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EVALUATION OF SEVERITY OF COLLISIONS WITH ROADSIDE FEATURES: DATA NEEDS

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PREFACE

This circular contains the proceedings of a workshop sponsored by the Committee on Safety Appurtenances and held at Pacific Grove, California, June 25-26, 1981. The proceedings include a number of invited papers and summaries of working group discussions. The summaries represent as objectively as possible the views expressed by group participants. Included also is a list of fifteen problem statements submitted by participants prior to the meeting and used as planning guidance by the program committee.

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INTRODUCTION

John G. Viner, Federal Highway Administration,
Workshop Chairman

This Circular reports on a committee workshop intended as a critical review of data needs relating to the evaluation of the severity of ran-off-road collisions. The workshop, sponsored by the Transportation Research Board's Committee on Safety Appurtenances, took place in Pacific Grove, California, June 25-26, 1981.

Sound data on the relative hazard of an existing roadside situation and proposed treatments are required in order to use cost-effectiveness techniques to determine the relative payoff of alternatives. A rational life-cycle cost/benefit comparison of alternate safety treatments is also heavily dependent on sound data on the relative severity of collisions with the proposed treatments. The scarcity of such reliable data as viewed from the prospective of the myriad of real-world decisions that must be made has been recognized as the major stumbling block in the effective use of these decision techniques.

This workshop had its origins in internal Federal Highway Administration (FHWA) discussions involving Julie A. Cirillo, Harry W. Taylor and John G. Viner concerning ways of obtaining reliable input severity data. These methods include accident studies (with related data and research design problems), controlled full-scale crash tests (with output in terms of vehicle and roadside feature kinematics and kinetics rather than predicted occupant-injury levels for most studies) and simulation (with necessary input data based on the above studies, thereby incorporating their limitations plus the question of degree of confidence placed on interpolation or extrapolation from the validation cases). It was felt that a workshop focusing on the strengths and weaknesses of these tools would be the most valuable means of assessing current technology in this area.

The Transportation Research Board (TRB) Committee on Safety Appurtenances (A2A04) agreed to sponsor such a workshop. Meeting attendees would include invited technical experts to supplement the technical expertize of TRB Committee A2A04 members in the above areas. The Environmental Factors Section of the American Association for Automotive Medicine (AAAM) provided support and assistance for the planning and conduct of this workshop. A workshop planning committee was established consisting of Forrest M. Council; William W. Hunter; Jarvis D. Michie, Chairman, TRB Committee A2A04, and John G. Viner. King K. Mak and all of the above noted individuals participated in initial workshop planning efforts. Local arrangements were handled by Eric F. and Mrs. Dee Nordlin.

The workshop would focus on knowledge gaps rather than with parts of the system that worked rather well. In so doing, it was hoped that a more meaningful dialogue among the various disciplines represented at the workshop would take place. The goals for the workshop were (a) to engage in a meaningful interdisciplinary dialogue on the impediments to obtaining improved collision severity data and (b) to identify several key problems and suggest solutions.

The technical discussion was divided into two major areas: (a) Physical Testing and Analysis and (b) Field Performance Studies: Evaluation and Data Issues. Each session included invited presentations and group discussions. A review of cost-benefit model algorithms preceded these sessions to set the stage for the specific workshop deliberations.

At the conclusion of these sessions, the four "most important" problem areas identified by the workshop attendees were discussed in subgroups of the attendees. Prior to the workshop, each attendee was asked to provide a statement of "The Most Important Specific Issue Relating to Severity Data." These statements were used as planning guidance for the workshop and are included in Appendix A. At the end of each session, each attendee was asked to list "The Four Most Important Problems Discussed in This Session." The workshop planners used both of these inputs to select the "four most important problems" which were the subject of Session 3, Group Consensus on Key Problems and Recommendations.

The invited presentations and comments by session moderators together with the written summaries of the group consensus statement are in the following sections of this paper.

Part 1: Roadside Appurtenances and the Need for Improved Collision Severity Data

William W. Hunter, Highway Research
Center, University of North Carolina

ISSUES

Increasing fuel costs are prompting a shift to smaller, more fuel-efficient classes of vehicles. In addition, fewer miles of travel are occurring. Coupled with inflation, these events are resulting in fewer revenues available for highway design changes and/or safety improvements. Perhaps more than ever, notions of cost effectiveness and prioritization of programs are assuming more importance. Some current issues include:

1. Are we designing and placing our roadside hardware optimally to maximize benefits and minimize costs?
2. What are the proper effectiveness levels for appurtenances (i.e., how can we quantify how well they work?) for use in cost effectiveness or budget allocation procedures?
3. And as an aside, what vehicles and what crashes will need to be designed for in the future?

Let us momentarily focus on the second question regarding effectiveness levels. We can attempt to answer the effectiveness questions by using three basic methods: (a) field testing of countermeasures (accident and proxy studies), (b) crash testing and (c) simulation. The basic problems relating to field tests are poor study design and poor data. These problems are so intrinsic to many studies that it is difficult to state where we are today in regard to evaluating much of the current hardware. Why is this the case?

PROBLEMS

Many designs have been developed and tried including impact attenuators, breakaway signs, transition guardrail at bridge ends, concrete median barriers, etc. In some cases accident data have been collected and some attempt at an evaluation made, but here the problems begin. Evaluations are often made after the fact, sometimes as an afterthought, as opposed to being built into the entire process. Sometimes the wrong type of data has been collected, such as not specifically examining the types of accidents the design or treatment is specifically supposed to affect. Many of the evaluation designs have been flawed, producing results that are meaningless or that are very hard to interpret.

In this field we have often used before/after designs, most often with no control or comparison group. When this occurs, the results vary widely due to regression to the mean, random fluctuation, etc. And even though it is not an easy task, it is imperative to try to develop some kind of control locations or data. And these should be determined early. Since we generally cannot fund all candidate projects, why not randomly set aside some for comparison purposes? So the first problem is really that of poor evaluations (1). (Numbers in parentheses designate references at the end of Part 1.)

Secondly, there is the problem of information dissemination. Many states are quite capable of setting up and performing evaluations of various devices. Yet many times the results never seem to get past their own people in the design or traffic engineering branches. Publishing the results of evaluations is not a high-priority item in most state highway departments. But it is important that states talk to each other, perhaps through working technical memoranda, short summary reports for remedial treatments or small-scale improvements, or maybe a detailed technical report for major redesign. It is also important that negative as well as positive fundings are reported. One convenient outlet could be FHWA Regional Offices.

NEEDS

All of the above leads to another area--what we need. Basically, for all the many types of roadside or appurtenance designs available, we need to know what works and how well or how poorly. The answers need to be couched in terms of appropriate levels of effectiveness, such as, "the water-filled cushion, when used at high-speed gore areas, reduces fatal accidents by 75 percent, reduces injury accidents by 65 percent and increases property damage only (PDO) accidents by 300 percent" (2). If possible, even further breakdown of the data is desirable, such as by class of roadway, Abbreviated Injury Scale, etc.

We need information for all the various kinds of hazards and accompanying treatments, such as what to do about trees and utility poles, exposed bridge rail end, substandard bridge rail, underpasses and exposed bridge piers, sign supports, etc. Here appropriate questions might be what types of accidents are critical? is it worse to strike a tree or utility pole or guardrail? and what are the relative severities of the various hazards?

We also need to know something about how the various treatments for the various hazards work in relation to each other (i.e., how can we compare appurtenances?) And in this day and age it may not just be a question or a comparison of appurtenances. We may be comparing hardware versus roadway maintenance. What we are addressing is a means of assigning priority to these different elements. If you are talking about roadside safety improvements, the funds today are far from sufficient. The states now seem to be tackling this problem, and most of the approaches tend to involve economic analysis procedures to produce rankings based on concepts like net present worth, benefit cost ratios and integer and dynamic programming.

These economic procedures then lead to some more data needs: for example, knowledge about the number of hazards per some distance of roadway (such as the number of utility poles per mile within 30 ft. of the edge of pavement on rural non-Interstate roadways). In other words, we need exposure data, and this implies an inventory of some sort. Exposure is such a vital concept in regard to evaluation that we need to give it a fair share of attention as it impacts on our severity and methodology concerns. We also need associated cost data (e.g., cost of these utility pole accidents and the cost of a proposed treatment, such as relocating the pole or making it breakaway). Many ideas come into play here, including (a) cost and service lives of various appurtenances (e.g., what does it cost to make a pole breakaway and how does this affect the service life of the pole?); (b) cost of fatal, severe, minor or PDO accidents, and related concerns about whether direct or societal costs should be used. If you then couple these data items with the estimates of effectiveness for the various treatments, then the basis is present for development of some prioritizing or ranking scheme.

ECONOMIC PERSPECTIVES

In many cases, what we are trying to do is calculate a benefit/cost ratio, generally in one of two ways (3):

$$B/C = EUAB/EUAC = PWOB/PWOC$$

where

EUAB = equivalent uniform annual benefits,
EUAC = equivalent uniform annual costs,
PWOB = equivalent present worth of benefits, and
PWOC = equivalent present worth of costs.

In this fashion a project or service life is determined, along with an appropriate interest rate, and present and future costs and benefits are discounted or amortized and reduced to a single number or numbers for calculation purposes. Again, costs may include items like initial capital costs, maintenance costs, salvage values and the like. The benefits may also include many considerations, such as reduced motorist delay, increased confort and convenience, reduced vehicle emissions, etc.; in the safety area, reductions in the frequency and/or severity of accidents over the life of a treatment generally produce the largest benefits and thus gain the most attention. So "how can we determine the real-world accident effectiveness of the design hardware put into place?" is probably the question that most needs an answer if we are to rationally allocate funds among competing needs. Indeed, the consensus is that the lack of this effectiveness data is still our biggest stumbling block to proper prioritizing.

Table 1: Calculation of Accident Benefits

(1) Year	(2) Type	(3) No. of Untreated Accidents	(4) Accident Costs	(5) Untreated Accident Costs	(6) Improvement Factor	(7) No. of Treated Accidents	(8) Treated Accident Costs
	Fatal	8	$350,000	$2,800,000	0.50	4	$1,400,000
1	Non-Fatal	152	$ 20,000	$3,040,000	1.14	173	$3,460,000
	PDO	240	$ 900	$ 216,000	1.00	240	$ 216,000
				$6,056,000			$5,076,000
				Accident Benefits = $980,000			
	Fatal	8	$385,000	$3,080,000	0.50	4	$1,540,000
2	Non-Fatal	158	$ 22,000	$3,476,000	1.14	180	$3,960,000
	PDO	250	$ 990	$ 247,500	1.00	250	$ 247,500
				$6,803,500			$5,747,500
				Accident Benefits = $1,056,000			

Let's look at one example of how effectiveness data can be used, or how we might proceed analytically (Table 1). Table 1 shows 2 years of an economic analysis procedure. We are dealing with fatal, non-fatal and PDO accidents. Column 3 gives the number of such untreated accidents. Column 4 then represents the accident costs, and these were based somewhat on the latest National Highway Traffic Safety Administration (NHTSA) figures. Column 5, the untreated accident costs, then results from multiplying Column 3 times Column 4. Column 6 is the improvement factor or the estimate of effectiveness for this particular piece of hardware. In this case, the hardware reduces fatal accidents by 50 percent, increases non-fatal accidents by 14 percent, and produces no change to PDO accidents. Column 7 then is the number of treated accidents that one would expect after this improvement was put into place and results from multiplying Column 3 by Column 6. The treated accident costs, Column 8, then results by multiplying Column 4 times Column 7. The accident benefits of $980,000 represent the difference in the totals of Columns 5 and 8.

In the second year, two assumptions are made. Accidents are assumed to increase by 4 percent, and this is reflected in Column 3 where the numbers increase to 8, 158 and 250 (rounded). We also assume that inflation increases the cost of the accidents by 10 percent, and this is reflected in Column 4. Proceeding with the calculations as in Year 1, the accident benefits then total slightly more than $1 million for this second year. This process is continued until the service life of the improvement is reached. At this point the net present worth can be determined or a benefit/cost ratio may be calculated.

As can be seen from the benefit totals here, any change in the improvement or reduction factors can have a large effect on the benefit calculation. And this is precisely what you see in the literature--a great variety in the determination of how well or how poorly the appurtenance design is working.

Given this line of thinking, there are other ways to proceed that can be shown by other examples. The following formulas appear in the American Association of State Highway and Transportation Officials (AASHTO) traffic barrier guide (4).

$$CT = CI + CD(Cf)(KT) + CM(KT) + COVD(Cf)(KT) - CS(KJ)$$

or, to determine these costs, which are directly incurred by the highway department (or implementing agency), use the equation below:

$$CTD = CI + CD(Cf)(KT) + CM(Kt) - CS(KJ)$$

where

- Cf = collision frequency (accidents per year),
- CI = initial cost (present dollars) of the obstacle,
- CD = average damage cost (present dollars) per accident incurred to the obstacle,
- CM = average maintenance cost (present dollars) per year for the obstacle,
- COVD = average occupant injury and vehicle damage cost (present dollars) per accident,
- CS = estimated salvage value (future dollars) of the obstacle,
- CT = total present worth cost (dollars) associated with the obstacle,
- C = total present worth direct cost (dollars) associated with the obstacle, and
- KT, KJ = economic factors for some current interest rate.

