TRAFFIC SAFETY
A NATIONAL PROBLEM

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FOREWORD

The National Academy of Engineering, as a service to the country, selected traffic safety as the subject for its Spring 1966 Symposium. Traffic safety is a matter of life and death, quite literally, for a large number of Americans.

The Symposium speakers presented a comprehensive view of the traffic safety, or traffic accident, situation, giving facts and figures that will be highly useful to all individuals and groups seeking answers to a complex of problems.

It is hoped that one of the groups taking responsibility for a broad cooperative effort to improve traffic safety will be the Academy itself. In undertaking such a responsibility, the Academy will be carrying out one of its principal objects and purposes, namely to provide means of assessing the technical resources that can and should be applied to the needs of the nation, and to sponsor programs aimed at meeting these needs.

J. HERBERT HOLLOMON

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AN INTRODUCTION TO THE TRAFFIC SAFETY PROBLEM

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We meet here today at a time of rapid transition in understanding of highway safety. Increasing numbers of people — in government, in industry, in foundations and other non-profit groups, and, most important, in the general public — are approaching highway safety as a 20th century problem to be solved rather than as a medieval affliction beyond our power of influence.

This is a very hopeful sign. It suggests that we will soon begin, as a nation, to apply adequately the scientific information already at hand, and to undertake the research we need to supply the many answers still missing.

We cannot do anything for the more than one and a half million people we have killed with vehicles. We can only partially help the many thousands of brain-damaged and other disabled individuals. The economic losses are irretrievable. But we apparently at last are willing to make the attempt to be very certain that the process is stopped and reversed to the maximum possible extent; that our great national resources are brought to bear in as well-balanced and coordinated a manner as possible, and targeted where the return in prevention will be the greatest.

This accelerating transition has been brewing for more than a decade in the research community and among the scattered pioneers to whom we owe so much. It is a process in which — as with any great and evolving issue — the old ideas are threatened and defended, attacked and proclaimed — a process which, in short, involves a great deal of turbulence and widespread confusion of issues.

Because in the present public debate there is much misunderstanding of the issues, even to the extent that clearly false alternatives are seriously and sincerely debated, I shall introduce the papers that

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follow by outlining the sequences of events with which we are concerned and the possibilities of doing something about them.

First, let all who discuss highway safety from any standpoint understand clearly that it is the *results* in death, injury, disability, and property damage that are of concern to us as a nation. This means that any factor that contributes to these results in any way, and in any stage in the steps that precede them, is our concern, whether or not the folklore of highway safety has previously identified it as a factor to be dealt with in preventing the carnage on our roads.

These results in human and other damage are the end-products of sequences of events that must for logical and practical purposes be divided into three consecutive phases. It is essential that the public understand these three phases of the highway safety problem. and demand that those who in any capacity discuss highway safety from any standpoint clearly identify just which phase they are discussing.

The First, or "Initiation," Phase is the period before a crash, or near-crash. In it operate the many driver, pedestrian, vehicle, highway, and other factors that lead to a crash, or to its avoidance.

The Second, or "Crash" Phase is the brief interval of the crash itself. In it the forces of impact — depending on their characteristics and on the degree to which they have been anticipated by appropriate vehicle and highway crash design — do their work, harmlessly or with damage to people and to the vehicle and other structures involved.

The Third, or "Cleanup" Phase is the after-the-crash period in which the present slowness and inadequacy of emergency medical care and transportation and other factors commonly lead to completely unnecessary death, disability, and prolonged medical care.

Since what goes on in *each* of these three phases of the highway safety problem contributes greatly to the tragic results now of such increasing concern, no discussion of highway safety is either balanced or complete unless it considers carefully all three of these phases and their individual importance in the production of damage and death. Unfortunately for the dead and injured, and for public understanding of the issues, balanced discussion of these three phases of highway safety and of the opportunities in each to prevent the end-results of concern has until recently been an extreme rarity.

