the higher quantity, but low content
state data banks are inadequate for the purpose. In addition to information
on the general accident environment, vehicle damage and occupant injuries,
details of the impact environmmt -- velocity at impact, change in velocity
during impact and possibly, vehicle deceleration -- are required for a
sample Of 100,000 to 500,000 automobiles annually.

CANDIDATE SYSTEMS

Candidate systems for achieving the required information are:

- Crash recorders, with accident, vehicle and occupant information supplied by "conventional" investigations by police and/or special teams.

- Off-scene computer reconstruction of accidents as reported by police and/or special teams.

- Computer aided investigation and reconstruction of accidents (e.g., SMAC) using appropriately equipped police and/or special teams.

Use of crash recorders alone to provide data on the impact environment for the required number of accident cases would be prohibitive in cost. For example, if accidents of tow-away severity or higher are of principal interest, then 30-40 times as many automobiles must be equipped with crash recorders as the number of accidents needed annually for analysis*. Also, and most important, the crash recorder only provides a portion of the data required; conventional investigative methods must still supply accident and vehicle descriptions, vehicle deformation, occupant injuries, restraint system use, etc.

_____

* Additional cost for each accident case would be 30-40 times the cost of each crash recorder installation.

-3-

Off-scene computer reconstruction (SMAC) of the more extensively reported accidents now resulting from the special team studies has already been demonstrated. A modest amount of additional work on SMAC is required to increase the generality of the reconstruction of the various accident types. Also, application of this reconstruction aid to accidents as presently reported by police should be studied with the objective of determining the minimum information required for each accident.

The computer aided investigation and reconstruction of accidents by police offers the most promise for the attainment of the large data base required. If the use of appropriately equipped accident investigation vans is determined by individual police agencies to be beneficial for their present activities, in terms of overall efficiency, then the mechanism for providing all of the necessary accident data for NHTSA will be accomplished. Providing the police with equipment that will be cost/beneficial for their present needs will obviously provide the means for the attainment of the data required by NHTSA at the lowest cost. Also, the digital format of the accident descriptions and reconstructions that would be output from this equipment would result in minimal data processing for a fast response data bank.

RECOMMENDED APPROACH

The overall objective is the attainment of a consistent, coherent data bank that will be adequate both in size and specific content for the purpose and is practical in terms of development time and cost.

Whether police or special teams are used as the basic collection agency need not be decided immediately. What should be decided as soon as possible is the efficacy of the computer aids to reconstruction and

investigation that have already been developed. The crash recorder may play a role in further validating these aids; it cannot be seriously considered as the ultimate data collection method because of prohibitive cost. A decision to continue with special teams should include the provision of demonstrated aids for these teams. If police want these aids and their efforts can be integrated into a national data system, then it appears axiomatic that a police based system would provide the most for the least cost.

A program is outlined below for achieving the improved accident data system:

1.)   Install crash recorders in special automobiles, e.g., air bag equipped vehicles, for additional validation of computer reconstruction aids.

2.)   Accident Reconstruction

a.)   Continue validation of SMAC via staged crashes (including crash recorders) for a broad accident spectrum.

b.)   Determine accuracy achievable on police reported accidents and establish minimum data requirements as function of accuracy achievable.

3.)   On-Scene Reconstructions

a.)   Accident vans for special investigative teams to improve data consistency and achieve more accurate reconstructions.

        b.)   Field trials with police agencies to
determine accident reporting and/or accident
reconstruction configurations.

4.)   As the result of 1, 2, and 3 (above), establish
national data collection system elements.

TIMING AND APPROXIMATE COST

Aggressive pursuit of this plan would provide detailed requirements and set up of the overall system within two years. Meanwhile, the present multilevel data collection centers would continue to provide data, but with a transition toward the final system in the second year.

An acceptable, complete data system could be achieved at a cost of five to ten million dollars annually. Actual costs to NHTSA are dependent upon the usefulness and acceptability of the investigation and reconstruction aids to selected police agencies and their subsequent integration into the system.

APPENDIX B

LETTER FROM JOHN VERSACE
FORD MOTOR COMPANY

February 6, 1975

Ford Motor Company

20000 Rotunda Drive
Dearborn, Michigan 48121 :
Mailing Address:
P.O. Box 2053
Dearborn, Michigan 48121

February 6, 1975

Mr. Howard P. Gates, Jr.
Economics & Science Planning
1200 18th Street, N.W.
Washington, D.C.   20036

Subject: OTA Automobile Collision Data Workshop

Dear Howard:

It did take some time in a very busy schedule to meet
with you and to put our thoughts down, but we appreciate the
opportunity to express our understanding of, and our position on
the subject of accident data.   In regard to societal costs: the
Ford Motor Company submission to Docket 74-15 -- Advance Notice
Concerning Higher Speed Protection Requirements -- contains some
estimates of the additional consumption of resources entailed in
trying to meet a high speed requirement.

It is difficult to determine all the ways in which
inadequate accident data would lead to unnecessary expansion of
costs, but we believe this one example will provide a general
picture of the possible magnitude of such expense.   I don't be-
lieve we conclude that raising the crash requirements is the
wrong thing to do, but rather because the cost implications are
so great nothing less than a commensurately significant analysis
and determination of need -- which has not been done -- should
precede any decision.

It is easy to lose sight of the fact that a good
 intention, or want, or objective gets converted, by means of a
regulation, into very specific operational requirements and
specifications which the manufacturer must meet, specifications
which may have little to do in the last analysis with the inten-
tions of the regulation. However, the regulation, in its specific
detail, is often defended on the basis of its motivation rather
than on what the particular requirements of the regulation are

likely to actually accomplish. Specifically, in this case, if it
is deemed desirable to provide better protection for those people
who are in high speed crashes, then it may or may not follow that
running an automobile into an immovable wall at 45 or 50 mph, and
then comparing readings gotten on accelerometer in dummies against
some mandated criterion level somehow validly signifies accomplish-
ment of the societal goal which motivated the standard. The like-
lihood of gross erosion of relevance is probably nowhere better
seen than in the accident avoidance series of standards, where
little or no validation has been attempted.