Just as before, the occupant and vehicle damage costs or severities represent our biggest unknown or emphasis point for what we are trying to accomplish in a prioritizing sense.

The final example is a cost-effectiveness model enhanced by Glennon in NCHRP Report 148 (5), which is a probabilistic approach for calculating a hazard index H.

$$H = (V)(PE)(PCE)(PIC)$$

where

H = hazard index or expected number of fatal plus non-fatal injury accidents per year;
V = vehicle exposure;
PE = probability of encroachment;
PCE = probability of a collision, given an encroachment; and
PIC = probability of an injury (fatal or non-fatal), given a collision.

Glennon then calculates the cost-effectiveness ratio defined as the annualized cost for the reduction of one fatal or non-fatal injury accident. Here, data are needed for all the probability terms, because much of this work is based on theory. Indeed, the probability of encroachment is based on the old work by Hutchinson and Kennedy (6).

In models like this, site layout considerations come into play. For example, a pole (breakaway or non-breakaway) is more likely to be struck if closer to the edge of pavement. The same would be true for median barrier placement. Barriers placed close to the pavement yield more hits at shallower angles, while more severe, higher-angle collisions result when distance from the pavement edge is greater. And while such considerations about site layout and impact conditions are important, what we are trying to focus on here are the inherent capabilities or limitations of the appurtenance and the relative severity of the collision.

CONCLUSION

It should be stated that some excellent work has been performed in developing or reviewing procedures for ranking alternatives by the Texas Transportation Institute (7) for FHWA. These methods include incremental benefit/cost techniques with improved algorithm, dynamic programming and inter programming--techniques that lead to optimal budget packages. However, one problem here is that much of the work has focused on fairly meticulous cost calculations (i.e., costs of accidents for various roadway and traffic situations). The accompanying knowledge about treatment effectiveness (frequency or severity reduction) can be stated with nowhere near the same precision. Indeed, the effectiveness factors could be orders of magnitude different.

Thus, we have a good handle on the economic techniques for ranking programs. It is time to develop research methodologies that will produce the needed estimates of effectiveness for our design hardware.

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Part 2: Session 1, Physical Testing and Analysis

Jarvis D. Michie, Southwest Research Institute, Moderator

This session was devoted to seven aspects of roadside hardware development, principally the design, laboratory and crash test evaluation and assessment of the hardware potential. The presenters were asked to critically evaluate a specific area with respect to generating data needed in the benefit/cost analysis procedure. As it was felt that the positive features of the seven areas have been emphasized in previous meetings and in the literature, the presenters were asked to concentrate on limitations. Accordingly, the reader is advised that the following purposely stresses the negative and should not be viewed as a balanced appraisal of highway safety technology.

BASELINE DATA NEEDS

Hayes E. Ross, Jr., Texas Transportation Institute, Texas A&M University

Benefit/cost analyses of roadside safety programs generally involve (a) an estimate of accident frequency and (b) an estimate of the severity of the predicted accidents. In most such analyses these estimates, through no fault of the analyst, are crude and statistically unsound. Data on which reliable predictions can be based are sparse. Numerous variables influence accident frequency and severity, further complicating data needs.

Attempts have been made to develop accident prediction models based on regression techniques utilizing accident data. These have met with little success for the reasons given above. In the absence of accident data bases, researchers have formulated probabilistic models based on observed and/or assumed vehicle encroachment data. Although widely used, the latter technique has relied on very limited encroachment data, and the results obtained are generally suspect.

The nature and frequency of inadvertent encroachments by a motorist are functions of numerous factors, including the motorist himself. Data are needed to determine this interrelationship. With regard to roadway variables, encroachments are believed to be a function of roadway type (interstate, divided, two-way undivided, urban arterial, etc.), roadway and roadside geometry (vertical and horizontal alignment, shoulder and curb, enbankment, etc.), traffic control devices (delineation, signing, lighting), traffic conditions (vehicle mix, volume, operating speed, environmental conditions, etc.) and vehicle size. An encroachment data base should be gathered sufficiently to develop a statistically reliable accident prediction algorithm with capability to predict the following:

1. Number of times an object will be struck in a given time period,
2. type of vehicles expected to strike object in a given time period,
3. speeds at which vehicles will strike object,
4. angle at which vehicles will strick object, and
5. attitude at which vehicles will strike object.

Once the number and type of vehicle involvements with a given roadside object have been estimated, one must ascertain the probability and level of injuries associated with each involvement. Impact severity can be estimated from physical test data (crash tests, skid tests, laboratory tests, dummy tests, etc.), accident data, computer simulation (vehicle and/or occupant dynamic simulation models), accident reconstruction combining accident data with test data and/or computer simulation, or engineering judgment.

Data from which the severity of a predicted accident can be quantified are also quite sparse. Variables that influence the severity of a given impact include the type of object hit (fixed objects, continuous objects, temporary objects used in work zones, etc.), type of vehicle (automobile, truck, special vehicle, etc.) and impact conditions (speed, angle, attitude, etc.). Impact severity data should be gathered to eventually develop a data base sufficient to evaluate the severity of the accidents predicted by the accident prediction algorithm.

CRASH TEST AND OPERATION EXPERIENCE

Eric F. Nordlin, California Department of Transportation

The procedures for testing and evaluating highway appurtenance performance have become increasingly more complex since 1962 when the original single-page guideline for crash testing guardrail with a 4000-lb. passenger car was first published in Highway Research Board Circular 482. Updated by NCHRP Report 153 in 1974 and Transportation Research Circular 191 in 1978, these guidelines have necessarily and progressively expanded into the present 42-page NCHRP Report 230, Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances. The new guidelines cover not only guardrail but also median barriers, bridge rails, crash cushions and breakaway or yielding supports for signs, luminaries and other selected highway appurtenances.

The vehicles of interest now include 1800-lb., 2250-lb. and 4500-lb. passenger cars, a 20,000-lb. utility bus, 32,000-lb. and 40,000-lb. intercity buses and an 80,000-lb. articulated tractor-trailer truck. It also appears that the range of vehicles will be even greater in the foreseeable future as the number of still smaller, lighter passenger cars and still large, heavier and longer tractor-multiple trailer trucks increase as the current trends continue.

Actually, the number of test vehicle variables alone become almost infinite when one considers all of the sizes, weights and shapes of vehicles; their different manufacturers, models and ages; their different mass distributions, location of center of gravity and suspension systems; the location of the engine and type of transmission; the numbers of axles and wheels, wheel and tire sizes and track widths; their general maintained condition and the many other characteristics that affect the structural integrity, stability and dynamic response of an impacting vehicle.

However, the number of potential test variables expands still further when consideration is given to the number of passengers, their physical conditions and ages, how they are restrained and the other occupant protective measures that have been designed into the vehicles; the types of other cargo (gas, liquid or solid), how it is located or stacked and how securely it is restrained; the vehicle velocity, angle, lateral offset and orientation at the time of impact; and the ability of the driver to react to, through and recover from the vehicle/appurtenance interaction situation.

In addition, there also are the many potential variables associated with the location of the appurtenance on the highway; the riding surface leading to and immediately adjacent to the appurtenance; the type and condition of the soil; the horizontal and vertical alignment and other highway geometric design conditions; the point of impact on the appurtenance; the design of the appurtenance and the quality of materials used to construct it; the environmental conditions that affect durability and weatherability; and the general maintenance upkeep efforts expended.

Full-scale vehicle crash tests performed, instrumented and photo documented in accordance with NCHRP Report 230 are very costly; ranging from $10,000 to $20,000 per test at Caltrans. Therefore, an agency must be somewhat restrictive in the number of tests and selective in the variables to be considered.

Structural laboratory tests, analytical procedures, computer simulations and pendulum or bogie vehicle tests are very useful techniques employed to reduce the number of full-scale vehicle impact tests. These less costly complementary procedures frequently serve to screen out the less critical variables and interpolate between the data points generated from a limited number of crash tests.

However, even with these complementary techniques, it is impractical and virtually impossible to duplicate and accurately determine, in a limited number of standardized crash tests, the effect that all of the aforementioned variables will have on vehicles impacting a highway appurtenance. Recognizing this, NCHRP Report 230 establishes normalized test conditions; straight longitudinal barriers are tested although curved installations exist; flat grade is recommended even though installations are sometimes situated on sloped shoulders or behind curbs; idealized soils are specified although appurtenances are often located in poor, frozen or saturated ground, etc. These normalized factors have significant effect on the performance of an appurtenance and may obscure serious safety deficiencies that exist under more typical but less ideal actual conditions. However, these normalized factors are thought to be secondary in importance when the object of a test program is to compare the results of tests on two or more systems. The normalized test conditions are more easily duplicated and thus promote better correlation of results by different testing agencies. For these reasons, the highway engineer is warned that when the performance of an appurtenance is required for a specific site situation or the performance of an appurtenance is suspected of being unacceptable under some likely conditions, it is important that these specific conditions should be used instead of, or in addition to, the normalized test factors.

For example, several years ago Caltrans was involved in a blanket safety program to install crash cushions in off-ramp gore areas with raised curbs where it was not feasible to remove rigid overhead sign supports. Based on the results of a series of vehicle jump and crash tests into a raised curb test installation, with and without a crash cushion installed, it was reasonably proven that it was not necessary to remove the raised curbed gore area provided the crash cushion was located sufficiently close to the curb to minimize the effect of vehicle vaulting or dipping. This test series also provided Caltrans engineers with valuable test data that could be applied to make engineering judgment at other situations and locations where the same height of curb existed.

However, even when performing a minimum matrix of normalized tests such as those recommended in NCHRP Report 230, seemingly inconsequential differences between test vehicles of the same mass can drastically change the outcome of the crash tests. For example, several years ago Caltrans conducted a series of four almost identical crash tests on the same concrete median barrier. In all four tests the passenger car weights were 4800-4900 lb., the impact speeds were close to 65 mph and the angle of impact was approximately 25 degrees. In the first two tests, one make of car was used and in both tests the car rolled over three times after impact with the barrier. In the last two tests, another make of car was used and did not roll over in either test. The difference in vehicle behavior could only be contributed to differences in the two comparable makes of cars; perhaps in the suspension systems, the crushability of the front ends, the dynamic strength of the front wheels and steering assemblies, etc.

For all of these reasons, standardized or normalized crash testing procedures actually can only constitute another screening phase in the development and evaluation of a highway appurtenance. In fact, it is questionable whether a crash testing program could ever be designed, regardless of cost, to predict and give complete assurance in regard to how an appurtenance would perform under all highway situations and conditions. This is why NCHRP Report 230 includes in-service evaluation as the final phase in the development of a new or extensively modified highway safety appurtenance. Appurtenances that have been judged to perform acceptably through controlled crash testing and the other complementary techniques are introduced into actual service on a limited trial basis and the installations are extensively monitored, preferably for a 2-year period where possible. The in-service evaluation is intended to expose the appurtenance to all of the variables of the "real world" to proof test or "debug" the design, learn the application limitations and/or modify the design before approving for broad operational use.

As an example, a number of years ago one of the first median barriers developed by Caltrans through crash testing consisted of a single steel cable 9 in. and a pair of cables 30 in. above ground, and chain-link mesh fencing all mounted on yielding lightweight steel posts. However, contrary to the controlled test results, the in-service experience on a limited number of trial installations showed the tendancy for vehicles to ramp up over this original cable chain-link mesh median barrier. A subsequent series of controlled crash tests resulted in the elimination of the single lower cable. In-service experience with subsequent trial installations of the modified design resulted in statewide approval and a number of years of successful experience with this low-cost median barrier in California.

However, the in-service monitoring and evaluation of all highway safety appurtenances should not cease with the initial trial period but should always be ongoing. This need is also best illustrated by the Caltrans experience with the cable median barrier. After a number of years of successful experience, impacting vehicles started penetrating under the pair of cables resulting not only in cross median accidents but even decapitation of the driver. Analysis of the accident data showed that the penetrating vehicles were all the low-nosed small sport cars that were just starting to appear in significant quantities on California highways. A third series of crash tests involving standard size and the small passenger cars and various terrain conditions resulted in lowering the pair of cables to a height of 27 in. above the ground and new warrants that limited the terrain conditions where the further modified cable median barrier could be used. With these changes, the modified cable median barrier continued to be effectively used in California until medians started to get much narrower and the range of vehicle sizes continued to spread to the point where this flexible cable design was no longer effective. However, by the time the concrete median barrier started replacing the cable median barrier, this low-cost system had paid for itself many times over. Furthurmore, through continued in-service monitoring and accident statistic review, the modifications and ultimate termination of this design were always made as unsatisfactory performance started to develop.