Since there is no reason to hope that we will, for the foreseeable future, completely eliminate the human, vehicle, and highway factors that lead up to crashes, we must also pay considerable attention to the great saving in life and limb that can still be made in far better packaging of the human cargo in the crashes that will continue to occur. Similarly, since even with the optimum in vehicle crash design substantial numbers of injuries will continue to occur, especially in the exceptionally high-speed crashes that fortunately are in the minority, it is essential that we also organize and provide the optimum in emergency care and transportation. It is well known to medical experts that the organization, rapidity, and quality of emergency medical care and transportation in much of the United States are scandalously deficient, by any standard. It is also well known to such experts that if we wished as a nation to bring such care even partially up to the excellent level provided our troops in the field, we would achieve very substantial savings in lives, injuries, and permanent disabilities. Yet this aspect of highway safety has also only recently begun to be a matter of public concern, and is commonly completely omitted in discussion of the field.

Nonetheless, despite this need for balance and specificity, we are still plagued by the oversimplifiers, who usually would have us pay attention only to the clearly unattainable goal of preventing all crashes, totally ignoring the opportunities in the crash and cleanup phases that follow. In its most common form, this position is even further simplified to say that, since the driver commonly has much influence on what follows, as is correct, we should concentrate largely or even exclusively on him, ignoring such newfangled ideas as protecting him and his passengers in the crashes that do occur.

Several things are wrong with this common argument that we should concentrate only on preventing crashes. First, it implies that we should apply most or all our public and private resources at only one of the places where we can influence the end-results of concern. Second, it often blames the driver for initiating crashes to an extent not completely justified by the facts. Highway and vehicle characteristics are also involved in crash initiation, as all of us know who have had blowouts and brake failures, or have precariously threaded our vehicles through our less modern streets and highways. That the first-phase crash-prevention effort should not be exclusively directed at drivers is also clear from the substantial reduction in crashes achieved by modern highway design.

We have all heard the argument that since drivers are most largely involved in causing crashes, vehicles cannot, therefore, also be of great importance. This argument, so simple and seemingly logical, is one of the tragically false alternatives still delaying progress in reducing the extent to which another major component in the problem, the vehicle, contributes to the end-results. People are only now beginning to understand that although the vehicle plays an important but secondary role in starting crashes, it is in the second phase — the crash itself — that vehicle design is of such paramount importance in determining over a wide range of impact speeds whether human damage results. To say that, because man plays a large role in the first phase, the vehicle is unimportant in the second is not only illogical nonsense; it is also destructive of the great progress in crash protection that we as a nation should have achieved many years ago. It is chiefly because increasing numbers of people are coming to understand that crash protection and other aspects of vehicle performance fall considerably short of the levels our scientific and technological know-how make possible that there is so much pressure for laws to force the issue. This pressure will continue until it is very clear to all concerned that the automotive industry is consistently leading rather than following.

It is not my purpose in this brief introductory paper to discuss in detail this gravely important question of the crash design of the vehicle. Let me instead mention a few important technical points to suggest to you in this engineering audience the most important considerations.

It has been known since early in World War II that if the body is properly packaged, it can usually sustain without any injury whatever transient but violent forces of the magnitudes commonly encountered in what are now often fatal highway crashes, a fact that has been applied well in protecting our astronauts, both leaving and returning to earth. Such packaging requires, *first,* that the structures outside the passenger compartment progressively crumble or otherwise attenuate the impinging forces. *Second,* the passsenger compartment itself must not collapse inward if the vehicle crashes under the operating conditions for which it is designed. For example, the steering shaft, if it cannot be substantially eliminated at least in its forward portions, should be designed to prevent its being driven at and into the driver. This is a point of some importance since, of the approximately half a million drivers killed in this country to date, it is conservatively estimated that at least a quarter-million received fatal injuries from inadequately designed steering assemblies.

Third, the package must stay closed, lest the occupants be thrown through opening doors to be killed either on hard surfaces outside or, as often occurs, by their own vehicles rolling over on top of them. To the credit of the automobile industry, there has been, since the mid-1950's, much progress in this aspect of crash protection, in preventing occupant ejections through better latch, hinge, and door design, although the problem is by no means completely solved.

The interior of the package must be designed in anticipation of the impacts of those who will hit its various parts. Such impacts are common and must be well provided for. An estimated one quarter or more of the vehicles manufactured are involved at some time in crashes in which occupants are either killed or injured by hitting their interior surfaces. An additional 4 percent of vehicles injure or kill pedestrians, chiefly with their front-end structures. Viewed differently, some 7,000 Americans are injured each day in impacts with vehicle-interior structures, most of which at present are not designed for these occurrences. The corresponding number of pedestrians injured each day is about a thousand.