A contrary argument is likely to be heard: that the
need is so great we cannot wait for all the evidence to be in,
that utterly adequate evidence will never be forthcoming, and
thus we must act now. But such an argument seems to beg the
question: for how can we know we must act now -- especially
with some particular countermeasure -- if that determination de-
pends on having adequate data? A variant on this argument is that
it can do no harm and might do some good. But, without data there
is no assurance that particular countermeasures will do no harm,
and certainly a cost without a compensating benefit is a net harm.

I am attaching a COPY of the Ford docket submission on
the higher speed protection requirements proposal, but you will
probably want to give special attention to the brief summary,
"societal Cost Implications of Inadequate Accident Data," which
puts forth the main points made there.

In addition, I am attaching an updated copy of the
remarks which I made at the Workshop. They are essentially the
same as the statement I read, but there have been some additional
clarifications which I felt were appropriate in view of the dis-
cussions which took place at the meeting.

Sincerely,

John Versace

John Versace
Executive Engineer
Safety Research

Attachments

The demonstration of need for any safety standard must ultimately be established by accident data -- in all its forms -- if objective safety standard performance levels are to be achieved. If standard performance levels are established on a subjective basis, the possibility of very high societal cost with inadequate return for that cost is very real.

As an example of proposed performance levels which could have severe societal cost implications consider NHTSA's Advanced Notice of Proposed Rulemaking (ANPRM), Docket 74-15 Notice 1. This ANPRM proposes to increase frontal barrier crash requirements from 30 mph to 45/50 mph -- an <u>increase</u> in crash energy management requirements of 125 to 177% <u>above</u> that required today.   The notice also proposes to implement the rule on September 30, 1980.

Ford Motor Company's response to this notice is attached. It presents the implications of implementing such a proposal in terms of increased car weight and car length. For example, to meet the frontal crash requirement alone, a 1974 Ford would be 500 pounds heavier and 16 inches longer; a 1974 Pinto would be 600 pounds heavier and 37 inches longer. Additional weight would be required to meet side and rear impact, roof crush, and fuel system crash requirements currently in being or presently proposed in other standards.

Weight increases of the magnitude discussed above imply completely re-designed cars -- not modifications to on-going designs. In addition to new metal structures, the added weight would require higher performance powertrain and running gear (brakes, suspensions> steering systems, etc.. . . .) which in turn would tend to weigh more. Ford Motor Company markets 16 domestically manufactured car lines built from eight separate body shell platforms. To completely redesign these platforms would involve staggering engineering and investment costs. Annual increased car purchase costs to consumers -- assuming such a gigantic task could be done at all -- would be on the order of billions of dollars annually.

Such a major weight increase in cars would have a two-fold effect on the consumption of energy. The fuel economy of vehicles would deteriorate and secondly, additional energy would be used to manufacture the added weight.

Fuel economy may be expected to decrease from the current average of 13.6 miles per gallon by about 10%. This represents an increase in fuel usage of 25 million barrels each year. Should this weight increase be applied to the entire vehicle population, the annual fuel economy penalty would be nearly 200 million barrels. In ten years gasoline purchase costs would be on the order of $5 billion more per year than 1975.

Adding this weight to 10 million new cars each year would increase manufactured material requirements by about 3 million tons annually. The gross effect of the vehicle weight increases would be to increase the demand for finished steel, steel castings and rubber for the auto industry by about 20%. The energy consumption for manufacturing this added material weight in 10 million new cars each year would approximate 130 trillion B.T.U's.

If all the cars on the road were at the higher weight levels, the total annual cost increase to consumers would be the sum of the annual cost of the decreased fuel economy (projected at $5 billion), PIUS the higher costs and energy associated with manufacturing the heavier vehicles (projected to be billions of dollars annually). This sustained annual societal cost impact could take place because of a regulation whose need has not been definitely or definitively established.

February, 1975

Ford Motor Company

The American Road
Dearborn, Michigan 48121

September 19, 1974

National Highway Traffic
    Safety Administration
Docket Section -- Room 5108
400 Seventh Street, S. W.
Washington, D. C.   20590

Gentlemen:

      Re: Advance Notice Concerning Higher Speed
            Protection Requirements (Docket 74-15:
            Notice 1)

      Enclosed are Ford Motor Company's comments on the
Administration's advance notice of proposed rulemaking to
increase the frontal barrier crash requirements of Federal
Motor Vehicle Safety Standard No. 208, Occupant Crash pro-
tection, to 45 or 50 mph effective September, 1980. Ford
has also participated in the preparation of comments being
submitted by the Motor Vehicle Manufacturers Association
and respectfully requests that those comments be incorporated
herein by reference.

      The comments address the several areas of interest
cited by the Administrator in the subject advanced notice of
proposed rulemaking. It is appropriate, however, to high-
light certain salient points on which the comments expand.

      There is the apparent assumption that a 'manifold
increase in lifesaving capability of occupant crash pro-
tection systems" can be demonstrated merely by increasing
the velocity at which a test vehicle impacts a fixed barrier
and having the recorded test results satisfy essentially
arbitrary criteria.

As the Administration well knows, there are many
unsettled questions and unresolved issues with regard to
Standard 208 including the correlation of test device
responses to those of humans, the subjectivity of test
procedure, the questionable appropriateness of the criteria,
etc. Barrier crash tests are not representative of actual
traffic accidents. Meeting some requirement using a test
device having a superficial resemblance to a 50th percentile
male adult positioned in a normal seated position is no
guarantee that human occupants will survive in actual col-
lisions of apparent equivalent severity.