Highway engineers should realize that safety appurtenances are not perfect and subject traffic to a degree of risk. They, themselves, are fixed objects regardless of the amount of testing and evaluation they have undergone and never should be installed if there is doubt about its need. For example, in California in 1980 on the state freeway system there were 267 fatal accidents involving fixed objects. Of these accidents, 19 percent involved guardrail and 15 percent involved median barrier. Undoubtedly, in many of these accidents a fatality would have occurred whether or not a barrier was involved in the chain of events. However, it is also obvious that contact between an out-of-control vehicle and a barrier does not always eliminate fatalities and serious injuries. In fact, it is possible that in a few of these accidents, the collision was more severe due to the presence of the barrier than would have been the case without it.

Highway agencies must generally rely on cost-benefit evaluations in establishing priority for appurtenance placement. There never are enough funds available to correct all of the safety problems. Appurtenances will generally have to be installed or modified where the resulting expenditures will save the most lives. However, the first cost for installing a safety appurtenance may not be the sole cost factor to be considered in selecting one of several candidate designs or systems. For example, a well-designed cable-type median barrier may be less costly to install than a concrete barrier. However, if installed in the median of a relatively heavily traveled urban freeway, it will be frequently hit unless the median is quite wide. Each hit would result in costly repair to 25-100 ft. of barrier whereas the concrete barrier would be relatively maintenance free. Thus, repair costs become a significant part of the total cost of a cable barrier over its service life. In addition, maintenance and repair effort in the median of an urban freeway is a hazard to maintenance personnel as well as to the traveling public, which can result in additional loss of life.

In establishing priority for roadside safety improvement, including appurtenance installation or modification, the highway engineer must be able to put spectacular individual accidents, such as the relatively infrequent accidents involving school buses, in proper perspective and consider them in overall highway safety strategy. Where funds are limited as they usually are, emotional issues must be tempered with thorough safety and economic analysis.

HARDWARE PERFORMANCE AS AFFECTED BY SITE CONDITIONS

Maurice E. Bronstad, Southwest Research Institute

In appraising dynamic performance of a safety appurtenance in a real-world accident, it is important that the device was subjected to conditions within its performance range. That is, the device should have been installed and maintained properly and that the vehicle impact conditions (i.e., mass, speed and angle) were within the device capability.

Examples abound in which the device was improperly installed or that some highway feature severely restricted the potential performance range, for instance, longitudinal barriers mounted behind mountable curbs that cause errant vehicles to vault over the system; flexible longitudinal barriers mounted too close to rigid fixed objects (during collisions, the barrier deflects to the fixed object subjecting the vehicle to pocketing and snagging possibilities); improper transitions between approach and bridge railing causing pocketing or snagging of the vehicle; post-and-beam bridge rail systems that are not compatible with the bridge deck; and improper or inadequate terminals that fail to develop the barrier strength or present undue hazard to the motorists.

In addition to improper installations, there is concern that many existing installations are not being maintained. Longitudinal barriers have been permitted to settle or the surrounding grade or pavement surface has been allowed to build up; this has essentially reduced the effective height of the barrier and has increased the number of vehicles that vault over the system.

Thus, in performing field evaluation of appurtenances, it is most important to document the condition of the system prior to the impact so that improperly installed or maintained devices will not reflect adversely on a system's general capability.

DESIGN REQUIREMENTS--DATA NEEDS

Robert J. Reilly, Cooperative Research Programs, Transportation Research Board

During this workshop, three questions concerning data on safety-appurtenance accidents will be addressed: What is needed? What is available? and How can the gaps be filled?

This presentation concentrates on the first question in the context of the evaluation of safety appurtenances, for which the design requirement is that the system demonstrate acceptable performance during specified crash tests.

The primary reason for installing a safety appurtenance should be to make a particular site safer than it would be without it. However, some appurtenances are needed primarily for other reasons, for example, breakaway supports for signs and luminaries, which are designed by conventional structural methods to resist wind, gravity and other loads. The basis for the structural design of such appurtenances is well accepted and is not directly dependent on field performance data. Although safety is not the primary reason for installation of such hardware, its presence should add the least possible extra hazard to the site, therefore, its safety performance must be determined by crash tests and field evaluation. An exception to the requirement for crash-test evaluation of safety appurtenances presently exists in the case of bridge railing systems. The AASHTO Standard Specification for Highway Bridges requires an allowable stress design except for railing systems that have been successfully crash tested.

NCHRP Report 230, Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances, published in 1981, introduced some significant changes to appurtenance evaluation as previously specified in NCHRP Report 153, Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances.

- Test conditions were modified to consider mini-compacts (1800 lb.), trucks and buses, and a multiple-service-level approach was introduced to require various levels of structural adequacy as appropriate for particular site conditions.
- Evaluation criteria had not previously been consistent among various types of appurtenances, in that some were based on average accelerations and others on change in momentum. The flail space concept, used in Report 230, sets limits on both the velocity with which the occupant may strike the interior of the vehicle and the subsequent ridedown acceleration.
- An entirely new chapter is devoted to in-service evaluation, in which an appurtenance is installed on a trial basis, monitored for some period of time (e.g., 2 years), and a conclusion is reached, whereby the period of evaluation is extended or the appurtenance is either accepted, rejected or modified.
- Report 230 also contains a new section on analytical simulation and experimental techniques other than full-scale testing (e.g., static tests and component testing).

We should now consider various types of accident data and how they might be used.

- Detailed, case-by-case accident information, such as envisioned in the system of in-service evaluation recommended in Report 230, is most useful for gaining insight into the behavior of a particular item. A few well-documented cases of unsatisfactory performance might be all that is needed to call attention to a problem in a particular system.

For example, reports on several accidents or even experimental crash tests showing that front-wheel-drive mini-compacts snag on longitudinal railing systems or that they fail to activate breakaway devices might be sufficient to indicate the need for further research, development and, possibly, a retrofit program. Exposure data or information on successful performance might not be particularly important for this purpose. It should be pointed out that practical details (e.g., coordination and funding) still need to be developed for a system of in-service evaluation like that suggested in Report 230.

o Data not specifically related to accidents can also be of value. For example, statistics on automobile sales might point to a trend such as the increasing number of mini-compacts, from which potential problems can be anticipated and, if possible, avoided before they occur.

o Data that can be evaluated statistically can be useful in several ways. Ideally, such data would be recorded for all incidents (drive-aways as well as reported accidents) on certain installations over a prolonged period. This information could be used to establish priorities for research and development expenditures or to justify the need for a major rehabilitation program to correct a particular problem. An example would be bridge railing transitions. Accident statistics gathered during the 1960s indicated a disproportionate number of fatalities associated with inadequate transitions, and subsequent attention to this problem resulted in a significant reduction.

o Accident data are also needed to establish improved crash testing procedures and evaluation criteria. The test conditions specified in Report 230 are based on judgment; they are idealized and are neither average, typical, maximum nor worse-case conditions. Nevertheless, the values selected might be viewed with greater confidence if they were backed up by more comprehensive data than are currently available. Similarly, the flail space concept for assessing risk to the occupant is new and will need validation and, possibly, revision based on insight gained from accident data.

In conclusion, the types of data needed on safety appurtenance accidents are diverse and, in considering our needs and methods of filling them, we should take care not to devise plans for collecting more than is needed for a particular objective

COMPUTER SIMULATIONS--LIMITATIONS AND DATA NEEDS

Richard L. Chiapetta, Chiapetta, Welch & Associates, Ltd.

Computer simulation can be a useful tool to provide input to the general problem of collision severity. Significant advances in simulation capability have been made in recent years and a reasonable degree of success has been achieved for many impact configurations. However, there are still several situations for which it is difficult to perform satisfactory simulations. This presentation focuses on some of the current major limitations of analytical simulation as applied to vehicle collisions with roadside features.

The definition of simulation is restricted here to the prediction of a response of the vehicle and roadside obstacle in a crash event; occupant response is not included.

An outline of various areas of simulation difficulty and the causes of difficulty is presented in Table 2. The causes may be divided into three categories:

1. Required input data not readily available,
2. difficulty in quantifying required input because of large variability in physical data of current vehicle fleet, and
3. proper modeling in some instances results in prohibitive costs because of the complexity of the model required to simulate the event (factors contributing to the costs associated with simulation include model development and validation; input data compilation and/or generation; operational costs of computer program; and review, evaluation and display of computer output).

Table 2: Limitations of Computer Simulations of Appurtenance Collisions

Areas of Simulation Difficulty	Causes of Difficulty
1. CMB Impact	Tire-road intersection at steep barrier angles Tire sidewall-rim deformation properties--stiffness, strength (axle-wheel-suspension system damage)
2. Impact of post-rail systems	Post-foundation interaction Snagging
3. Impact with terminals	Texas twist - vaulting behavior BCT - spearing, tripping action
4. Traversal of high curb-like obstacles; high curbs; timbers in construction barriers	Suspension bottoming characteristics Tire properties at severe deformation--stiffness, blowout loads
5. Shifting loads	Swinging loads--packing procedures (spacing), cargo stiffness, vehicle wall stiffness Sloshing loads--partially-filled tanker trailers Secured cargo--fastener strength, cargo module size and location in truch Passenger shift--buses

Table 2: Limitations of Computer Simulations of Appurtenance Collisions

Areas of Simulation Difficulty	Causes of Difficulty
6. Impact with sign posts, liminarie supports	Vehicle wrap-around locally--snagging; details of post-vehicle interface geometry Localized deformation property of vehicle Post-soil interaction Breakaway supports--limiting dynamic strength of supports
7. Crash cushion impact	3-D effects--ramping or nosing--relative interface geometry and c.g. heights of vehicle and cushion; curbs Characterization of cushion module deformation properties--stiffness, rate effects, fracture, mass loss
8. Articulated vehicles	Constraint conditions at fifth wheel--slack, stiffness
9. High center of gravity vehicles	Rollover resistance--suspension tension properties, slack; suspension compressive bottoming properties
10. Vehicle deformation properties	Function of position on exterior envelope
11. Simulation output	Vehicle accelerations--not as accurate as kinematics--correlation with occupant risk

LIMITATIONS ASSOCIATED WITH ANTHROPOMETRIC DUMMIES

Keith Friedman, Minicars, Inc.

Due to current anthropometric dummy technology limitations, dummy response data from crash tests do not provide a sufficient linkage with roadside feature collision severity. As shown in Table 3, limitations can be categorized into three areas: surrogate representativeness, surrogate response interpretation and relationship between surrogate response and performance of roadside feature.

With regard to representativeness, current dummies were developed for vehicle restraint evaluations in which the vehicle experiences a highly directional and abrupt velocity change such as a head-on collision into a rigid barrier. Their use in evaluating roadside features in which the collision may be prolonged over several hundred millisecond duration, where there may be multiple vehicle impacts, where the vehicle may be redirected and where the dummy may be unrestrained is certainly questionable. Of particular concern is the current dummy biofidelity for crashes in which large side forces are introduced, such as a typical longitudinal guardrail redirectional test.

Table 3: Limitations Associated with the Use of Anthropometric Dummies to Evaluate Roadside Countermeasures

Limitations	Issues of Concern
Surrogate representativeness	Biofidelity--general indication of collision severity seen by occupant, not intended for highly specific lesion prediction/assessment Kinematics Occupant population Current 50th percentile dummies Hybrid II (Part 572)--restraints development and vehicle safety evaluations, FMVSS testing, thought undesirable for side restraint development Hybrid III--improved chest and neck characteristics, thought undesirable for side restraint development; dummies for side impacts--being evaluated, injury measures undecided, matching responses from dummies to injuries in real-world accidents

Table 3: Limitations Associated with the Use of Anthropometric Dummies to Evaluate Roadside Countermeasures

Limitations	Issues of Concern
Surrogate response interpretation	NHTSA pass/fail criteria Head injury criteria $\leq$1000 Chest acceleration $\leq$60 g Femur loads $\leq$2250 lb. Other injury measures proposed Repeated tests for statistical validity More research needed on relationship of dummy injury measures to human injury level probabilities Methodology for deriving relationships has been developed and implemented; work needs to be continued Current relationships interpret measures as indicators of overall injury probability
Relationships between surrogate response and performance of a roadside feature	What the response is measuring Roadside countermeasure and restraint-structure system performance combined Performance relative to "expected" vehicles Free flight distance/padding effects, etc. Repeatability--variations due to nature, positioning, instrumentation Problems in assessment in accordance with the Report 230 procedure--time of contact - different for various body regions, differences between driver and passenger Increased testing costs

Interpretation of dummy response is a second issue of concern. The FMVSS 208 criteria are a fail/pass standard directed specifically to restraint system development. The question concerning the suitability of using these criteria for evaluating roadside hardware is: Are they appropriate and suitable severity indicators? The FMVSS 208 criteria are being questioned as to their relationship to real-world collision results even in the most restrictive use; what does a Head Injury Criteria (HIC) of 1000 mean, and how does it relate to the probability and degree of occupant injury?

And third, the relationship between surrogate response and performance of a specific roadside feature is at present most tenuous. Given the variability of the vehicle occupant flail space and interior geometry and padding, sensitivity of positioning of dummies, increased costs associated with testing with dummies, etc., it is evident that considerable research is needed before the dummy can provide the linkage between crash test results and highway accident statistics. Specifically, research should be implemented to conduct further work on refining relationships between dummy injury measures and injury probabilities and to examine what the sources of variability in injury measures and injury levels for given crash severities and impact conditions are and their relative contributions to overall variability.