Occupant restraints must also be provided and used to the maximum possible extent, to make more gradual the decelerations of those involved.

We can summarize this brief introduction to the crucial importance of vehicle design in preventing injuries in the second or crash phase by pointing out that we have long been content as a people to ship ourselves and our loved ones in packages deficient in the very characteristics we insist on when we ship teacups and other less valuable merchandise equally subject to human and other mishaps in transit.

The present emphasis on the importance of vehicle-crash and other performance stems chiefly from two facts. First, as I have indicated, the public is beginning to understand that, despite the long neglect of the vehicle in discussions of highway safety, we can achieve substantial reductions in crash injuries and deaths by practical improvements in vehicle design. The correctness of this scientifically well-informed statement will be well demonstrated as much better vehicles replace those now on the roads. Unfortunately, this process, even if begun immediately, will not completely replace the present cars on the roads for many years, a period during which many completely unnecessary deaths and injuries will occur.

A second reason for the great emphasis on vehicle design, an area in which considerable information is already available, is the increasing public discovery that there is little scientific evidence that the many exhortations and programs so long directed at manipulating human behavior as a means of preventing crashes themselves are to any substantial degree effective. For example, although the evidence is overwhelming that about half of our fatal crashes are initiated at least in part by the prior use of alcohol, no one has yet bothered to do the research necessary to find out whether any of the programs directed at reducing its contribution are in any way effective. This is not to say that some of these various measures do not work, or work well, but rather that the research that would enable us to say which are effective, to what extent, under what circumstances, and at what relative costs, is almost completely lacking.

This is a situation we can no longer tolerate. Unsupported assertations, however long repeated and however widely believed, are a poor substitute for facts, as the medical, scientific, and engineering professions discovered generations ago. Unfortunately, however, we cannot stand still while the research that should have been done long ago is begun. In addition to ensuring that the complex range of necessary scientific study with respect to all phases and components of the highway safety problem is undertaken, completed, and applied, we must proceed energetically as a nation to do the things that are most reasonable at our present stage of substantially imperfect knowledge.

In doing so, we must be acutely aware of a great hazard in this necessary course of action. This is the very real risk that we will so freeze our present ideas and approaches that future progress will be impaired. This is not only a problem in connection with standards for vehicles, the case most commonly cited in recent weeks. It is also very serious in licensing, education, enforcement, highway engineering, traffic control, and emergency medical care. This is not to argue that we should avoid the necessary forceful action by government, industry, and the other important groups that must cooperate effectively to solve this problem. Rather, it is to point out that we must build into our approaches ample provision for rapid and flexible change as new knowledge and technological innovations become available. Unless we do this, our success will fall far short of our capacity to reduce the present slaughter both in the near future and for the longer pull.

We are faced with a complex but not insoluble problem. It has many facets that need attention. In dealing with each of these, we must not exclude attention to the others. Nor can we long afford the present luxury of poorly balanced, uncoordinated efforts of substantially unknown efficacy. If hostile military action were killing and injuring our people at anywhere near a comparable rate, we would be very certain that our national resources were well used and that everyone pulled together as constructively as possible. Surely we can do as well in the face of the problem that brings us here today.

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THE STATISTICS OF ACCIDENTS

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To open this discussion of traffic accident data, please consider three research approaches. At one extreme is the statistical approach in which we collect information about a large number of accidents, giving much perspective but sacrificing detail on any one accident. A second approach consists of intensive study of a limited number of accidents, usually by a team of "experts." This gives less perspective and breadth than the statistical approach, but yields considerably more depth — more information about each individual accident. At the other extreme are the experimental, staged car crashes in which "infinite" detail is obtained on individual test crashes, but the number of such tests and the resulting perspective is necessarily limited.

Because of traditionally limited resources for accident research, it has never been possible to combine the first two into a study in which detailed data were collected on a large enough sample of accidents to gain perspective.

Each of the compromise approaches has its unique strengths and weaknesses.

