Compendium of Positive Perceptions

95% of the 12 million vehicles involved in motor vehicle crashes in 1997 were passenger cars or light trucks.

Photographer: Frank Staples

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Compendium of Negative Perceptions

Persons 16 to 20 years old had the highest fatality and injury rates per 100,000 population.

Photographer: Frank Staples

Concern	**Number**	**IV. Financial Issues**	**41**
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Positive Comments

49 states, plus the District of Columbia and Puerto Rico, have safety belt use laws.

Photographer: Frank Staples

Objective use of the data may improve vehicle systems.

Objective use of the data may improve highway systems.

The data may aid in regulatory initiatives.

The data may aid in alleged defect investigations.

The data may aid in litigation cases.

The data may help in initiatives to improve driver behavior.

The data may aid law enforcement efforts.

May increase driver awareness.

May help determine dangerous traffic areas.

May help engineers design a safer car.

May help gather statistics: seat belt usage, etc.

May lead to decreased vehicle prices.

May lead to decreased insurance rates.

May identify conditions and situations were additional safety devices could be used.

May provide information as to why some crashes are fatal and others are not.

May provide actual crash velocity data in real time conditions.

May reduce the amount of crash testing in labs.

May become so ordinary that owners/drivers will not know/care if it is present.

May help provide quicker emergency response time to crashes.

May provide better understanding as to how a driver responds to a crash.

May provide better understanding as to how occupants in various positions respond.

May provide a better picture of overall crash behavior.

May catch people who intentionally crash cars to collect insurance.

May determine the number of occupants within a vehicle and help cut-down on insurance fraud.

May provide critical information that will determine causes of injuries and fatalities.

Will allow us to better understand automobile crashes.

Will help to determine who was at fault in an accident.

Will make the insurance company's job easier.

Will increase the safety of cars to be built in the future.

Will most likely increase seat belt usage.

Seat belts will save lives if increasingly worn with a sensor.

The speed of the automobile at the time of the crash can be determined accurately, whereas before it could not.

We will have factual information instead of estimated data on police reports.

It may scare drivers resulting in safer driving knowing that they are being recorded.

Insurance reports should be more consistent.

Crashes without eyewitnesses will now have evidence.

Insurance fraud will be less frequent because all the facts of the accident will be on record.

Drivers may maintain safer speeds.

Data can distinguish between two parties that disagree on what really happened.

In crashes, the driver who was not at fault will receive justice, instead of being cheated.

Could help detect defective parts that cause crashes.

May assist doctors in understanding injuries.

May determine if the vehicle systems were all operating at the time of a crash.

Could better determine if the driver was operating the vehicle in a reckless manner.

Could tell if the road conditions were poor.

Make people more aware of their vehicle.

May lead to different occupant restraint systems.

May lead to improved air bag safety.

May determine if children were in-position or out-of-position.

May determine if children were in the front seat.

May help locate stolen vehicles.

May provide an accurate number of daily, weekly, monthly, and yearly crashes in specific locations.

May provide a more realistic number of crashes that actually occur and are not reported.

May be tied-into the defect/recall system of identifying unsafe products.

May help to reduce road rage behavior.

May aid in eliminating habitual drunk drivers from the highways.

May aid in school bus safety.

May provide time of crash.

May provide location of crash.

May provide seat belt usage.

May determine faulty systems.

May signal emergency response.

May cause the driver to drive more cautious and considerate.

May create new industries and jobs:

People to manufacture the box,

People to install the box,

People to inspect & maintain,

People to analyze the data,

People to use the data when designing future vehicles, making safety standards, etc.

Could aid a variety of medical personnel (doctors, EMT's) in determining injuries the occupants suffered.

The data could be used in your favor and help defend your interests.

Used on a select population of at-risk drivers...say teenagers...if so, it may cut-down on irresponsible driving and save precious lives.

Negative Comments

The majority of persons killed or injured in traffic crashes were drivers (64%), followed by passengers (32%), pedestrians (2%), and pedalcyclists (2%).

Photographer: Frank Staples

This technology would make it possible to place private vehicles under continuous surveillance.

This technology could eliminate what little informational and personal privacy remains.

Links to the Global Positioning System of satellites would make it possible to track the whereabouts of private vehicles at all times.

The cost of installing transportation recorders could increase automobile prices.

The complexity of these devices could increase repair and maintenance costs.

The data gathered could be misused by the government.

The data gathered could be misused by law enforcement.