RELATIONSHIP OF CRASH PARAMETERS AND ACCIDENT INJURIES

William T. Hollowell, National Highway Traffic Safety Administration

In order to compete in the marketplace in the 1980s, automobile manufacturers are rapidly moving toward more sophisticated designs and design techniques that shall provide smaller, lighter in weight and energy-efficient vehicles. The smaller front-wheel-drive vehicles, diesel engines, material substitution and advanced computer technology will play significant roles in the future of this industry. Predictions by NHTSA and others indicate that the small car will comprise the majority of automobiles in the vehicle fleet by the mid-1980s. In addition, projections have been made indicating an increasing number of fatalities with nearly one million fatalities and tens of millions of serious injuries to occur in automobiles during the next 20 years. The goal of the safety community should be to reduce these numbers by as much as possible.

To reach this goal of reduced injuries and fatalities requires knowledge of the relative crash characteristics of automobile designs. A coordinated effort to establish a standardized computer data base from which this knowledge can be extracted should be pursued. The NHTSA has developed and is maintaining such a data base. Currently, this data base contains almost 400 crash tests of recent model vehicles. In addition, an effort to determine the relationship between crash tests and real-world accident experiences should be better defined. Again, NHTSA is pursuing this activity. In June 1981, at the SAE Conference in Detroit, Mr. Hackney discussed a methodology for determining the relationship of crash parameters and injury measures such as that between the Head Injury Criteria (HIC) and Chest Severity Index (CSI) and the Abbreviated Injury Scale (AIS). These relationships, shown in Figures 1 and 2, were further explored by Hackney to determine the probabilities of serious injuries and fatalities. Comparisons were made to relationships obtained from the accident data files (using the change in velocity as the common denominator) and are summarized in Figure 3. It must be emphasized that these results are preliminary and further refinements are in progress.

Figure 1. Relationship of HIC and Head AIS.

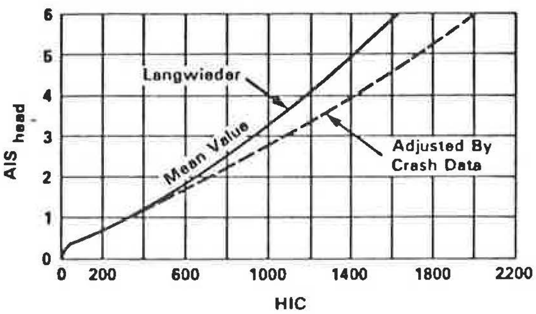


Figure 2. Relationship of CSI and Chest AIS.

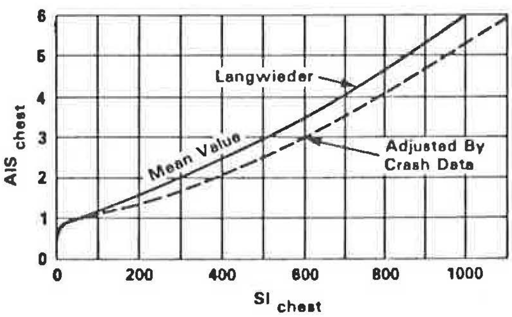
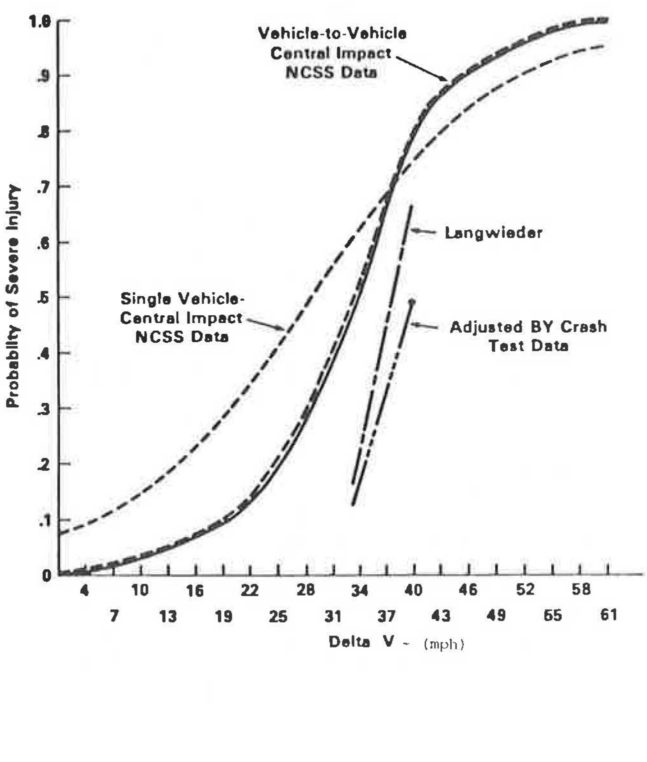


Figure 3. Logistic Curves for Front Impact Subsets (Age = 30 Yrs.).



SUMMARY OF PART 2

Jarvis D. Michie, Southsest Research Institute

In support of benefit/cost analysis procedures of roadside safety programs, the seven presenters in this session outlined data needs and limitations associated with current data acquisition methods using computer simulation and physical testing.

Ross delineated the need to have baseline data of the untreated roadside for use as a reference for safety improvement comparisons and appurtenances warrants development. Nordlin discussed the impracticality of using full-scale crash tests to investigate all possible collision conditions and the importance of evaluating appurtenance under field conditions. In evaluating field performance of appurtenances, Bronstad cautions the investigators of the importance in assessing the compatibility of the specific hardware with the traffic and site characteristics. Reilly stressed the need to acquire detailed clinical data from selected accident cases; in addition, he sees the need of establishing a substantial data base of inadvertent roadside encroachments that are generally not reported because the errant motorist is able to drive his vehicle from the accident site. With this information and with projections of vehicle sales trend, Reilly maintains that testing procedures and test matrices can then be validated or modified to correspond to actual conditions and, therefore, made more effective.

As a complement to vehicle crash testing methods during appurtenance development, computer simulations have been shown to be cost effective under certain conditions. However, Chiapetta has alerted the reader to difficulties and limitation of current simulation technology.

With regard to establishing a linkage between vehicle crash test severity and potential injury of vehicle occupants, Friedman discussed the use and limitation of anthropometric dummies and indicated that dummy responses are currently insufficient for use in the benefit-cost analysis procedures. On the other hand, Hollowell presented some promising findings from recent NHTSA efforts to establish a link between FMVSS 208 and accident severity.

From the standpoint of physical testing and analysis, data needs for cost-benefit analysis procedures have been assessed. Whereas considerable information pertaining to a specific appurtenance hardware items can be acquired before the item is introduced into actual service, it is recognized that extensive in-service evaluation including numerous collision cases is necessary to develop sufficient input to the cost-benefit equation.

Part 3: Session 2, Field Performance Studies: Evaluation and Data Issues

Forrest M. Council, Highway Safety Research Center, University of North Carolina

The second part of the overall program was designed to raise issues related to the use of field data in determining severity indices for highway hardware. To open the session, the moderator presented a brief introduction to the two basic issues or areas of interest: study design problems and accident data. Presenters were chosen to raise problems and to generate discussion in each of these two areas.

STUDY DESIGN PROBLEMS

WEAKNESSES IN CURRENTLY USED STUDY DESIGNS AND ALTERNATIVE RECOMMENDED DESIGNS

Lindsay I. Griffin, III, Texas Transportation Institute, Texas A&M University

While the study design area has many inherent problems, perhaps the most important involve (a) which criterion should be used in answering a specific question, (b) the pre-determination of sample size to be used to ensure that statistical significance and (c) the choice of and planning for a strong study design. This last issue, the choice of study design, is the most important of all. Because of its importance, this initial presentation will discuss the strengths and weaknesses of three designs that have been used to evaluate highway safety improvement programs related to roadside hardware. These include (a) the before/after design, (b) the before/after design with a comparison group and (c) the before/after design with a comparison group and a check for comparability.

The before/after design consists of two measurements in time separated by the imposition of a treatment. The assumptions which are made in using this design are (a) the after measure would have been the same as the before measure without the treatment and (b) any difference observed between these two measures is totally due to the treatment imposed rather than to any other cause. Testing to determine whether an observed difference is statistically significant is relatively straightforward with:

$$Z = (Y-X)/(Y+X)$$

where

X = accidents during the before period and
Y = accidents during the after period.

While very popular in the highway accident research field, this design is the weakest design possible. Any results determined with this design must be viewed with great skepticism. Indeed, two of the leading experts in research design, Campbell and Stanley, in a monograph entitled Experimental and Quasi-Experimental Designs for Research indicate that the before/after design is susceptible to all eight possible threats to internal validity. As such, they dismiss this design as a pre-experimental design. Similar sentiments have been expressed by other authors. Unfortunately, the design is still used by quite a few highway researchers, even in current studies. The disturbing part is that with little extra work, much more powerful designs, and thus much more reliable results, are possible.

An alternative to the simple before/after design, and one that can provide much stronger results, is the before/after design with a comparison group. In essence, a treatment is implemented at a given set of locations. A second set of locations (as "similar" to the first set as possible) is left untreated as a comparison group. Measurements are again taken before and after treatment is imposed in both sets of locations. The comparison made is between the rate of change of the treatment and comparison groups. (This rate of change comparison is the same as "predicting" the after level in the treatment group based on what happens in the comparison group and then comparing the observed after level to the "predicted" after level in the treatment group.)

The most appropriate statistical procedure to be used in this testing is:

Calculate tau = the cross product ratio = (BC)(AT)/(AC)(BT)

where

BC = accidents for the comparison group during the before period,
AT = accidents for the treatment group during the after period,
AC = accidents for the comparison group during the after period, and
BT = accidents for the treatment group during the before period.

Also, calculate VAR (ln tau) = (1/BC) + (1/AT) + (1/AC) + (1/BT)

Then,

Z = (ln tau)/(VAR (ln tau))1/2

This design can help protect against two threats that seriously affect the before/after design--regression to the mean and the "history" threat (other causes occurring at the same time as the treatment). The strength of this design rests on how comparable the comparison group is.

The final design discussed is referred to as the before/after design with a comparison group and a check for comparability. The difference between this and the preceding design is that multiple before and after readings are taken at both the treatment and control locations. The purpose of these multiple before and after readings (particularly those in the before period) is to determine whether or not the two groups were comparable (i.e., whether "trends" in the data are similar). Here, the treatment and comparison data in the period are first checked for "non-comparability" (independence) using a likelihood ratio chi-square:

G2 = -2 X ln (E/X)

where

X = observed accident frequency for a given condition (treatment or comparison) and a given time period (year) and
E = expected accident frequency for a given condition (treatment or comparison) and a given time period (year).

If the trends are comparable (not significantly different), the data in the periods are collapsed and a simple before/after with comparison group analysis is carried out just as was done for the second design. If the data are not similar, the evaluation is terminated since results will be meaningless. This design helps control for both underlying trends and regression effects.

In conclusion, the simple before/after design should never be used in highway accident research due to its inherent weaknesses. The before/after with a comparison group is a clear improvement. Even stronger is the recommended design--the before/after design with a comparison group and a check for comparability.

ACCIDENT RESEARCH ISSUES FACED BY THE NATIONAL TRANSPORTATION SAFETY BORAD

Roy Anderson, National Transportation Safety Board

The biggest problem faced by the National Transportation Safety Board (NTSB) in its attempts to improve the efficiency of the highway safety field is the lack of sound research data that are available to the agency. This lack of data results both from the size of the samples of raw data that are available to the agency and from the lack of good information that can be gleaned from other research reports. Basically, the problem facing the highway hardware community is that we cannot support what has been done in the past to Congress. The community cannot "prove" the benefit of the millions of dollars that have been spent on highway design (and in part on the roadside). We cannot specifically define which countermeasures are the best to apply, and the degree to which they are better than cheaper alternative countermeasures. Currently, information to make these judgments does not exist.

To better understand how this problem affects NTSB, the following information related to how the agency operates is presented. The NTSB is a small independent agency. It has a staff of approximately 350 people, some of whom are located in the headquarters office in Washington, D.C., with the remainder located in field offices across the nation. The NTSB has no regulatory authority per se but, instead, has as its primary role the oversight of the various modes of transportation. In the past, the majority of work has been done in the air transportation field. The NTSB's mandate involves assessing how well the various transportation agencies are using the technology that they have available to them, both in the sense of how well they are managing this technology and in the sense of how well they are finding and correcting failures in the technology. Thus, the basic headquarters and staff involvement is in both direct accident investigation and in studies of management of safety programs.

In the accident investigation area, each year approximately 15 of the total number of highway accidents that occur across the nation are investigated. Major investigations are conducted on approximately eight accidents per year. Thus it is obvious that conclusions drawn from accident investigations are not "statistical" conclusions, but instead must be characterized as "clinical" in nature. The agency in its investigation is attempting to determine the source of failure of a given system and then to use the data to convince the appropriate agency to correct this failure. The accidents to be investigated are selected on several criteria including "public interest" in the accident that has occurred, the size of the accident (in terms of number of fatalities or potential fatalities) or the degree to which an accident fits into a category where NTSB staff feels that a problem exists. In the major accident investigations, the staff is usually looking at a variety of issues to determine the probable cause of the accident. In the field accident investigations carried out in certain circumstances, only one major issue is usually examined.