The basic strength of the statistical approach to the study of traffic accidents is that the statistics deal with real events that happen to real people. Accident statistics directly concern the lives and deaths of people; thus findings from carefully compiled accident statistics have an immediacy that makes them believable. The most important weakness of the statistical approach is that by its very nature it looks backward, describing events that have already happened. This fact alone dictates the necessity of other types of accident research that innovate and look to the future.

Finally, we should think of statistics as a language — one dialect of the language of mathematics; statistics, like English or French,

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is a way of conveying ideas of quality and quantity. Numbers, like words, can be manipulated to tell lies or half-truths.

Whatever the characteristics of statistics per se, the fact is that in this country we do not have suitable statistics to provide us with the information needed to combat the problem of accidents, injuries, and deaths. As a nation, we do not have the quantity and quality of necessary statistical information that would allow us to evaluate and weigh the driver factor in accidents. We do not have information that would permit us to assess adequately road environment factors in the production of accidents. This is partly because existing statistical systems usually do not even allow pinpointing the accident location with suitable precision. Obviously, if one wishes to study accidents in terms of road factors, it is at least necessary to know where the accident occurred, and the physical characteristics of that exact spot.

Finally, in our statistical systems today we do not have enough information to provide an evaluation of the role of the vehicle in the production of the accident (matters such as vehicle failure, improper maintenance, etc.) nor in the crash protection phases.

I believe that the clamor today reflects the determination to raise the vehicle to the level of full partnership in the study of the accident process. This has not been the case in past years when the greater weight of our attention has been on driver variables.

By considering road, driver, and vehicle as full partners, perhaps we can eliminate the fruitless numbers game in which we try to decide on a percentage basis how much of the accident toll is attributable to the road, how much to the vehicle, and how much to the driver. As an operating tactic, we might as well assume that each of these three factors produces 100 percent of the accidents, and then set out to find the most cost effective means of combating the problem. For example, it does not necessarily follow that because the driver played the primary role in producing the accident, the driver represents the most fruitful way in which to seek the solution.

Beyond that of a few research projects, the basic sources of accident statistics are motor vehicle, and other state agencies around the country. There are also research projects collecting certain data, but the large mass — the millions of accident reports — is collected by state motor vehicle agencies. The data are so poorly utilized that we do not know the character of the data, or even whether its collection is a worthwhile endeavor. This leads to difficulty in two ways.

On the one hand, apologists who would justify taking no action to meet this growing problem can shrug and say, "We know of no statistics that suggest that 'X' is a problem warranting action." For example, with respect to vehicles, one might truthfully say, "We know of no statistics suggesting that tires are any greater problem today than ever before."

On the other hand, those who advocate swift, sweeping changes usually have few facts to back them up. Therefore, we move into new and expensive programs without appropriate measurement to tell us that we have moved in a desirable direction. The decisions involve resources of public agencies, of private industry, and of individual citizens; yet, the decisions are made without the reliable data that should be available. For example, what *is* the situation with respect to tire failure in accidents? What is the failure rate? Under what circumstances do tire failures occur? Is the role of tires in accidents greater or less now than in years past? I don't know the answer to these, and I do not think anyone else does; yet the decisions have been made.

This example is only illustrative. There are others. Thus, we are unable to make any kind of a priority evaluation on many changes mandated by the General Services Administration for federally purchased cars. We have no accurate data to tell the level of vehicle failure. Is it now higher than in former days?

Let me hasten to say, particularly to this group of engineers, that obviously we must make decisions every day in the absence of complete data. We cannot delay today's action until we have *all* necessary research, but let us provide a measurement system so that tomorrow's decision will be more rational than today's.

To do this through accident statistics, we must have data in great quantity — accident data by the hundreds of thousands, if not the millions. This is an expensive program to contemplate, but fortunately the data collection operation already exists. Millions of accidents are reported each year. Records are forwarded to state capitals in every state. These records are usually compiled in some kind of a machine records system. Superficial tabulations (I do not call it analysis; I think that would be an inappropriate term) of these data are prepared. For example, from such tabulations, we know with a great deal of certainty that more accidents occur on Saturday and Sunday than on other days of the week, but I am not sure we know very much more about the matter.

The real question is one of utilizing and refining the data. The reason for the low data quality is that in the agencies responsible, appropriate professional staff has been inadequate or non-existent. I do not suggest that all we need is a few statisticians and, by magic, good information will pour out. I wish it were so simple; but no, the systems will take years of refinement. The tragedy is, however, not so much that the questions haven't been answered, but that the questions haven't been asked.