Despite the uncertainty associated with Standard
No. 208, in an effort to aid the Administration in defining
the potential effects of adopting requirements such as those
in this proposal, Ford has conducted a theoretical study
related only to front end impacts using a Simplified model
and idealized assumptions as to restraint systems, structure
behavior, etc. That study, as explained in the attached
comments, convinces us that the results of the Administra-
tion's proposal would be to increase the weight of a vehicle
with a Pinto size passenger compartment by about 600 pounds
and that of a Ford size vehicle by between 500 and 900
pounds for a 50 mph barrier impact speed. Length increases
of as much as 37 inches for the Pinto and 16 inches for the
Ford would be required. Specific modifications would be
dependent upon restraint systems parameters that are yet
undeveloped.

It is obvious that vehicle weight increases of
this magnitude will have a pronounced effect on vehicle
cost. The engineering and investment costs necessary for
major redesigns of all existing cars in a short time period
of a few years might best be described as staggering. Based
on our analysis to date, Ford would not be able to meet the
proposed effective date of September, 1980.

These weight and length increase estimates are
based on a simplified, idealized analytical study and we
consider them the minimum changes required, if only the
requirement for front end impact speed was increased. It
is significant that these results are not greatly dissimilar
to those that could be derived from an analysis of the
vehicle designed and built under the Experimental Safety
Vehicle programs. It is also significant to note that
none of the full sized Experimental Safety Vehicles were
successful in meeting the requirements during a 50 mile per
hour barrier crash despite, in some cases, the somewhat
exotic designs employed.

Ford believes that the increased speed requirement with its attendant cost and weight increases cannot be justified without an analysis of highway accident data showing that a safety need exists for the proposed increase. The accident impact speed data currently available with which to perform a benefit analysis of higher speed requirements are dependent on subjective human evaluation. Speed estimates in existing data files are thought to be unreliable because they are formed by witnesses or by accident investigators having varying degrees of experience.

The lack of a sound data base with which to evaluate the need for higher speed performance requirements further underscores the need for a large scale crash recorder program to evaluate the actual crash dynamics. The initial results of crash recorder analyses have indicated that impact speeds estimated by police and accident investigation teams are consistently higher than the speed change noted by the recorder.

Ford is currently engaged in a research project under DOT contract to define the performance parameters of a **3000** pound safety vehicle which will be practicable to manufacture in the mid 1980's. We believe this research will be of value in evaluating future motor vehicle safety needs in the area of higher speed protection. This project is scheduled for completion in April, 1975.

We, therefore, recommend that NHTSA's efforts in the area of higher speed occupant crash protection be concentrated on developing an accurate data base from which the Administration can determine, on an informed basis, the safety need, if any, for a barrier crash test and identify appropriate and practicable test speeds.

At the present time we can only conclude that adopting the proposal advanced in this notice would have the certain effect of increasing weight and vehicle size (with the attendant adverse effects on fuel and material consumption) and consumer cost. The amount of benefit to be gained is only speculative.

If we can be of further assistance in explaining our position, we will be available at the Administration's convenience.

"Respectfully submitted,

J. C. Eckhold
Director
Automotive Safety Office

bgw

Attachments

HIGHER SPEED PROTECTION REQUIREMENTS
DOCKET 74-15; NOTICE 1

COMMENTS OF FORD MOTOR COMPANY

Ford Motor Company, with Offices at The American Road, Dearborn, Michigan 48121, as a manufacturers of motor vehicles, is commenting on the Advance Notice of Proposed Rulemaking concerning Higher Speed Protection Requirements published in the Federal Register on March 19, 1974 (39 Fed. Reg. 10273).

The Notice states that the Administration is considering amending Federal Motor Vehicle Safety Standard No. 208 (FMVSS 208) to include a 45 or 50 mph frontal crash requirement with a suggested effective date of Septmber 1, 1980.

In our evaluation of the Administration% proposal, we found we were impaled by the lack of adequate factual information. Analysis of the available accident data lead us to the conclusion that such data are not sufficiently reliable to assess safety need.

Review of the public record on FMVSS 208 did not disclose the existence of technology which would show that a practicable vehicle could be designed to meet the frontal impact requirements of that Standard at 50 mph. The domestic ESV's, including the one built by Ford, represent the most comprehensive attempts to comply with such a requirement and all of them failed in that endeavor.

Nonetheless, we have gained some insight into the problem and have prepared the following comments based in part on engineering judgment, relying heavily upon theoretical studies.

Technology

The Administration states in the Notice that based on research which is extensively documented in the Docket on FMVSS 208, it is of the opinion that technology has advanced to the point where protection can be offered in crashes equivalent to those into a fixed barrier at more than 40 mph. We have examined the public record concerning FMVSS 208 and have found no evidence that the Administration has ever conducted the complete test series required by FMVSS 208 even at 30 mph, much less at 45 or 50 mph.

Technogy (Cont'd)

None of the domestic experimental safety vehicles
built under DOT contracts met the performance requirements
of FMVSS 208 at 50 mph. These vehicles exceeded the 4000
pound weight objective by between 1000 and 2000 pounds. One
such vehicle even used unconventional lightweight materials
in an effort to minimize weights. These materials are gen-
erally impractical for high volume automotive use because
of supply limitations, high cost and lack of adequate manu-
facturing technology.

More recent higher speed research by NHTSA con-
tractors has concentrated on maintaining passenger compart-
ment integrity independent of programs to develop restraint
systems* Advanced structures have not been evaluated in
combination with advanced restraint systems in a 50 mph
fixed barrier impact test series which would otherwise
conform to FMVSS 208 although the intent to do so has been
expressed in requests for contract proposals issued by NHTSA.