An example of a series of accident investigations that were carried out because of a predefined problem involved the National Driver Register, a computerized multistate register of driving offenses. In relation to this specific problem, NTSB has investigated a number of large truck accidents involving drivers who had licenses revoked in various states, but were continuing to drive on licenses valid in other states. A second example of a problem area investigated by NTSB staff involves the safety of construction zones. Here a number of years' efforts were involved in documenting the problems related to roadway striping, timber barricades and other hazards in locations. Until a major accident occurred that involved fatalities, however, the Board itself was not convinced that a problem existed. This failure to recognize the problem existed not only because of the limited number of accidents that could have been investigated by NTSB staff, but because there were no good studies by other highway researchers indicating this to be a problem. The one sound study that did exist, the California study, was referenced extensively in NTSB's position paper. A final problem area that has existed for a number of years and continues to plague the roadside safety area is in the traffic barrier area. Here, NTSB has collected data for nine years concerning the failure of various traffic barrier designs beside the roadway. A problem exists in that while NTSB feels this to be a problem, FHWA has disagreed with the magnitude of the problem based on the low percentage of failures and the overall number of hits found in large-scale data bases (i.e., the problem has not been proven to be major when mass accident data sets are examined).

In terms of the outlook for the future of the highway safety field as related to the development and use of good research data in decisionmaking, one would have to conclude that the picture is rather bleak for a number of reasons. First, FHWA does not have a good enough grasp of the highway-related problems that exist to be able to prioritize these problems in a good management scheme. This lack of priority will hurt the agency, and thus the national program, in selling the program to Congress in the future. Second, good data are not being collected, recorded or used in many of the state highway agencies. While most states require police investigation of at least some accidents, some states do not computerize the needed data and even more states fail to carry out well done evaluations. Very little meaningful research is now ongoing. Not only are the states and the nation not developing new technology, but we are not even applying what we know to be good designs. This results in designs, which are inherently unsafe, continuing to be placed onto the roadsides, even in new construction areas. Many of these are designs that no knowledgeable highway engineer would allow in the field. While the issue of tort liability may press some states into improving their programs, it may also have the adverse effect of causing some highway engineers to decide to do less research in order to "not know" what problems exist and thus use ignorance as an excuse in court.

Attitudes must be changed, both at a local, state and federal level. Failure to do so will continue to hurt the program and thus the driving public for years to come. The United States is moving into an era in which less emphasis will be placed on new construction and less emphasis will be placed on spot improvement along our roadside. Less money will be available for safety work in general. Because of the influx of small vehicles mixed with even larger trucks, the fatality and injury curves are accelerating more rapidly than in the past. Without a change in our roadside hardware and our total highway picture, the United States will be in much worse shape 10 years from now than it is today. Without a change in our research methodology and the data we are using, we will still not know the answer to many of the questions that will be asked 10 years from now.

The only bright spot in this overall picture appears to be the NASS system. Here highway researchers must begin to specify the data that need to be collected and to supplement this system to get them collected. Special studies must be used more often and, when used, these studies need to be better designed. The NTSB feels that this NASS system can be one of the more innovative and beneficial changes that have been made in the highway safety research area in years.

PROBLEMS IN ACCIDENT DATA

The second major area where problems arise in field evaluations of highway hardware is in the data themselves. For discussion purposes, this major topic was further subdivided into (a) police data and (b) accident reconstruction data--the NASS system.

PROBLEMS ASSOCIATED WITH POLICE-LEVEL ACCIDENT DATA IN EVALUATION OF ROADSIDE APPURTENANCE PERFORMANCE

King K. Mak, Southwest Research Institute

Police data have long been used in a variety of ways in highway accident research including use in the identification of problems and the evaluation of countermeasures. Yet, problems exist in these data sets, particularly with reference to location identification, definitions and reporting criteria, accident data elements and environmental data elements.

Location Identification

Inaccurate location information is one of the major problems associated with police-level accident data. The main problem does not lie with the specification of route number, but with the estimated distance from a reference point. Rounded estimates (e.g., 500 ft., 1000 ft., 0.5 mi., 1 mi., etc.) are often used.

While this results in problems in many studies, two specific examples involve accidents on bridges and accidents in interchange areas. In regard to bridges, since the average length of a bridge is only 0.03 mi., the above noted rounding error results in very poor bridge-related accident data. In the interchange area, the same problem plagues the researcher trying to identify accidents that occur within specific parts of the total interchange (e.g., in the gore area of exits).

Definitions and Reporting Criteria

While poor definitions, the failure to use the proper terminology and failure to consistently utilize the specified reporting criteria can bias a given data set, the major problems arise when data sets from different jurisdictions have to be combined in a research study. Great care must be taken to transform all of the data to a common set of definitions and to a common reporting threshold. This may or may not be possible with a given set of jurisdictions.

Accident Data Elements

While researchers often complain about not having sufficient detail on the accident data to properly conduct a study, this problem is particularly acute with crashes involving roadside appurtenances, particularly where the object of the research is to carry out what might be referred to as a "clinical" study in which detailed information on the crash-related performance of the appurtenance is needed. Because the items "object struck" or "first harmful event" are generally so coarsely categorized, and because the incorrect use of nomenclature is so prevalent, it is very difficult and sometimes even impossible to segregate out the particular roadside appurtenance of interest. A specific example of this is in a study of luminaires where the terms "utility poles" and "luminaires" are often used interchangeably by police. In such clinical studies, in addition to knowing what roadside appurtenances have been struck, the researcher studying barrier impacts, for example, would also be interested in knowing:

1. What part of the barrier was struck?
2. What are the impact conditions (e.g., impact speed, impact angle, vehicle yawing, etc.)?
3. Did the barrier contain and redirect the impacting vehicle or did the vehicle penetrate, override or vault over the barrier?
4. What damages were sustained by the barrier and what damages were sustained by the vehicle?
5. What were the separation conditions (e.g., separation angle and speed, vehicle snagging, vehicle rotation, etc.)?
6. What happened after the vehicle was redirected?

Unfortunately, very little of this information would be available from police accident files.

A related problem in accident data elements is the problem of poor scales for vehicle damage and occupant injury severity. While an occupant injury-severity rating using K, A, B, C and No Injury is reasonably accurate in distinguishing between no injury, injury and fatal accidents, it is a very poor indicator of the severity of an injury. A more refined and accurate measure is required in much accident research.

Environmental Data Elements

In addition to the specific accident information noted above, additional environmental elements would also be needed by the researcher. Using the same example, the barrier study, one would also need information on

1. What type of barrier was struck and what are its physical and design characteristics?
2. What are the roadway and roadside characteristics (presence of curb, lane and shoulder widths, etc.)?
3. What were the horizontal and vertical alignments when the vehicle left the highway?

In summary, this paper has painted a rather bleak picture of police-level accident data, data that have many limitations. However, because such police-level data are the only tool (and thus the best tool) that researchers interested in the real world have to work with, it must continue to be used and strengthened. While the following papers specify some ways the police data can be strengthened, I feel that perhaps one of the most important ingredients to good police data is engineering input. While necessary, we, as engineers, very seldom ensure that our needs are met by the police by taking the time to work with them on their report forms or in their training. While this work on our part may not be a sufficient condition to good data, it is most certainly a necessary one.

POLICE ACCIDENT DATA: POSSIBLE SOLUTIONS TO SOME TROUBLESOME ISSUES

Charles V. Zegeer, Goodell-Grivas, Inc.

In continuing the discussion of police data problems, this paper will attempt to present some possible solutions that have been found in use in various states. The information used in the paper was taken primarily from research conducted for the National Academy of Sciences under NCHRP Project 20-5, "Use of Data Processing and Accident Location Systems for Highway Accident Analysis."

As a first step in understanding possible solutions to problems with police data, it is necessary to understand what data problems exist and to categorize these problems in a meaningful manner. For discussion purposes, the problems discussed in this paper will be categorized into the following four groups:

1. Location-related problems.
2. Problems associated with the data on police accident report forms.
3. Problems associated with developing and utilizing computerized data bases (accident data as well as roadway data).
4. Problems associated with conducting project evaluations.

Location-Related Problems

Accurate accident location is a key element in most highway research studies. Numerous reference methods exist and are used by various states and include the milepost method, reference post method, coordinate method, link-node method and others. Some of these methods, when used properly, can help solve many of the accuracy problems that have been cited above. Some agencies have made great strides in obtaining accurate locational information by investing the necessary time and efforts, such as working closely with police agencies, field posting of referencing signs and using detailed route logs and reference maps by office coders as done in California, to carefully locate and reference individual accident sites.

Locational accuracy is also being enhanced by the use of computerized highway networks, which are computer files containing the route names or numbers and linear distance information. An example of a successful computerized network is the Michigan Accident Location Index (MALI), which provides fast and accurate traffic accident information for all public roadways within the state. Many large cities use a Dual Independent Map Encoding/Geographic Base File (DIME/GBF) system, which was originally developed by the U.S. Bureau of the Census for coding census data, but has been applied to accident location, such as the system tested in Rhode Island. The file commonly consists of not only street names and segment lengths, but also x and y coordinates for each node, geographic area codes, block numbers, zip codes, addresses and other detailed information to enhance locational accuracy.

Problems Associated with Quality of the Data on the Forms

As stated in the preceding paper by Mak, one of the primary problems with research data is the quality of the data collected on the forms. For example, the standard data item "accident cause" is perhaps one of the worst data items that exist. It could be one of the more important in terms of accident causation studies. For example, in a study of rear-end accidents, one invariably finds that the accident cause is "following too closely," an obvious but not very enlightening finding. The problem that exists is that states generally collect too much "unused" data on their forms. A study of one state's accident form and related research indicated that it only uses about 7 percent of the data that are collected by the police in that state for highway safety or research purposes. To help solve this problem, the researcher should never ask the police to collect "all the data you could ever want," but rather should selectively pick which items will be used. By reducing the number of items collected, efforts can then be made to ensure better quality for those important data elements. In addition, where special data are needed, researchers could utilize supplemental data forms which can be put in place, used for short periods of time, and then removed from the data collection requirements.

Problems Associated with Computerized Data Bases

There is a growing need in every state to merge accident data, traffic data (volumes, speeds, etc.) and roadway data (geometrics, roadway obstacle data, etc.), which are often located in separate files. This merging process is important for two basic reasons. First, a computerized merge is needed since the researcher very often needs to be able to choose or select a limited number of specific data items from different files for use in a given analysis. Thus he or she only needs to "match" certain accident data items with selected characteristics items and, since the entire record is very seldom needed in any analysis, the length of the record makes it very unwieldy and inefficient. Second, the state often needs to be able to merge separate files to produce routine, periodic calculations of accident rates or other data summaries to be used in required reports.

While most states can merge data concerning the primary roadway system, very few have systems that can merge data related to secondary or local road systems. Several states have little or no capabilities to merge their computer accident file with their roadway or traffic file. Perhaps one of the more difficult and costly types of data to collect and extract from any file are inventory data related to specific highway "hardware" (i.e., bridges, poles sign posts, guardrail, etc.). Often the researcher not only needs to know the number of a specific type of hardware that is present per mile of roadway, but also needs such specifics as the distance of obstacles from the roadway, the obstacle type, whether the pole is breakaway or not, the type of breakaway, the type and condition of the crash cushion, etc.

To collect such roadway data, some states have gone to an on-the-road sampling system where the road is actually driven by a team of observers who make counts of various hazards and highway hardware that are present on the roadside. An alternative method that might save both time and money and would use an existing system would involve the use of the photologging systems that already exist in many agencies. The photologging system can be sampled and, while sitting in his office, the data collector can "drive" the section of roadway obtaining the data that are needed for the inventory. In summary, while computer merge problems are not easy to overcome, the fact that most states have overcome these to some extent indicates that computer software systems do exist to make this possible. Also, numerous statistical software packages are currently in use to provide a wide range of statistical analyses (i.e., SPSS, DART, RAPID, SAS and others).

Problems Associated with Evaluations

Any discussion of police data problems should end with a discussion of why the data that are collected are not used in better evaluations. Even with their problems, the existing data could be used to give researchers answers to many of the questions that we face. Review of the states' systems indicate that perhaps the main reason for the lack of good evaluations is the fact that evaluation is usually given a low priority by most highway agencies. In some cases, this low priority may stem from the fact that the engineer is not anxious to find out what projects have "failed" in terms of accident reduction. Second, there are problems with utilizing the data, since most states do not maintain a computerized data base that is readily suitable for performing evaluations. Currently, however, some states have developed or modified software packages that will allow for systematic and economical project evaluations using computerized systems. The Michigan system, for example, makes the use of the previously described before/after with comparison group design quite simple, in that characteristics data are stored by homogeneous sections and, after certain sections are treated, comparison sections can be drawn from the remaining untreated pool by the computer itself, matching on certain roadway and traffic variables.