What must come in the future is a suitable charter and a suitable definition of mission for the agencies concerned by which millions of accidents can be suitably recorded and suitably analyzed. In this way, it should be possible to develop information that can guide future programs, and provide the true effectiveness evaluation.

Is it feasible to get this kind of information from a statistical system? Based on experience of the Cornell Automotive Crash Injury Research project, I would say yes, that in certain subject matter areas, even with the modest sample of 5000 accidents per year (contrasted to New York State with its 400,000 reports per year), it has been possible to detect significant benefits of certain vehicle changes when (1) these changes are virtually constant throughout the corporation (data quantity), and (2) when these changes have a profound effect on the outcome.

The questions being asked today are properly much more demanding than have been asked before. Therefore, the broad scale surveillance system that we must achieve has to be equal to these demanding questions. This will require fundamental and sweeping changes in the nation's approach to collection and analysis of accident statistics.

DISCUSSION

Moderator, J. HERBERT HOLLOMON

ROY HAEUSLER: Would you say that there are limitations to the expansion of data and the improvement in its quality because of the pressures upon and limitations of the officials who make the initial reports? Most traffic accident data today are collected by the police, who have minimal training as expert investigators, who may be short on objectivity, who have a great many other duties to perform and pressures to harass them. Should we perhaps make other provision for the recording of data?

MR. CAMPBELL: I believe the question as to who does fundamental accident investigation in the future should have open, frank discussion. There are certain classes of information whose recording is within the capabilities of the police and consistent with their other duties — if police training is upgraded. However, I believe there are some questions that cannot be handled by police investigators. I think that in the future for certain purposes we will supplement the investigation of the police officers with investigation by professionally trained people who will not have conflicting duties. I do not mean to criticize the police. After all, if they are at the accident scene and people are lying there injured, the police must tend the injured, and worry about skid marks later.

ELMER ENGSTROM: You made reference to the alcohol problem. Are there any statistics on the effects of antihistamines and other drugs that are generally available today?

MR. CAMPBELL: As I recall, there was a study of single vehicle accidents in California in which drugs of various types were present in the bloodstream of the driver. Their presence was not as frequent, however, as alcohol.

DR. HADDON: Limited studies in the laboratory show that the effect of various drugs on driving performance, as measured by simple or complex types of driving simulators, is to decrease some of the body functions, such as reaction time. These decreased functions may or may not be particularly relevant to driving performance. Of course, if alcohol is added to the driver's bloodstream, there is an augmentation of the effect of the other drugs. There are some other considerations in regard to the use of these pharmaceuticals. They are undoubtedly maintaining the good health of many people who otherwise would be in serious trouble both off the highway and on the highway. Insulin is a good example. Insulin may well be preventing far more accidents than its overuse might produce.

As for the narcotics type of drug-taking, there is some interesting recent evidence from California, the work of Dr. Julian Waller in the State Health Department. It indicates that persons who have records of conviction for narcotics use and possession have no more accidents per mile than other individuals. Thus it is by no means a definite cause and effect matter. The data are extremely scanty, and it would be hazardous to join the oversimplifiers who would make a scapegoat of the drug-users group.

Here again we need much more specific information. In the meantime we should adequately warn users of these various agents about the effect they might have on driving performance.

MR. HOLLOMON: Would you reply to the implied question of the statistical role of alcohol with respect to accidents?

DR. HADDON: We have very solid data from a wide variety of locations in this country and elsewhere that alcohol is causally involved in upwards of 50 percent of fatal crashes. One source for this figure is recently tabulated data in a report about the 27-county area in which over 90 percent of the California population lives. Other information from scattered places shows that alcohol is causally involved in 30 or more percent of all fatal pedestrian accidents.

For non-fatal accidents, preliminary studies indicate a much lower figure — 20 percent. In other words, alcohol tends to be involved to a far greater extent in severe traffic accidents than in non-fatal accidents.