This was noted by Dr. Patrick Miller of Calspan
Corporation in his statement before the Senate Commerce
 committee on February 21, 1974. He stated that "although
impressive structural performance has been demonstrated
during frontal collisions, we have not yet developed restraint
systems which could take advantage of these advances".

Another problem which has not been adequately con-
sidered is the possibility of adverse consequences on occu-
pants of vehicles designed for a 50 mph barrier impact when
they are involved in lower speed impacts. The possibility
exists that due to increase in vehicle stiffness the injury
level in low speed collisions will Become worse.

Many of the crash tests have been conducted at
test weights substantially less than that required by FMVSS
208. Under DOT Contract HS-257-2-461, 'Frontal and Side
Impact Crashworthiness-Compact Cars" the contractor con-
ducted the crash test without any dummy occupants and with
the vehicle weight 700 pounds under that required by FMVSS
208. The effect of added weight is to place even greater
demands upon the vehicle structure and, thus, to produce
substantially different results.

Further, our review of structural integrity research
under NHTSA contracts indicates that these efforts have not
been directed toward designs which are practicable in high
volume production. The usefulness of the resultant designs
for commercial marketing has been inadequate in most cases.
For example, the domestic ESV's were five passenger sedans
with the occupants tightly packaged while the exterior

Technology (Cont'd)

dimensions were equivalent to current vehicles capable of
carrying six passengers. One NHTSA contractor raised the
body of a Pinto six inches higher off the ground and moved
the driver four inches into the rear passenger space.
(DOT Contract HS-113-3-746, "Crashworthiness of Subcompact
Vehicles")

We anticipate that the structural modifications
introduced to meet the 50 mph fixed barrier impact require-
ment would aggravate any existing car to car impact com-
patibility problems. The stiffer frontal *structure* and
greater mass would have an effect in frontal, rear and side
impacts.

Size and Weight Effects

There is only minimal data and limited experience
with vehicle designs needed to approach a 45 or 50 mph
fixed barrier frontal impact requirement. Therefore, we
have attempted to extrapolate data from existing cars to
determine the size and weight effects of the Administra-
tion's proposal. The results of Ford's and other domestic
ESV programs, along with additional Ford research, were
used even though the ESV's did not meet the occupant pro-
tection requirements of FMVSS 208 at 50 mph and exceeded
the vehicle weight objective by large margins.

The test data used as a basis for the engineering
assumptions and projections were gleaned from recorded
force and acceleration measurements upon various anthro-
pometric test devices. Though such data was found to lack
repeatability, it nevertheless was averaged and used for
directional guidance.

Simplified analytical techniques were used along
with assumed performance parameters for advanced restraint
systems to derive an estimate of the size and weight
increases necessary to meet the proposal.

For purposes of this analysis, the parameters for
an advanced air bag system and an advanced belt restraint
system were hypothesized to represent restraint systems
which are not currently available but which may be possible
by September, 1980.

The results of numerous barrier crash tests were
examined to evaluate the performance of various experimental
and production belt and air bag restraint systems. Values
for effectiveness time, rate of deceleration onset, and
equivalent uniform deceleration or "square wave" decelera-
tion were then determined. The key criterion was the 60 g
deceleration limit of FMVSS 208. We concluded that for an

Size and Weight Effects (Cont'd)

advanced belt restraint system, a deceleration curve with
an effectiveness time of 20 milliseconds, a uniform onset
rate of 1200 g/see, and a constant deceleration of 40 g's
gave an idealized representation of the deceleration which
could be produced on the chest of an anthropometric test
device. For an air bag, the values of 40 milliseconds
effectiveness time, 1500 g/see and 48 g's were determined.
The deceleration levels represent the square wave that
would simulate the average of the peaks and valleys of a
dynamic curve in which the peaks would still remain under
the 60 g limit of FMVSS 208. Onset rates and effective-
ness times were chosen based on predicted future system
performance capabilities.

        The advanced belt system would include a crash
sensor and a preloader device and possibly a load limiting
webbing material. The advanced air bag system would require
developing improvement to present systems to achieve effec-
tiveness within 40 milliseconds.

        The restraint system parameters were used with a
simple mathematical model consisting of two point masses
representing vehicle and occupant. Idealized occupant
stopping distances were determined and then compared with
the available vehicle crush and interior occupant space.
The vehicle deceleration necessary to produce the assumed
occupant deceleration was also computed.

        The output of the simple mathematical m-cl thus
gives an indication of the amount that a vehicle must be
lengthened or stiffened to approach a 45 or 50 mph barrier
impact requirement. The length and stiffness increases
were used to determine weight effects using engineering
judgment based on Ford experimental results and ESV exper-
ience, and a review of the ESV's designed by others.

        One particular assumption included in the length
calculations is that 65% of the added length will actually
crush during impact. Deformed structure would occupy the
remaining 35% of space. The frontal area occupied by
relatively incompressible components such as the engine
are considered unavailable for vehicle crush. However,
the space occupied by the engine was also considered avail-
able for the deformed structure. For purposes of this
analysis, length added to the vehicle was considered
totally usable for computing crush distance up to the
point where the 65% efficiency level was reached. After
that point, 1.54 inches of vehicle length were added for
each inch of crush length needed.

Size and Weight Effects (Cont'd)

The resultant length increases, stiffness, and weights are shown in Fig. 1 for a vehicle with a Ford size passenger compartment and Fig. 2 for one with a Pinto size passenger compartment.

The Ford size car with an advanced air bag system intended to meet a 50 mph impact level would be over 16 inches longer and an estimated 530 pounds heavier than the current Ford. The same car with an advanced belt restraint would only be 2.4 inches longer than the 1974 model but would be nearly 900 pounds heavier.