In summary, better police data and better use of police data can result from careful planning on the part of the engineering researcher. For better location information, the researcher should look to better reference systems, to increased and improved training for the police officers and office data coding techniques and, possibly, to computerized highway networks. In relation to the problem of improving the quality of the data elements themselves, the researcher should understand what data items are actually required and then select the best available data bases to meet those needs. The collection of roadway data may be better achieved through photologging or other techniques, compared with costly field surveys. The researcher should always attempt to simplify and standardize the definitions used and insist on using valid statistical techniques and experimental designs. In any merged systems, extra attention must be placed on handling special locations, such as interchanges, bridges and gore areas. In addition, increased emphasis should be placed on improving edit programs such that the computer itself can detect some of the errors in the data. In terms of routine collection of accident and roadway data, the cost of collecting the data must be weighed against the benefits to be gained from it before the collection of any variable on a wide-scale basis. Finally, the researcher must decide how best to use the data that exists in answering the question at hand, and after the research is completed, it should be disseminated widely so that we can learn from each other's mistakes and successes.

POTENTIAL USE OF THE NATIONAL ACCIDENT SAMPLING SYSTEM (NASS) IN STUDYING ACCIDENTS INVOLVING ROADSIDE OBJECTS

Russell A. Smith, National Highway Traffic Safety Administration

In any discussion of the potential use of the NASS system in studying accidents involving roadside objects, one must have some understanding of the system itself in terms of the accidents that are to be sampled, the accident elements that are available and the data collection methods used. NASS itself is a sample of all police-reported accidents. It is designed to provide nationwide estimates of selected accident statistics and to support design and evaluation of safety countermeasures. The sample is designed to provide these national estimates; however, the sampling error may be unreliably large for certain estimates. When this occurs, special studies can help overcome small sample sizes and can help collect special data not otherwise collected.

The data are collected by small teams of trained persons (2-4), most of whom are college graduates. Data collected include information collected at the accident site, inspection of involved vehicles, interview of drivers and information from police reports, medical records of injured persons and driver history from license files. Photographs are taken by the team and are retained for future study. The data are subjected to an extensive review and edit procedure to ensure quality and consistency.

The sample design is based on a two-stage selection of accidents. The first stage involves the selection of "lists" of police reported accidents by choosing cities or counties among groups of 1280 such "lists." These lists are called Primary Sampling Units (PSU). Because we do not have a master national list of accidents, we assume that the relative size of these lists and, consequently, their probability of selection is proportional to the population in this associated county or city. Currently, 75 PSU's are planned for NASS including large central cities, suburban areas, cities, towns and rural areas. The second phase of the selection involves selection of accidents within the list of a city or county. This is done by random selection within groups or strata defined by accident type (pedestrian, truck, motorcycle and passenger car) and by injury severity (fatal, A-injury or minor injury and property damage). Each of these accident selections is based on a known probability of selection whose inverse is the "weighting factor" for the selected accidents. These weighting factors are used to expand the sample to national estimates. The selection of a given accident occurs approximately four days after the accident itself has occurred.

This scheme can be demonstrated to work well for certain phenomena including number of involved persons by level of injury, age, sex and vehicle type, etc.; number of involved vehicles by vehicle type and size; injury rates to occupants by crash type (percent of serious injury in head-on accidents).

The data are also useful in determining incidence of injury associated with seat belt use, helmut use, contact with vehicle components such as steering wheels or windshields, reported alcohol use, prior driving records described by convictions, and other factors. Because there is no associated exposure or "opportunity to crash," data available to compare with the accident data being collected, use of these data in studying accident prevention questions is somewhat limited. However, the data will be useful in studying such measures when joint efforts in NHTSA and FHWA to collect companion exposure data reach fruition.

Of interest to this group is the use of the

NASS system in the collection of roadside hardware data. The NASS data can be used to estimate the number and characteristics of impacts with roadside hardware and objects. However, without a roadside inventory, it is difficult to assess the reliability of the off-road environment in the 75 NASS PSU's as a sample of the national picture. Because guardrails, median barriers and bridge rails are prevalent in the roadway environment, it is likely that these objects are reasonably represented. Unusual types of objects may not be so well represented. For example, because breakaway poles and crash cushions are less often in the environment and thus less often in the sample of accidents collected, true national totals may be unreliable for these hardware. As shown in Table 4, the yearly total of crashes involving certain hardware is very limited.

NASS, as currently designed, is best suited for study of the performance of roadside objects when struck by vehicles. This would include measures of outcome to occupants (i.e., injury rates given impact) and observations of special features such as rollover, vaulting, undesirable interaction between vehicle and structure and any other feature whose attributes can be specified in the data collection protocol. Some of these data are not now collected. However, the fact that NASS is in place and that the teams can be trained to collect data in special collection processes means that data such as these could be included in the system. (Data that might be collected in the support of a study of off-road objects and roadside hardware are type of guardrail; height of guardrail; location of impact in relation to guardrail end; length of guardrail; end treatment on guardrail; post spacing and post type; location of guardrail relative to roadway; length of contact between vehicle and guardrail; angle of impact; performance--vault, penetration, override, redirection; vehicle rollover; scene sketch with vehicle trajectory; and photographs of vehicle, guardrail damage and surrounding roadway and roadside. Similar data could be obtained on median barriers, breakaway poles, crash cushions, bridge rails and other roadside hardware.) Indeed a special study on this subject, funded by FHWA, is now underway.

In summary, while modification of the system would be required to collect specific roadside-hardware-related information, and while there is a need for exposure data to be used in conjunction with the accident data now being collected, the NASS system can in the future provide useful information to the highway researcher.

Table 4: Frequency of Impacts to Roadside Hardware and Other Objects and Motor Vehicles in Police-Reported Towaway Accidents[a/]

OBJECT	PRIMARY IMPACT		SECONDARY IMPACT	
	NO. IN SAMPLE	NATIONAL ESTIMATE[b/]	NO. IN SAMPLE	NATIONAL ESTIMATE[b/]
Poles	176	172,900	47	36,600
Breakaway poles	6	5,900	2	4,000
Guardrails	53	56,800	49	49,500
Median barriers	7	10,700	11	13,600
Bridge rails	5	4,800	5	4,000
Abutments and overpass supports	20	18,500	8	5,900
Crash cushion	2	1,900	-	-
Impacts with other objects	721	773,000	552	540,000
Impacts with motor vehicles	2,696	3,176,000	491	480,000
Impacts with non-motorists	191	203,000	22	21,700

[a/] 1979 NASS data from 2,623 accidents (approximately 20 percent system design) observed in recording data on no more than 2 impacts per involved vehicle. The 2,623 accidents include motorcycles and cars and trucks in towaway accidents.

[b/] These estimates may be unreliable because of small sample size.

LIMITATIONS OF THE CURRENT NASS SYSTEM AS RELATED TO FHWA ACCIDENT RESEARCH

Julie A. Cirillo, Federal Highway Administration

This paper will include a discussion of the NASS system from the highway user's point of view. It should first be noted that if there is a segment of the highway research community who can use NASS as it now exists, it is the segment represented by the researchers at this conference--the researchers interested in highway hardware.

I will first discuss the problems with the existing NASS system and then move to the areas in which NASS can help the highway researcher. First, the NASS system as it exists cannot give statewide estimates of the accident problem. The sampling scheme being used is designed to produce national estimates, and is not set up to provide estimates within states. Second, and most important, there is currently no way to link the accident data collected with any exposure data. Thus, rates involving million vehicle miles or other highway-related measures cannot be calculated. There is currently a great deal of ongoing activity to help correct this problem, but major problems still exist. Third, it should also be noted that the rates that are of interest to the NHTSA side of the U.S. Department of Transportation are not necessarily the same as the rates that are of interest to FHWA. (Indeed, herein lies part of the problem.) Thus, while the emphasis in the data collected is on accident severity, which is a plus for the researcher interested in highway hardware, this is a negative bias for the researcher who is interested in countermeasures that could prevent accidents. As noted earlier, the NASS system only studies accidents. There are no highway sections where no accidents have occurred.

Fourth, there are problems with the accident reconstruction processes used with barrier crashes and multiple-hit situations. The computer programs that have been developed to reconstruct accidents involving barriers are not very good. So far, the emphasis in computer reconstruction has been on the driver and the vehicle, and it is for this reason that the highway barrier programs are not as adequate as they might be. Fifth, there are some problems with the basic information collected, particularly with some definitions that have been used up until now. As an example, any intersection that included raised channelization would be coded in the current system as a "divided highway" segment, a definition that would mean that these channelized intersections would be grouped with other divided highways if a researcher were interested in pulling out all accidents on divided highways. Thus, it is fair to say that FHWA and NHTSA are not yet completely together on the definitions to be used. There are ongoing efforts to correct these problems.

Let us now turn to what the NASS system can do. First, it can provide national estimates of the accident picture. These are very adequate estimates of type of accidents, total numbers of accidents, accident cost, accident severity, etc.

Second, the NASS system can help carry out what we could refer to as "performance evaluations," particularly evaluations of highway hardware. The system can be structured to collect specific data items to see if a piece of hardware is functioning properly in terms of its severity reducing benefits.

However, even in carrying out these performance evaluations, the NASS user interested in highway hardware must be aware of a basic issue--available sample size. In most highway evaluations, the researcher is interested in analyzing the performance of given pieces of hardware while controlling the numerous other factors such as speed of impact, size of striking vehicle, width of shoulder, presence or absence of curb, etc. Thus, many of these performance evaluations will be done in somewhat of a factorial design. However, as any researcher who has studied factorial designs is aware, an increase in the number of factors can greatly increase the required total sample size. While it may be possible to initiate special studies with the NASS system that can help increase the sample size for various questions, these special studies will cost additional money. Thus, the researcher must use the absolute minimum sample size in all cases, whether the study is using continuously sampled data or is a special study in which special data are collected.

For certain objects beside the roadway, the continuously sampled data can be used to carry out performance evaluations under certain conditions. For example, the items such as trees and guardrails are found along the roadside in enough places and are thus struck enough times that an adequate sample may exist. Using estimates based on one year's NASS data, it is possible for the researcher to estimate the length of data collection time required to fill the cells of the factorial design of interest. While various examples could be cited, suffice it to say that in most cases the researcher must compromise on the number of controlling variables. FHWA has funded two special studies, involving (a) longitudinal barriers and (b) crash cushions. To support the point made above, it is noted that even when compromising on a number of different factors and thus reducing the sample size to a bare minimum, it is estimated that the longitudinal barrier study will require 3 years for adequate data to be collected and the crash cushion study will require 6 years of data. Thus, in most NASS studies, the researcher interested in highway hardware issues must anticipate a study that will require both lots of money and lots of time to complete.

In addition to the problems of defining the cells for a given study and of collecting the data, the researcher must also remember to define the specifics of his data carefully enough so the data collectors can collect them accurately. It should be remembered that the data collectors are not accident investigators, but are indeed data collectors. Precise definitions are required..

In summary, the highway-related researcher who is interested in using the NASS system first must (a) carefully think through the problem of interest to him or her, (b) must decide how to compromise on the number of factors that might possibly be of interest, (c) must define variables as specifically as possible and must provide adequate training for the data collectors and (d) must ensure a method of good quality control for the data while they are being collected.

Thus, as it currently exists, the NASS system may be of limited use to the highway accident researcher. To make this system of greater use to FHWA and other highway researchers, however, will require major changes. The biggest requirement is that good exposure data must be collected and must be merged with the accident data now being collected. There is a need to periodically review the system to be sure that data items that are not being used are culled out in order to decrease the number of unused items and increase the quality of those that are collected. Finally, as a suggested major change in the system, I would suggest that the NASS system as it now exists be scrapped, or rather modified, as a system that, instead of monitoring accidents, monitors highway segments. By sampling from all the segments across the nation and monitoring certain of these segments, accident data could be collected from accidents that occur on these segments and exposure data could be collected at the same time. This would change the nature of the NASS system in that those teams that are currently at one location pulling accidents from one set of files would become "traveling salesmen" who would travel in a larger geographic area to continually monitor numerous segments of highway. It is obvious that the problems with changing the system to this new format would be very formidable. However, drastic changes like this should be carefully considered in order to make this system as useful as it possibly can be for the researcher interested in the highway side of the accident problem.

SUMMARY OF PART 3

Forrest M. Council, Highway Safety Research Center, University of North Carolina

As might be expected, the above six papers generated a great deal of discussion among the participants at this workshop. While many points were raised in these discussions, two issues of interest arose.

First, in terms of terminology, it became apparent to those in the workshop that two types of in-the-field accident research were being discussed. For lack of better names, these two types of research might be termed "statistical research," which is aimed at evaluating how well a given piece of hardware reduces injuries to occupants of striking vehicles, and "clinical studies," which are aimed at determining the failure modes of a given piece of hardware once it is put in the real world. These clinical studies are used to validate the results of the crash testing. While many of the requirements for these two studies are similar, the data and study design needs are not always the same.