The data gathered could be misused by insurance companies.

The data gathered could be misused in litigation, or could increase the overall quantity of insurance- and crash-related lawsuits.

The data gathered could be misused by automotive or archiving corporations, or in warranty- or drivers' license-related disputes.

The cost of deploying transportation recorders and other emerging technologies will increase the taxpayers' burden.

Personal identifiers could be compiled along with the non-personal data.

There are serious concerns regarding third-party access to the data.

There are serious concerns regarding the security of the data from unauthorized intrusion, access, corruption, or alteration.

There are serious concerns surrounding the proposed permanent archives of transportation recorder data, including:

The security of the archive from unauthorized intrusion and tampering;

The availability of the archive to third parties;

The availability of the archive to government or law enforcement agencies;

The extent and nature of the data to be archived;

The questionable need for such an archive in the first place.

The public is almost completely unaware of the existence and planned deployment of transportation recorder and related technologies.

The consumer has thus far been given no choice regarding the presence of transportation recorders in private vehicles.

There are serious concerns that no choice in this matter will ever be offered.

Transportation recorders and the data they gather could be used to infringe Constitutional rights, including:

First Amendment rights to freedom of religion, speech, and assembly could be abridged if government agencies have detailed knowledge of private vehicles' movements;

Fourth Amendment rights to freedom from unreasonable searches and seizures could be abridged if government and law enforcement have access to transportation recorder surveillance data;

Fifth Amendment rights to freedom from self-incrimination could be abridged by government or law enforcement access to transportation recorder data.

No technology is infallible. Concerns arising from this fact include:

The transportation recorder could malfunction or cease operating;

Electrical or other computer systems in the car could be damaged by such a malfunction;

The transportation recorder could be damaged or destroyed in a crash;

The transportation recorder could provide inaccurate or corrupted data.

There are serious concerns regarding the admissibility of transportation recorder data in litigation, especially in the case of malfunction, inaccurate data, or contradictory eyewitness accounts.

Different transportation recorder models could provide differing degrees of accuracy.

There are serious concerns arising from potential transportation recorder surveillance, including:

The feeling of "being watched" could cause a reluctance to use private vehicles;

The existence of such surveillance could infringe the right to personal autonomy.

The ownership of transportation recorder data, and the chain of custody for such data, is in question, especially regarding a fear that the consumer would be denied access to the data.

It is possible that a black market for falsified transportation recorder data could appear.

Emergency calls relating to minor crashes could divert resources needed for handling more serious problems.

The transportation recorder would be unable to see outside factors at work, including the actions of other automobiles and drivers, and so could not provide a complete picture of a crash.

The data gathered by transportation recorders might have little or no value to victims of automotive crashes, for instance providing no information that would assist doctors or Emergency Medical Teams in caring for the victim.

The data gathered by transportation recorders could be used as a substitute for pre-market crash testing, effectively using the victims of automotive crashes as crash-test subjects, and also leading to lowered vehicle safety as untested automobiles are released to market.

It is questionable whether transportation recorders could have any use except as a substitute for pre-market crash testing, and thus the entire premise could be flawed.

Finally, there are important questions that must be answered before any decision in this matter can be made:

Can we ensure that the personal privacy of drivers will *never* be infringed by this technology?

Can we ensure that the informational privacy of drivers will *never* be infringed by this technology?

Can we so regulate the gathering, archiving, and usage of this data that it will *never* be misused by any entity, whether government, law enforcement, private, or corporate?

Can we be utterly certain that all data gathered and archived is safe from unauthorized intrusion and tampering?

Is there any valid connection between the ability to record this data and the premise that it will in some way make driving safer?

Most importantly, are we responsible enough properly to cope with the enormous power inherent in the ability to observe, track, and archive the movements of all private vehicles and their owners?

Addenda

The majority of vehicles in single- and two-vehicle crashes were going straight prior to the crash.

Photographer: Frank Staples

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

PREFACE

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, sustaining a continuing societal l0SS 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,

George Mahon

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 simulations of 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)

John J. McFall
Chairman, Subcommittee on
Transportation Appropriations

(signed)

Silvio O. Conte
Ranking Minority Member
Subcommittee on Transportation
Appropriations

Contents

1. INTRODUCTION AND SUMMARY

At the request of the House Appropriations Committee, the Office of Technology Assessment, through contract OTA-C1l, 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 accident 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

- to support rulemaking and to estimate the benefits of proposed safety standards
- to determine the effectiveness of existing safety standards
- to determine causes of accident, injury and fatality to aid crashworthy vehicle design
- to identify new safety problems as they develop
- 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 inadvertant 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.