The Pinto size car with an advanced air bag system intended to meet the same 50 mph requirement would become 37 inches longer and an estimated 600 pounds heavier than the 1974 version. Under the assumptions for the advanced belt restraint, the Pinto would be 18 inches longer and 630 pounds heavier than the existing car.

Front end structural stiffness would have to be increased substantially for both cars with either restraint system.

Lesser, although dramatic, weight increases would result on both Ford and Pinto size vehicles as shown in Figures 1 and 2 if a 45 mph barrier impact goal were established.

These weight increases are estimates for meeting only frontal impact requirements. No provision has been made in this estimate for increased side, rear and roof structure which we anticipate would be necessary to meet the existing levels of such Standards as FMVSS 214, Side Door Strength, FMVSS 216, Roof Crush Resistance and FMVSS 301, Fuel System Integrity. Structual modifications would be necessary to withstand the increased static or dynamic test loads imposed as a result of the weight added to the vehicle to meet the increased frontal impact speed. The weight increase resulting from these side, rear and roof structural modifications would cause further changes to be made in the frontal structure to meet frontal requirements. These effects would be more pronounced on small cars under 3500 pounds curb weight due to the provisions regarding curb weight in FMVSS 214 and FMVSS 216. Neither is there provision in these weight estimates for revision or deletion of any other standards.

Size and Weight Effects (Cont'd)

The weight and length additions shown in Figures 1 and 2 were derived, in part, using simplified analytical techniques which do not fully consider the dynamic interactions of vehicle structure, restraint system and test device. They represent minimum levels of vehicle modification which we believe would be necessary to approach the frontal impact performance levels of FMVSS 208 at 45 and 50 mph. Restraint system performance parameters were chosen which we believe are possible by 1980, but do not represent any system which we currently have available. Vehicle structures with the necessary frontal crush characteristics would have to be developed. Objective, repeatable conformance demonstration procedures for FMVSS 208 have yet to be developed. We therefore consider these estimated weight and length increases to be minimum levels.

The weight increase shown in Fig. 1 includes that due to structural additions to meet the higher barrier speed requirement plus added weight to upgrade such areas as engine, brakes, suspension and steering. Weight estimates for these other systems were determined by increasing their weight in proportion to the increase in structural weight. This was done by determining the portion of total vehicle weight due to the other systems for several large size vehicles as shown in Fig. 3. The portion of total weight contributed by each system was found to remain fairly constant. The increased weight of these systems was computed by an iterative process based on the added structure weight. This process would add weight to the various supporting systems for each pound of crashworthiness structure added. We realize that in a practical sense weight additions occur in discrete increments.

A similar analysis was conducted for smaller size vehicles to determine the weight additions for a Pinto. (See Fig. 4).

cost

We have not determined the cost effect of the proposal, but it is obvious that addition of this amount of weight will result in substantial vehicle cost increases. The engineering and investment cost to redesign all of our vehicles to attempt to meet a 45 or 50 mph requirement would be staggering.

Timing

The vehicle modifications required to meet a 45 or 50 mph barrier impact requirement are so extensive that we would be required to redesign all of our affected vehicles. After a final rule of this type is established, technology

Timing (Cont'd)

is available, and practicability is achieved, it would take
approximately three years to redesign and retool a single
car line family.

Ford normally cannot develop more than two totally
redesigned car line families in the same model year due to
manpower and facility limitations and available capacity
within the tooling industry. It would require a total of
four additional years to introduce new designs of all exist-
ing passenger car models. However, Ford has never before
undertaken a task of this magnitude. Even this cycle is
optimistic as it is unlikely the tooling industry could con-
tain the magnitude of such programs if all domestic auto-
mobile manufacturers found it necessary to implement similar
redesigns.

On the basis of our analysis to date, we could not
meet a Septmber, 1980 effective date for all cars, even if
the means of meeting the proposed requirements were fully
developed. Due to the uncertainties that now exist, we
cannot determine whether or not we can meet this date even
on one car line.

A new car body and chassis design is produced for
a minimum of three years and in many instances can exist
for eight years before a major redesign. Therefore, the
redesign program that would be required by the proposal
would probably obsolete relatively new car lines before
the end of their normal cycle with additional cost conse-
quences.

The precise timing effects of the Administration's
proposal have not been determined. Small cars would cease to
exist as they are known today and large cars might well be-
come impracticable due to increased size. We do not know
what vehicle model mix the market would support if it is
artificially constrained by a requirement which has such
a pronounced effect on vehicle size.

Accident Data Analysis

Ford and others have previously noted the unreli-
able nature of reported accident speeds available for
analysis. The source of data errors and some of the
methods which have been used to adjust these data are
shown in Exhibit I. Recent crash recorder results have
confirmed that reported crash speeds are usually too high.

Accident Data Analysis (Cont'd)

Twenty accident cases involving vehicles equipped
with crash recorders were summarized in SAE Paper 740566 by
S. S. Teel et al[1] of the National Highway Traffic Safety
Administration (NHTSA). The results of an analysis compar-
ing each case vehicle's velocity change, as reported by the
police and/or an accident investigation team, are summar-
ized below. The impact speeds used in this analysis and
their differences are contained in Exhibit II.

The accident cases in Teel's paper which contained
the necessary information were used to construct a sample of
the population of differences between velocity "changes est-
mated by an accident investigator and the velocity change
experienced by the vehicle, as reflected by the crash re-
corder. The sample of 22 differences as tested for normal-
ity using the Kolmogorov-Smirnov test[2] and the hypothesis
that the population of impact velocity change differences
is normally distributed could not be rejected. Although our
sample of accident cases is small, it indicates that the
distribution of the difference in estimates is a bell-shaped
curve centered at 14 mph (the sample mean) with an estimated
standard deviation of 11.9 mph. Using these figures, we
are 95% confident that ten percent of the reported impact
speeds overestimate the true change in velocity by at least
35 mph while one-quarter of them overestimate the true
change in velocity by at least 25 mph.