While there is a great need for clinical studies, there is perhaps an even greater need for the well-controlled field statistical studies that provide information concerning how well a design actually works--its benefits in terms of severity or frequency reduction. Indeed, if the tough question being asked by Congress, consumer groups, state legislators, the U.S. General Accounting Office and other fiscal analysts is one of "how many lives can it save" (i.e., how well does it work), then the second type of research, the statistical study, is the most important in that it alone can provide severity reduction factors to the cost/benefit analyses so desperately needed.

This lack of good statistical studies generated the second major point of the discussions. There was a strong feeling that one major roadblock to the improvement of accident research is the system under which the evaluations must now be conducted. The current requirements for "evaluation" of all improvements by every state in every project results in inadequate funding for a given evaluation, pitifully poor research designs and thus results of little or no value. As noted in the discussions, there are alternatives to this existing system. For example, rather than require the "evaluation" of every improvement project conducted in a given state, a system could be devised that would require the state (perhaps as an option) to conduct one well-designed evaluation in which control or comparison groups are required. This single well-designed evaluation could be done in place of the numerous before/after studies that are now conducted. In this manner, at least one piece of new information would arise from each state each year. Thus, in summary, while discussion indicated that inertia and other pressures continued to make changes in the existing system difficult, such changes are needed and are worth working for.

Part 4: Session 3, Group Consensus on Key Programs and Recommendations

As stated in the Introduction to this Circular, pre-workshop and workshop written opinions of key data problems were used to select four key issues for more detailed subgroup discussion and recommendations. These findings were then presented to the workshop attendees at large. The four topics selected were

1. Use or Revision of Existing Data Banks to Obtain a More Efficient or Improved Analysis of Accidents with Roadside Features;
2. Clinical Engineering Analysis of Performance of Roadside Features in Real-World Collisions;
3. Utilization of Simulation to Predict Probability of Injury; and
4. Linkage Between Physical Testing and Likelihood of Injury.

The time allotted in the workshop for this process was quite limited. Thus in some cases the identification of an area of the workshop as a top-priority issue in obtaining needed impact severity data is in itself the contribution of this workshop.

ISSUE: USE OR REVISION OF EXISTING DATA BANKS TO OBTAIN A MORE EFFICIENT OR IMPROVED ANALYSIS OF ACCIDENTS WITH ROADSIDE FEATURES

Julie A. Cirillo, Federal Highway Administration, Moderator

Other group members: Roy Anderson, Lindsay I. Griffin, III, Russell A. Smith, Harry W. Taylor, Edward J. Tye, Charles V. Zegeer

Methods of improving evaluations of safety appurtenances was the basic topic of our subgroup. Much discussion centered on the design of the evaluation. Use of NASS for this type of special study was also discussed. In general it was agreed that:

1. Well-designed in-service evaluations of accident countermeasures is one of the biggest gaps in the safety field.
2. Requirements to evaluate every safety improvement are a big deterrent to good evaluations.
3. Some policy change may be necessary to allow states to undertake a limited number of well-designed evaluations.
4. Use of a NASS special study to do evaluations may be feasible.
5. Proper selection of sections for installation of countermeasures is critical for accurate evaluations.
6. Standard evaluations are important for transfer of information.

ISSUE: WHAT METHODS CAN BE USED TO ACQUIRE OR DEVELOP IN-SERVICE COLLISION PERFORMANCE DATA OF ROADSIDE APPURTENANCES?

Wayne T. VanWagoner, Wayne T. VanWagoner & Associates, Moderator

Other group members: Lester A. Herr, David Hustace, King K. Mak, Robert J. Reilly, Flory J. Tamanini

After considerable discussion of the type of collision data that should be of primary concern to this undertaking, a conclusion was reached that purely statistical performance and analysis data were not what was wanted. Rather, data of a clinical nature such as of vehicle impacts, appurtenance performance, highway environment and specific collision performance information associated with each type of safety device would be relevant. Depending on the appurtenance system being considered, the desired pertinent data may possibly lie somewhere between clinical and statistical in nature. This would include descriptive information such as size and weight of impacting vehicles, number of collisions, angle of impact, resultant damage and personal injury and system performance.

The group next discussed who should do it by considering the pros and cons of four distinct resource bases: insurance companies, transportation agencies (state, county, municipal, police), public entity and private sector and NASS system (PSU's). After much deliberation, it was felt that the transportation agencies were the most qualified and better-suited groups to perform the data acquisitioning for collision performance of safety devices on our transportation network. Only new systems should be included in this endeavor because of the urgency for the required greater performance of smaller and lighter-weight automobiles. Further discussion emphasized the many complexities associated with evaluating existing installations in this program. When detailed clinical data would be required, the PSU's or private accident investigators could be employed.

The planned program for the collection of collision performance data should be capable of short-term as well as long-term continuance activity. The developed program must be implemented with conditions of the real world in mind, i.e., considering actual field conditions. There should be a trial period for experimental design. Failures and successes of systems under evaluation should be recorded.

Because of personal decisions, subjectivity and appurtenance performances, two types of studies must be contemplated: system performance having recorded accident reports and system performance without accident reports.

Optimum use of photographic recording and on-site visual reports should be considered to supplement written accident report data by police, eyewitnesses, etc. In some cases, remote sensing, TV camera systems, etc., could be most worthwhile for the purpose. For on-site visual reporting, there must be involved personnel who have the best experience background with the technology associated with the contemplated system in order to determine actual collision performance. Employment of maintenance organization personnel could be rather effective and productive for performing this task. With experience and training, subjectivity in evaluations could be greatly reduced. Proper use might also be made of some degree of accident reconstruction, noting the attitude of the vehicle on contact with the appurtenance as well as information detailing the dynamics of the vehicle and kinematics of vehicle occupants.

ISSUE: THE LINK BETWEEN CONTROLLED VEHICLE CRASH TESTS AND LIKELIHOOD AND EXTENT OF OCCUPANT INJURY IN A SIMILAR REAL-WORLD COLLISION

Eric F. Nordlin, California Department of Transportation, Moderator

Other group members: Jeffery A. Bloom, Edward R. Post, Maurice E. Bronstad, William L. Raymond, Hayes E. Ross, Jr.

The following statements summarize the group's consensus:

1. Over the past 20 years or more, a great number of controlled crash tests have been conducted involving a fairly broad range of vehicles and a wide variety of highway safety appurtenances. Test variables have included impact velocity, impact angle, point of impact on the vehicle and/or the appurtenance, terrain conditions, etc. Data acquisition systems of varying capability have been employed to document the dynamic and the kinematic responses of the crash vehicle and the appurtenance. In most of the tests, the crash vehicle has contained one or more dummy occupants. In all of these crash tests, the pretest and posttest conditions were thoroughly documented by still photography. In most of the tests, the entire crash event, including dummy movements, were documented on high-speed film. Also, the responses of accelerometers mounted in the occupant compartment of the vehicle, and sometimes in the dummies themselves, were often recorded throughout the crash event.

2. In summary, crash test researchers know what will happen to the vehicle (acceleration, momentum change, velocity, trajectory, damage, etc.) during collision with a wide variety of highway safety appurtenances or can acquire such data through further crash testing when required.

3. Computer simulation programs are a valuable supplemental source for data on crash vehicle dynamics and kinematics during interactions with various highway appurtenances and/or terrain conditions provided they have been validated with the data from a sufficient number of crash tests, particularly tests that "bracket" the area of concern.

4. Crash test researchers have developed and/or used various "ballpark" criteria to estimate the likelihood of serious injury or fatality (a life-threatening situation) occurring in a specific vehicle/appurtenance crash test. These criteria have been based on the dynamic and kinematic data acquired from a controlled crash test, i.e., vehicle damage (body crush, occupant compartment integrity, etc.); vehicle kinematics (rollover, rebound, etc.); vehicle and/or dummy acceleration responses; degree of occupant restraint (unrestrained, lap belt, shoulder harness, etc.); dummy damage and movement; etc. These criteria have generally been developed from research performed by other than the normal highway research community and financed by NASA, NHTSA, etc. At best, these criteria have produced conservative estimates or predictions on the likelihood of serious injury or fatality occurring in a specific vehicle/appurtenance crash test. These criteria have not been capable of producing occupancy injury/fatality

estimates in the more detailed and exact terms (the probability of property damage, injury or fatality) needed to compare appurtenance or safety improvement alternatives on a cost/benefit basis.

5. The relationship between occupant safety and vehicle dynamics during interaction with a highway appurtenance is very tenuous because it involves to many widely varying factors such as occupant physiology, size, seating position, attitude and restraint and vehicle interior geometry and padding. For this reason, it appears that a "general" tie could best be developed between vehicle compartment acceleration and the probability of occupant injury. This tie should probably be based on unrestrained occupants unless the use of restraint systems becomes mandatory in the future. The development of such a tie would enable researchers to go back to make new injury severity judgments for past vehicle/appurtenance crash tests where good acceleration data were documented.

6. It is reasonable for the minimum acceptable occupant injury levels to vary, dependent on the type of highway safety appurtenance involved. This is on the basis that the "art of the possible" enables lower impact resistances to be achieved, for example, with small highway signs compared with crash cushions.

7. Efforts are underway by others, such as under NHTSA sponsorship, to develop an improved instrumented anthropomorphic dummy that would be more capable of simulating human movements and recording human injury indicators in the occupant compartment during a vehicle/appurtenance crash test. The development of an improved dummy would enable researchers to make more detailed and accurate injury severity predictions. The dummies currently used in vehicle/appurtenance crash tests do not provide this capability.

8. Efforts have been made in the past by researchers such as Michalski in Oregon and Olson in Texas to relate the dagree of injury sustained in an accident to the vehicle damage. Although considerable additional work would be necessary, it may be possible to relate the observed type and magnitude of vehicle damage to occupant compartment accelerations, which in turn could be related to occupant-injury severity.

9. A better tie between crash test data and "real-world" accident injury severity could also be developed by reconstructing actual accidents where vehicle/appurtenance variables such as occupant restraint, vehicle damage, impact speed, impact angle, etc., and the actual level of injury are known. Known accidents could be reconstructed in controlled crash tests and simulated in computer programs. Through this process, the relationship could be developed between the data currently acquired in a vehicle/appurtenance crash test and the severity of injury that occurs in real-world accidents where the parameters are similar to vehicle/appurtenance crash tests already performed. This would reduce the cost of such an effort.

ISSUE: UTILIZATION OF SIMULATION TO PREDICT LIKELIHOOD OF INJURY

William T. Hollowell, National Highway Traffic Safety Administration, Moderator

Other group members: Richard L. Chiapetta, Keith Friedman, David J. Segal, Lawrence F. Spaine

The discussions first centered about the role simulation has in the benefit evaluation for a proposed countermeasure to be introduced to the highway roadside. In considering all the parameters associated with the accident environment, it was concluded that crash testing alone provided limited data for a full benefit evaluation, and therefore simulation could fill the data needs provided that a meaningful analysis could be accomplished. The essential ingredients of a meaningful analysis included: an accurate depiction of the accident environment, an accurate (qualitatively and more desirably quantitatively) vehicle-roadside object simulation, an accurate occupant model and an accurate injury predictor model (based on deterministic occupant responses). The discussion then was directed toward each of the simulations.

The vehicle-roadside object simulations were first discussed. In particular, the status of the GUARD, CRUNCH, BARRIER VII and HVOSM models was presented with a particular emphasis placed on the data needs of the models for simulating the accident environment. Such data as soil-post interactions were mentioned to be lacking. A special concern expressed was the validation of simulation output compared with crash test results and/or accident reconstructions. Also, the changing fleet of automobiles presents a benefit evaluation problem in that an accurate projection of fleet distribution and characteristics are required for the evaluation effort.

The occupant models were discussed. It was generally agreed that, for the accidents simulated, a three-dimensional occupant simulator was required. In particular, the Calspan 3-D Crash Victim Simulator (CVS) was discussed. The particular data needs for this model included accurate data for modeling various size occupants, accurate geometry of the compartment interior, accurate energy absorbing characteristics of the vehicle interior components, accurate crash pulses from the vehicle-roadside object simulations, accurate models of the restraint systems, etc. Of prime importance was the need to make the CVS model user friendly. In that detailed data sets are required for the model, it was determined that efficient handling of data sets would lead to fewer man-hours required by the engineer to construct the model for the analysis.

The discussion next centered on the prediction of injury and hence leading to the prediction of the likelihood (or probability) of injury as related to physical information. First, the transformation of results processed from crash test data to injuries observed in the accident environment is required. Second, responses calculated from occupant models are generally different from those obtained from crash testing. Hence, a transformation from occupant simulation is required to close the loop compared with the injuries observed in the accident environment. Ongoing research being conducted by Chi Associates (probability of injury) and the University of Virginia /Safety Systems Optimization Model (SSOM)/ was discussed as to how these goals are being approached.

The concluding discussion then centered on performing the benefit evaluation once the models are in place. Again, the SSOM was discussed as to how that model approaches the evaluation. In addition, the Benefits Prediction Model (BPM) was discussed.

APPENDIX A

PROBLEM STATEMENTS ON "THE MOST IMPORTANT SINGLE ISSUE RELATING TO SEVERITY DATA"

These problem statements were identified and submitted by participants prior to the workshop and were used as planning guidance by the program committee.