- 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.

- 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

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

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

- 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. Crash recorders provide data that may be admissible in a court of law.

5. Program alternatives include the following:

   - Doing nothing to improve the current crash data acquisition system. 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.

   - Upgrading current data collection programs without adding a mass data acquisition system. 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.

   - Providing a mass accident data acquisition program at a cost of $3 to $10 million yearly. 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.

   - Upgrading mass accident data acquisition program to provide accurate severity reporting at a cost of $10 to $20 million annually. 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.

- 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 conservatively 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 responsible, 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 evaluating the efficacies of the existing standards to determine which should be kept on the books and which should be eliminated.

----

* 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 modifications 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 effectiveness of 90%. The lap belt alone is estimated by NHTSA to have intrinsic fatality prevention effectiveness of 20% in frontal collisions, with 22% for all collisions. Yet extensive field experience from North Carolina indicates an overall fatality prevention effectiveness 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.

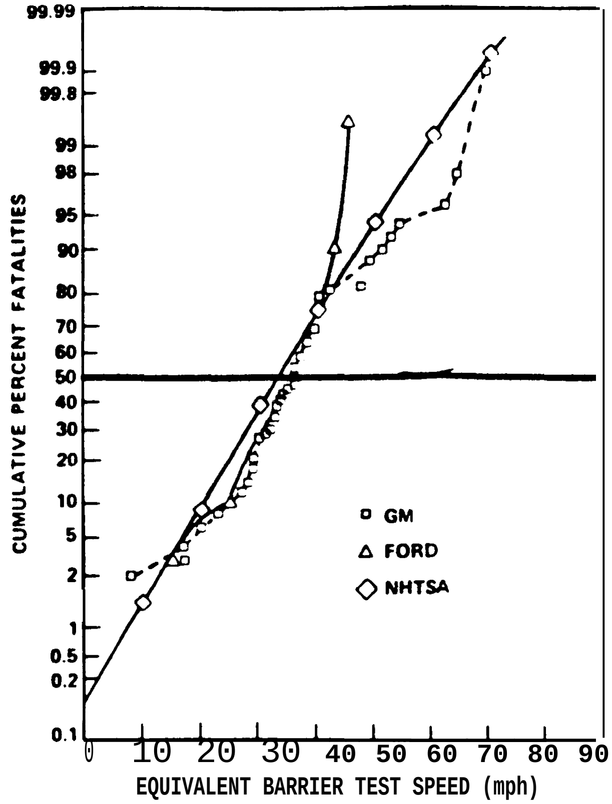

FIGURE 3 - Comparison of Fatality Distribution Data (Frontal Collisions)

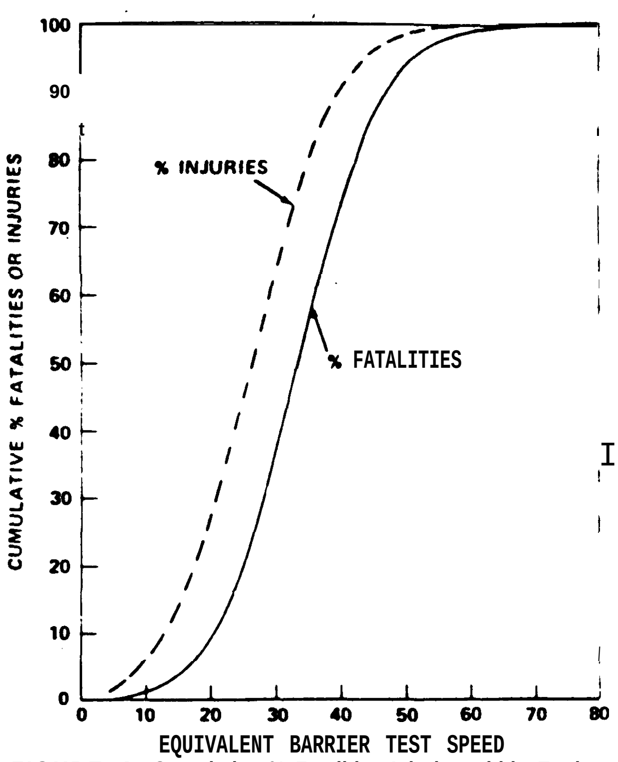

FIGURE 4- Cumulative % Fatalities Injuries within Equivalent Test Speed Range

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 Transportation 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 collection 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 representative, 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 investigating 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 unsuccessful 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. Specifically, 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 distribution 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 <u>intrinsic</u> or <u>causal</u> 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 measurement 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:

$$V = \sqrt{2ad}$$

The commonly used head injury criterion is:

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

Where Δt is the time duration and ΔV is the head speed change during the hardest bump. If the final head speed is zero and there is only one bump, this becomes

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

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

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

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_0 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 an 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 measurements 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 deformation 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 information 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 accelerometers 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 sophisticated 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 procedures 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 approximately 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 identification 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 photograph** 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 $10-2O 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.

** Mr. 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.[1/, 10, 11, 13, 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 representation 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, PIUS 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)
(0 - 120 mph, speedometer accuracy)

Longitudinal and lateral vehicle acceleration
± 1 g, accuracy ± 5%

During the crash is recorded the time history of:

Longitudinal acceleration (± 50 g, accuracy ± 3%)
Lateral acceleration (± 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 ± 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 responsible 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 standardization 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.

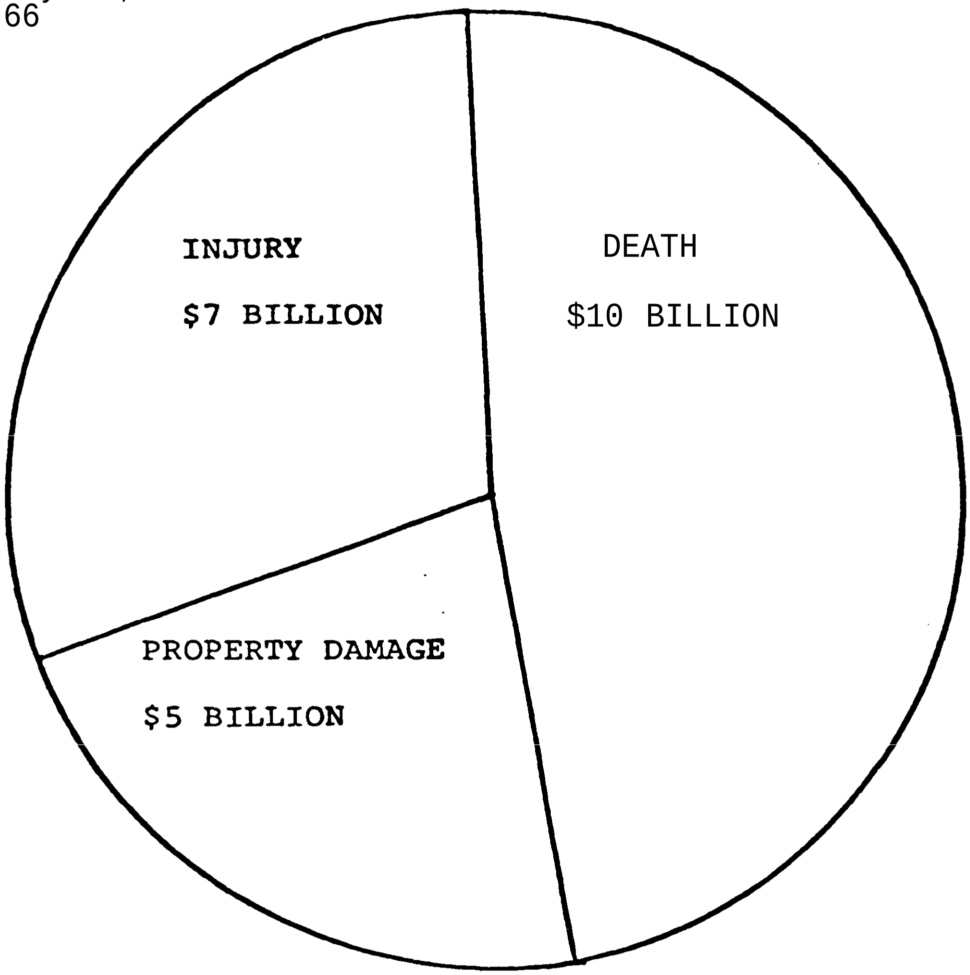
In addition to the question of responsibility, there is the question of capability. On this question, John Versace of Ford Motor Company[16]/ has the following comment.

> "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).



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 admissible 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.

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* 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 particular 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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