An interval which contains the true mean differe-
nce between the estimated and the recorded velocity change
of a vehicle in an accident, with 99% confidence, was con-
structed using the Students-t distribution. This interval,
7.1 mph < Mean Difference < 21.4 mph, indicates that, on
the average, accident investigators can be expected to over-
estimate accident impact speeds by from 7 to 21 mph. Our

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1 Teel, S. S., Pierce, S. J., and Lutkefedder, N. W.,
    "Automotive Recorder Research --A Summary of
    Accident Data and Test Results", SAE 740566, 3rd
    International Conference on Occupant Protection,
    July, 1974.

2 Lilliefors, H. W., "On the Kolmogorov-Smirnov Test
    for Normality with Mean and Variance Unknown",
    JASA, June, 1967.

Accident Data Analysis (Cont'd)

accident sample also indicates that impact speeds can be
overestimated by as much as 40 mph. These large over-
estimates do not depend on the magnitude of the crash
recorder velocity change.

          As an alternative statistical test, a non-
parametric test, the Wilcoxon Matched-Paris Signed-Ranks
Test, also indicates that estimated impact speeds from
accident investigators are positively biased. Based on
crash tests, Teel concludes that changes in velocity
reported by crash recorders are accurate to within ± 2 mph.
Therefore, as a conservative approach, the differences
between the estimated and the recorded changes in velo-
city in Exhibit II were reduced by 5 mpht ad the Wilcoxon
test was re-run to determine if the velocity differences
could be due to the crash recorder accuracy. The results
still indicate that impact speeds estimated by police and
accident investigators are too high.

          The lack of a sound data base with which to evalu-
ate the need for higher speed performance requirements
further underscores the need for a large scale crash
recorder program to evaluate actual crash dynamics.

EXHIBIT I
September 19, 1974

THE TREATMENT OF RECORDED IMPACT SPEEDS

- A Summary-

Methods which have been used to deal with reported impact speeds from the ACIR accident case file are summarized below.

A. Cooke, Conrad H., "Safety Benefits of The Occupant Crash Protection Standard", January, 1971.

Cooke reduced all reported traveling speeds by 10 mph to obtain his estimated impact ‘speeds.

B.   Mela, Donald F., "A Source of Substantial Error In Estimating The Distribution of Traveling Speed For Accident-Involved Vehicles .*O", DOT, Septmber 3, 1968.

Mr. Mela stated that, by using the estimated impact speeds to determine speed distributions, "the fraction of vehicles in the speed ranges 20-30 mph and 70-80 mph is overestimated by a factor of 3, and the fractions below 20 mph and above 80 mph are overestimated by a factor of 17". If this statement is true, then it suggests that some variable type of correction factor (and not a constant 10 mph as Cooke used) be applied to the estimated impact velocities in the ACIR file.

c. White, S. B., Nelson, C., "Some Effects of Measurement Errors in Estimating Involvement Rate as a Function of Deviation from Mean Traffic Speed", Journal of Safety Research, Volume 2, June, 1970.

White and Nelson show that even if errors in estimation are non-systematic, an overestimate of high-speed frequency would be found. That is because any error of measurement always serves to inflate the variance of the distribution of reported values, regardless of the nature of the data. Thus, reported variance (i.e., the mean-square deviation from the mean) is equal to the sum of "true)' variance and "error" variance. White and Nelson point this out, in suggesting that high speed estimates would tend to be exaggerated. They state that "errors in estimating speeds of accident-involved vehicles causes the

EXHIBIT I
Page 2
September 19, 1974

involvement rate, when plotted as a function
of the speed deviation, to be U-shaped --
overestimated for large derivations (from the
mean) and underestimated for small deviations".
White and Nelson refer to traveling, not impact,
speed, but the principle is the same in either
case.

D. Grush, E. S., Henson, S. E., and Ritterling,
    O. R., 'Restraint System Effectiveness",
    Report No. S-71-40, Ford Motor Company,
    September 21, 1971.

    In this report, ACIR impact speeds were con-
    verted to barrier-equivalent velocities. The
    following factors were considered in the con-
    version: the estimated relative closing speed;
    the weight differential; a center of gravity
    adjustment; and an accident location adjustment.
    A second method of obtaining the barrier-equiva-
    lent value for each accident-involved vehicle
    was based on photographs of the vehicle damage
    and the study showed that this latter method
    produces better results.

E. Mason, R. R., D. W. Whitcomb, "The Evaluation of
    Accident Impact Speed", CAL Report No. YB-3109-V-1,
    August, 1972.

    This report presents several formulas, one for
    each type of vehicle impact, which can be used
    to estimate a vehicle% impact speed. It pro-
    vides some insight into how Calspan may estimate
    impact speeds.

EXHIBIT II
September 19, 1974

IMPACT VELOCITY CHANGES

Recorder Number	Crash Recorder Velocity Change (mph)	Accident Investigator Estimated Velocity Change (mph)	Difference (mph)
1086	20	60 +	+ 40
485	15	50	+ 35
485	15	50 to 60	+ 35
642	10	30 ,	+ 20
322	5	25	+ 20
335	6	25 to 30	+ 19
641	13	30	+ 17
694	9	25	+ 16
596	10	25	+ 15
596	10	24 to 26	+ 15
596	10	25	+ 15
641	13	25 to 35	+ 12
642	10	22 to 25	+ 12
306	19	30	+ 11
463	19	30	+ 11
463	19	30	+ 11
485	15	25	+ 10
25	18	25 to 35	+ 7
352	15	22	+ 7
463	19	20	+ 1
94	11	5 to 8	− 6
352	15	5	− 10

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Reference: Teel, S. S., Place, S. J. and Lutkefedder, N. W., "Automotive Recorder Research -- A Summary of Accident Data and Test Results", SAE 740566, 3rd International Conference on Occupant Protection, July, 1974.