1. Title: Utilization of Accident Severity Data in Cost-Effectiveness Procedures for the Selection of Countermeasures That Have the Best Benefit/Cost Ratio for the Situation at Hand

Problem Statement: Many sponsored safety R&D studies have been completed with excellent results. Following publication of the results, there is very little, or no, follow-through on the actual employment of cost-effectiveness techniques or procedures in making appropriate budget allocations and countermeasure selections. The publication and dissemination of R&D results and dependence on states' initiatives do not appear sufficient to justify the expenditure of millions of dollars for R&D where no evaluation of the implementation value is made.

Solution: Make a study of existing cost-effectiveness procedures for determining the allocation of funds in selecting countermeasures that have the best benefit/cost ratio. Select one procedure that is most likely to be used by state agencies because of its simplicity. Conduct a correlation study of the fatalities, injuries and property damage severity factors associated with vehicle collisions with natural and man-made roadside objects. Make selections from the listing of highway safety countermeasures presented in D-20: Comparison of Effectiveness Ratings (The National Highway Safety Needs Study, March 1976). Using the selected cost-effectiveness procedure, fund programs in six states, regionally distributed, to determine safety priority programs and resource allocation to implement the selected countermeasures. Referring to the GAO Report, CED-80-87, July 1980, "Highway Safety Research and Development--Better Management Can Make It More Useful," we find highly critical review comments relative to NHTSA and complimentary ones on FHWA's R&D procedures. However, the GAO Report was critical of the inadequate interest and follow-through by FHWA and the states to use and evaluate implemented research results. On page 52 of the Report, one sentence in the quoted NCHRP statement typifies this concern: "... it simply does not make good sense to invest millions in research on critical problems and then not give adequate attention to a determination of the implementation value of the findings."

2. Title: Dissemination of Research Results to the Practicing Highway Engineer

Problem Statement: Extensive research has been conducted, and will be in the future, concerning roadside countermeasures. However, the results, conclusions and remedial measures are not filtering down to the engineers designing highways.

Solution: A task force, possibly a subcommittee of A2A04, should accumulate research results on a regular basis, formulate a consensus of results and conclusions, and periodically publish these data in a format that the highway design engineer can readily apply to his or her work.

3. Title: Establish Appurtenance Collision Performance

Problem Statement: Establish collision performance of selected appurtenance for a wide range of impact conditions (i.e., vehicle type and size, impact speed and angle, etc.) in terms of consequences of each collision (i.e., vehicle trajectory, occupant injury, property damage, etc.)

Solution: Acquire accident data for selected roadside feature or appurtenance. Should have 100 to 200 cases after screening out improperly maintained installations. Estimate impact conditions through reconstruction procedures. Define consequences of collision in terms of vehicle penetration, redirection, rollover, pitchover, occupant fatalities, injuries, property damage. Possibly determine cost of collision in terms of impact conditions by means of multiple regression techniques.

4. Title: A Simple Impact Severity Descriptor

Problem Statement: In order to compare the safety aspects of various highway appurtenance designs, a simple ranking system based on something similar to the AIS scale, which assigns a severity descriptor to an impact condition, is needed. The descriptor would have to be based on the worst-case vehicle (mini-car) and would vary for impact speed and angle. The impact speed and angle could be selected by the user based on conditions of the highway site. The use of a simple severity descriptor eliminates the requirement that a person be able to understand the test data, which may not make any sense to him or her.

Solution: In order to assign a descriptor to an impact situation, the test results (deceleration, change in momentum, vehicle physical conditions) need to be tied to occupant injury potential. This can be done by utilizing research indicating occupant-injury potential based on the various parameters and combining this research into a system of injury ranking.

5. Title: Performance Evaluation of Roadside Safety Appurtenances

Problem Statement: The performance of roadside safety appurtenances is mostly evaluated on the basis of a small number of full-scale crash tests and some parametric studies using simulation techniques. The measure of effectiveness is some predetermined criterion based on vehicle kinematics and kinetics, such as acceleration level, momentum change, etc. However, there is a missing link between these measures of effectiveness and the "true" measure of effectiveness that is reduction in accident severity and, to a much lesser extent, accident frequency. On the other hand, accident studies deal directly with accident severity and frequency, but lack the detail in vehicle kinematics and kinetics, plus other related data and research problems. This missing link must be established to provide better definitions in the performance of roadside safety appurtenances.

Solution: A study to establish this missing link between the various measures of effectiveness (used in full-scale crash testing and simulations) and accident severity is needed so that the performance of roadside safety appurtenances can be evaluated prior to their field applications. The study can take the form of an accident study in which sufficient information is collected for each accident to allow reconstruction of the vehicle kinematics and kinetics. The collected data can then be used to establish the relationships between the various measures of effectiveness and accident severity. In addition, data from the study can be used to critically review the appropriateness of the current full-scale crash test conditions. For example, how appropriate is the use of 60 mph, 25 degree impact for longitudinal barrier systems? What proportion of real-world impacts exceeds this upper limit of impact conditions? Is vehicle yawing a problem? Once this missing link is established, the results from full-scale crash tests and simulation runs can be translated into predicted reduction in accident severity and frequency that in turn can be used in cost-effectiveness or resource allocation analyses.

6. Title: Correlation of Severity Determinations Between Motor Vehicle Accidents and Full-Scale Impact Tests or Surrogate Methods

Program Statement: Police accident reports generally report severity as either fatal, injury or property damage only. Vehicle collision severity for full-scale impact tests is usually reported in the form of triaxial decelerations or momentum change. The problem arises when there is a request to relate the latter to the former, especially when evaluating highway safety hardware.

Solution: Establish guideline thresholds for the basic levels of accident severity as related to measured or computed vehicle decelerations. These thresholds should be based on some reasonable probability of occurrence, say 80 percent. Although neat line thresholds are ideal, it is understood that there are a multitude of other factors that enter into the ultimate resultant accident severity. A first step in establishing such guidelines would be to compare the assessment of severity to various vehicle occupants in full-scale tests with the measured decelerations recorded in these tests. If data from existing test reports are not adequate for a synthesis, provisions should be made to obtain this data from future tests.

7. Title: Integration of Field Experience with Laboratory Crash Tests and Simulation

Problem Statement: Safety countermeasure effectiveness in terms of accident reduction or injury mitigation must ultimately be related to real-world performance in the operating environment. To accomplish this, measures of performance based on simulation and crash testing must be related to measures obtained in the field. They must also recognize the multivariate probabilistic nature of accident outcome or occurrence.

Solution: Countermeasure design and evaluation should integrate field experience in the development process. Detailed laboratory measures such as acceleration should be related to surrogate field measures because such detail is not obtainable in the field. Conversely, laboratory surrogates for injury must be related to field observation of injury severity. All of these measures must recognize the indeterminable uniqueness of specific crash events by constructing probabilistic functions of accident occurrence or outcome.

8. Title: Severity Data--What Does It Really Tell?

Problem Statement: One of the most important issues relating to severity data must surely be the ability of qualified drivers and roadworthy vehicles to avoid any accident in the first place. How can this be taken into account in evaluating the severity of collision with various roadside features?

Solution: Grade driver performance based on operating history, grade vehicle performance based upon major characteristics affecting handling and roadability. Establish specific grade levels for driver/vehicle combinations in terms of ascending accident proneness and modify severity rating of actual crash tests accordingly.

9. Title: Development cf Effectiveness Estimates for Specific Roadside Safety Treatments

Problem Statement: In recent years, considerable research has produced a variety of roadside safety devices. Many states have installed such devices in places of known high-accident frequency. Many before-after evaluations have been conducted to determine the effectiveness of these devices in reducing accident potential and/or severity. However, the evaluations are often flawed and produce meaningless results.

Solution: Utilize a multistate cooperative approach to collect data elements (accidents and encroachments) specific to certain roadside safety appurtenances. Instead of a "shotgun" approach, proceed on a treatment-by-treatment basis to fill in the knowledge gaps. For example, let a requisite number of states concentrate on median barrier treatments until the necessary data are available. Then proceed to another treatment. Maintenance personnel should be considered.

10. Title: Treatment of Side Road Culverts

Problem Statement: Would it be cost/beneficial or accident/beneficial to treat side road culverts with a 6:1 slope and grate?

Solution: Compare the beneficial effect of such an example safety treatment versus the cost/benefit effect of providing better pavement surface or paved shoulder.

11. Title: The Lack of Solid Accident Statistics (Frequency, Serious Injuries, Fatalities, Etc.) and Details Involving Heavy Vehicles and Longitudinal Highway Barriers

Problem Statement: Proposals are frequently made that research or construction funds are urgently needed to develop or construct relatively costly longitudinal barriers capable of containing heavy vehicles. But time and time again the proposal has no heavy-vehicle accident data other than broad, vague statements to support the need for such an effort. Thus it is virtually impossible to allocate developmental or construction funds for heavy vehicle barriers on a cost-effectiveness or priority basis in view of the many other safety corrections also competing for the limited funds currently available.

Solution: Establish experienced multidisciplinary teams to investigate and document the details of all serious injury or fatal accidents involving heavy vehicles on specific lengths or portions of the different types of highways (freeways, primary highways, secondary highways, local roads, rural, tangent, curved, flat, hilly, heavily traveled, lightly traveled, etc.). Automatic traffic counters should be established and maintained to count and record the number, type and even the speed of all traffic on each of the selected lengths of highways on a continuous 24-hour basis. The entire data collection effort should be maintained for 1 year, or whatever period is necessary to obtain a significant amount of data.

12. Title: Correlation of Vehicle Crash Test Measurements with Measures of Injury Severity

Problem Statement: The utilization of standard procedures for vehicle crash testing has been recognized as a valuable means of comparing the relative safety performance of two or more roadside safety devices since at least 1962. Great strides have been made in refining and revising these procedures as new knowledge becomes available and new problems were identified as in the publication of NCHRP Report 230. In like manner, measures of collision trauma, as perhaps best typified by the AIS scale have been developed to the point where multi-injury cases have been correlated with probability of survival, and AIS correlations have been attempted in certain classes of collisions. What is needed is a validated way of linking controlled crash test data with measures of occupant injury.

Solution: In looking at the problem by impact models is appears that the current state of knowledge in this area is best in direct head-on impacts and that there is great promise in near-term progress in direct side of impact due to the existence of the Part 572 anthropometric dummy and the development of the new side-impact dummies. The problems of off-center head-on anthropometric dummies have not been either developed or validated to consider these problems (which include most all traffic railing impacts, many pole impacts and numerous cases involving non-level terrain installations and mini-sized cars).

A possible solution for this problem would be a large-scale research program involving (a) identification of real-world accidents of interest; (b) reconstruction of these accident cases; (c) full-scale instrumented crash tests of the reconstructed conditions; and (d) computer simulation of the events.

13. Title: Benefit/Cost Analysis of Accident Countermeasures

Problem Statement: There is a need to quantify highway safety countermeasures to demonstrate effectiveness. Items needed to make these analyses are

1. Injury severity profile of accidents before countermeasures,
2. Injury severity profile of accidents after countermeasures,
3. Cost of accidents by injury profile, and
4. Cost of countermeasures.

Solution: Accident studies can be used to determine items 1 and 2. Items 1 and 2 could also be quantified by knowing relative hazards of "before" and "after" and relating to probability of occurrence. Encroachment rates and characteristics are needed to quantify probabilities; these data can only come from field measurements. It would be helpful if some standard accident cost values could be employed on a nationwide basis (e.g., National Safety Council).

14. Title: Interpretation of Crash Test Results and the Development of Performance Standards

Problem Statement: The evaluation of new roadside countermeasures is not quantitatively tied to the reduction of injuries and fatalities. To create such a tie, one must be able to interpret the results of crash test and analytical simulations in terms of injury probability. Methodologies to enable these interpretations have not been used in the roadside countermeasures area.

Solution: A study should be established to relate system performance to expected injury and fatality probabilities. This would involve the assessment of the relationship of the observed dummy injury measures (and new measures under development) to human injury probabilities. The study would consider, for instance, the results from baseline crash tests with dummies (conducted with and without roadside countermeasures); if such results were not available, they would have to be developed. A more advanced program would improve this knowledge through projects in biomechanics, dummy development, and detailed crash testing and modeling of unrestrained occupants and roadside countermeasures.

15. Title: Crash Test Data Base Studies

Problem Statement: The relationship between crash test results and accident statistics is not well defined and for the most part is misunderstood. This limitation may lead to performance criteria for roadside hardware and/or vehicle components that do not lend to optimum solutions for safety-related problems.

Solution: The Structures Research Branch of NHTSA has designed and is maintaining a crash test data base for storing the results of all crash tests conducted since 1978. This data base contains 358 crash tests. An effort should be initiated to see that all crash tests conducted by the Department be entered into the data base. (This is being accomplished somewhat by informal means.) In addition, a matrix of baseline testing should be established for conducting crash tests of the accident modes not now represented in the data base. Studies should then be conducted on the crash data in the same manner that the accident data are evaluated. This would lead to a better understanding of test results as well as provide the data for determining the relationship to accident statistics.

APPENDIX B

WORKSHOP ATTENDEES

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