FORD

SUMMARY: LENGTH AND WEIGHT INCREMENTAL EFFECTS FOR FRONTAL IMPACT

SPEED	RESTRAINT SYSTEM TYPES	AVERAGE g's S.W.E. 2/	WHEELBASE LENGTH INCREASE 1/	VEHICLE WEIGHT Additions (LBS.)							TOTAL WEIGHT INCREASE	CURB WEIGHT (LBS	INCREMENT OVER BASE (%)	FMVSS 208 TEST WEIGHT (LBS)
				STRUCTURE	RESTRAINT SYSTEM	BUMPER SYSTEM	ENGINE SYSTEM	DRIVELINE SUSPENSION AND BRAKES	FUEL SYSTEM INCLUDING FUEL	STEERING SYSTEM				
30	Production	11.3	◁————————————————— Base ———————————————▷									4400	Base	5600
45	A	19.3	6.0	182	20	21	53	69	6	7	358	4759	8%	5958
45	B	22.5	0	283	20	31	81	104	9	10	538	4938	12%	6138
50	A	19.6	16.2	282	20	31	80	104	9	10	536	4936	12%	6136
50	B	26.0	2.4	483	20	52	134	172	14	17	892	5292	20%	6492

Restraint Type A: Air bag - 40 msec. effectiveness - 1500 g/ sec. onset - 48g max.

Restraint Type B: Seat belt with sensor and preloader - 20 msec. effectiveness - 1200 g/Sec. onset - 40g max.

1/ Square Wave Equivalent of vehicle deceleration pulse based on impact speed and total crush *distance*.

2/ Crush length increases in excess of 5 inches are adjusted by a 65% efficiency factor

Figure 1
September 19, 1974

SUMMAR EN TH AND WEIGHT NCREMENTAL   TS FO FRON AL MP

				VEHICLE WEIGHT ADDITIONS (LBS.)									
SPEED	RESTRAINT SYSTEM TYPE	AVERAGE g's S.W.E. 1/	LENGTH INCREASE 2/ 3/	STRUCTURE	RESTRAINT SYSTEM	BUMPER SYSTEM	ENGINE SYSTEM	DRIVELINE SUSPENSION AND BRAKES	FUEL SYSTEM INCLUDING FUEL	STEERING SYSTEM	TOTAL WEIGHT INCREASE	CURB WEIGHT (LBS.)	INCREMENT OVER BASE (%)	FMVSS 208 TEST WEIGHT (LBS.)
30	Production	14.4	◁———————————————— Base ————————————————▷									2457	Base	3300
45	A	18.4	23.5	188	20	23	57	83	8	7	386	2843	16%	3686
45	B	25.0	5.7	227	20	27	69	99	10	8	460	2917	19%	3760
50	A	18.9	37.2	305	20	36	89	130	13	10	603	3060	25%	3903
50	B	24.7	18.0	319	20	37	94	136	13	11	630	3087	26%	3930

Restraint Type A: Air bag - 40 msec. effectiveness - 1500 g/sec. onset - 48g max.

Restraint Type B: Seat belt with sensor and preloader - 20 msec. effectiveness - 1200 g/sec. onset - 40g max.

1/ Square Wave Equivalent of vehicle deceleration pulse based on impact speed and total crush distance.

2/ Crush length increases in excess of 5 inches are adjusted by a 65% efficiency factor

3/ 2.8 inches can be added to front overhang without wheelbase increase (19° minimum approach angle).
    (wheelbase increase is 2.8 inches less than length increase)

Figure 3

WEIGHT OF VARIOUS VEHICLE SYSTEMS
AS A PERCENTAGE OF TOTAL WEIGHT

	RSV*	TORINO	FORD	LINCOLN	AVERAGE
Curb Weight:	3000	4030	4398	5373 !	
Percentage of Curb Weight:					
Bumper Systems	6.0%	1 5.9%	5 4%	5 6%	5.8%
Engine	15. 6%	14. 2%	15. 8%	15 0%	15 .0%
Suspension Driveline Brakes	21. 3%	19.8%	18. 5%	17. 5%	19.3%
Fuel System:	To maintain the current Ford vehicle range fuel system weight should be increased at-the rate-of .01415 lb. per lb. of added vehicle weight. The fuel tank weight is approximately 17% of the total fuel system weight.				1.6%
Steering	2.0%	1.5%	2.3%	1.8%	1.9%
TOTAL:	**46.5%**	**43.0%**	**43.6%**	**41.5%**	**43.6%**

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*RSV figures are an average of 10 Unitized vehicles
 with curb weights from 2000 to 3300 lbs.

Figure 4

WEIGHT OF VARIOUS VEHICLE SYSTEMS
AS A PERCENTAGE OF TOTAL WEIGHT

	PINTO	MUSTANG	MAVERICK	GRANADA	AVERAGE
Curb Weight:	2457	2753	2831	331.9	
Percentage of Curb Weight:					
Bumpers	6.1%	N. A.	6.0%	5.7%	5.9%
Engine	14•0%	14.6%	14•9%	15•9%	14•9%
Suspension Driveline Brakes	21•3%	21•7%	22•1%	21•3%	21.6%
Fuel System:	To maintain the current Pinto vehicle range fuel system weight should be increased at the rate of .01415 lb. per lb. of added vehicle weight. The fuel tank weight is approximately 17% of the total fuel system weight.				2.0%
Steering	1.7%	1.5%	2.0%	1.7%	1.7%
TOTAL:	45.1%		47.0%	46.6%	46.1%

APPENDIX C

STATEMENT AT THE AUTOMOBILE COLLISION DATA WORKSHOP

B.J. Campbell
HIGHWAY SAFETY RESEARCH CENTER
University of North Carolina

January 17, 1975

STATEMENT BY B. J . CAMPBELL
University of North Carolina
Highway Safety Research Center

Presented at
Automobile Collision Data Workshop

Sponsored by
Economics & Science Planning

In acquiring automobile accident data several approaches are used in the U.S.: First, are intensively investigated accident crashes of which several thousand have been collected. The advantage of this approach is that the cases are extremely detailed with photographs and good injury data. The most important disadvantage is that by virtue of the changing sampling criteria and the small sample size, the ability to generalize these few cases to the population is restricted heavily.

I believe too much reliance has been made on this type of data for guiding NHTSA decisions. It leads one to situations in which too much is made of a small number of cases. For example, in interpreting the 35 or 40 crashes in which air bags are present some feel the crashes support air bags because relatively few moderate or serious injuries occur. However, what if these air bag cases were matched with several hundred cases in which no protective systems are used at all (i.e. no belt or bag)? What if one found pretty much the same proportion of injuries in both series? Wouldn't that suggest that 40 cases is just not enough?

Second is an approach called the tri-level system. There the samples are larger, but the negative aspect is that the reporting threshold is based on accident severity which results in eliminating certain cases in which safety belt and perhaps other safety device effectiveness is greatest.

Third, and at the other extreme from individual case studies is the attempt to use an entire state accident data system as the basis on which to do research and make decisions. The biggest advantage in this case is the perspective gained from very large sample sizes and the ability to partition and control the data. But on the negative side many such systems contain too few content variables of interest. The quality of reporting may be poor and the injury data is crude.

In my opinion a crucial need in the field of crash injury is the means to forge a meaningful link between laboratory test crash data and events as they occur in the field. Much can be gained from laboratory sled and full-scale crash tests involving dummies, Cadavers or even live subjects, and also much can be gained from the study of actual crashes on the highway. But each lacks a significant variable.

In the staged crashes in the laboratory, telemetric procedures are used for recording data and one can specify in considerable detail the physical system in which the crash occurs--the "g"-forces, the rate of onset, delta "v" etc. But when one is forced to use nonhuman subjects then one is left in the situation of knowing a great deal about the physics of the crash but knowing little of the actual injuries that might have occurred in such a crash. On the other hand, in real world automobile crashes one can learn about the actual outcomes in terms of survival and injuries, but the input variables mentioned before are unknown.

The need to link these two systems is apparent. Engineers who design protective systems need to know about stopping distances, forces, decelerations, etc. But knowing these things is of too little help unless one has a way to relate them to real world injuries. An

illustration of the need for this data link is the NHTSA analysis
conducted in connection with the air bag. This NHTSA analysis
initially indicated that lap and shoulder belts would only reduce
fatalities by 35-40 percent, and that lap belts alone would be of
almost no benefit at all in reducing injuries. These conclusions
were presumably based in large measure on results of crash tests
involving cadavers and dummies. The problem is that these conclu-
sions disagree sharply with studies of tens of thousands of crashes
that have occurred on the highways. Studies from all over the world
indicate that in actual crashes injuries <u>are</u> reduced by lap belts,
and that lives are saved, and that the degree of lifesaving is much
higher than 35 or 40 percent NHTSA has indicated.

It is the very occurrence of this type of disagreement that shows
that the analysis system in each sector (laboratory vs highway) by
itself is inadequate and that means must be found to bridge the gap.
The primary advantage of a crash recorder program would be a means to
forge this link between the two data systems. It would finally be
possible to gather data on a few thousand actual highway crashes in
which crash conditions, the decelerations, the forces, the amplitudes
and so forth would be knowable as well as the injury.

By using these several thousand crash recorded events as a cali-
bration standard it would be possible to work outward to the hundreds
of thousands of other actual crashes in which recorders weren't
available, and the thousands of lab tests in which recorders are
available but human injury is not.

It is not necessary to have an "infinite" number of crash recorders
in the field, only enough to validate other approaches. I personally

do not see the crash recorder program as an end in itself but one which would support and validate other types of crash studies.

My remarks do not suggest the level of detail needed from the crash recorder, but in any case, the program will be expensive. For six million dollars one could equip 100,000 cars with crash recorders that cost $60 each. It would also be possible to equip more cars with a simpler, less costly crash recorder.

It is for others to determine the needed complexity of the crash recorder. Perhaps it is not necessary to have a crash recorder that records force time histories in three dimensions. Maybe vertical accelerations can be sacrificed.

Perhaps it would also be useful to consider a "tri-level" crash recorder program; this could involve a modest number of cars equipped with a very complex recorder and a larger number of cars equipped with a simpler, less expensive recorder system.

As a prelude to the program it might be appropriate to have a research project to synthesize past laboratory crash data to try to agree what measure in the field is the one that would account for the most injury variance. Would it be impact speed, barrier equivalent velocity, delta "v" or what?

The crash recorder, of course, is not the only need in studying and understanding actual crashes. Much better and much larger collections of highway crash cases are also necessary. I stated my belief that too much reliance has been placed on the small number of intensively investigated crashes. This country needs a multi-state data collection program which would accumulate records on 600,000 to 1,000,000 accident-involved vehicles per year. This would require three to five states the size of North Carolina.

For a surprisingly small additional cost it would be possible to collect that many cases with reasonably good deformation data, an operationally defined injury scale, vehicle identification numbers, belt usage, and various file linkage numbers to cross-link accident data and driver history files, road data, etc. It is extremely important to have this quantity of data in order to get timely answers to questions.   If a safety device has gone astray or a dangerous car is coming onto the market--we need to know it soon--not after ten years.

I would be pleased at some future time to discuss some of the characteristics such a multi-state data system should have.