The matter does not stop there, however. There is increasing evidence, rather substantial evidence, that although the social drinker is involved to some extent in traffic accidents, and sufficiently so that information and programs should be directed at him, it is primarily the pathological drinker who is involved in traffic accidents. For example, Dr. Waller in his California study showed that the presence of cirrhosis of the liver was surprisingly high — over 60 percent — in those persons who had substantial amounts of alcohol in their bodies at the time they were killed in accidents. In fact, it begins to look as if a small percentage of the population is responsible for a major portion of the accident statistics. I find this encouraging on the one hand because it suggests we can localize the cause of much of our traffic accident problem in a small portion of the public, but discouraging on the other hand because dealing with alcoholics is extremely difficult. There is always hope, however, that scientific research will produce some magic solutions.

H. B. VINSON: You mentioned that most accidents happen on Saturday and Sunday. On which day do most accidents occur?

MR. CAMPBELL: In terms of the frequency, there are more accidents on the weekend, but the rate may not be higher then because more people drive on weekends. I think perhaps more accidents occur on Saturday.

MR. VINSON: Is there a study that reveals what time of day most accidents occur?

MR. CAMPBELL: Again one has to speak in terms of frequency and rate. In terms of frequency, the afternoon and evening hours are the highest; that is, the homeward-bound rush hour traffic. However, in terms of rate, taking into account the number of vehicles on the road, the "wee small hours of the morning" — somewhere around 3 a.m. — have the highest rate. I am referring to fatal accidents.

J. H. LAKE: Would you say one reason that our present accident record system is a poor tool as far as research is concerned is the fact that the system has been developed over the years to determine legal responsibility for negligence or culpability in an accident, and that this purpose may not be compatible with that of determining the cause of the accident?

MR. CAMPBELL: I think that is quite true. The data collecting system has been developed with no mission for research. The question has been one of determining fault, implying human fault. Doing objective research is incompatible with deciding which driver is at fault. As long as there is a possible penalty involved, drivers will not tell a police officer certain classes of information absolutely necessary for research into the cause of the accident. For example, the driver who goes to sleep at the wheel, runs off the road, and kills another person is not going to tell the police officer that he went to sleep at the wheel. He might tell a confidential research investigator. At Cornell, for example, in our intensive study of accidents, drivers have given us information that I am certain would not have been forthcoming to a policeman or an insurance man. I am not sure how we can solve the problem of drawing out candid, objective research information from all drivers involved in accidents.

THE LEGAL ENVIRONMENT AND TRAFFIC SAFETY

JAMES P. ECONOMOS

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The legal environment of the traffic safety problem consists of traffic laws, driver licensing authorities, enforcement officials such as city policemen, county sheriffs and state police or highway patrols, prosecutors, and judges. In a broader sense, it also includes those members of the public who demand laws in this area, since without their support, there would be no regulation or controls for officials to enforce.

It includes, in addition, the public as it reacts to traffic control policies of officials. Judges, for example, must adopt policies that meet with public acceptance for coping with the traffic problem. This public acceptance is difficult to achieve not only for the policies of the courts but for the entire traffic safety movement.

Since time will not permit the exploration of all facets of the legal environment, I will direct attention primarily to the legal framework that has developed over the years in the area of traffic laws, regulations, and rules concerning automotive travel.

The "right to travel" has been recognized ever since the Magna Carta. The United States Supreme Court, in a series of decisions, has recognized that this "right to travel" is a guaranteed liberty. It cannot be taken away without due process under the Fifth Amendment and the Fourteenth Amendment. It is also protected against restrictions that may be imposed by the states. Whether as pedestrians or drivers of vehicles, all persons under the common law have an equal right to travel. However, whether the public road is a foot path, wagon trail, gravel road of the past, or paved highway of the present, its use must be subject to the reasonable regulations of society.

It is basic, therefore, that the law must achieve an appropriate balance between the rights of the individual and the rights of society. This is the heart of the traffic problem, the most important legal aspect with which the traffic courts must deal.

Last year almost 50,000 Americans lost the right to life, mostly as a result of their misuse of the privilege, or right, to travel by motor vehicle. For years, the mileage-death rate had crept downward, but in each of the past four years, it has increased from 5.2 deaths per 100,000,000 miles of travel in 1961, to 5.3 in 1962, to 5.4 in 1963, then to 5.7 in 1964 and 5.7 in 1965. Those who may have shown a tendency toward complacency in the years during which the line on the chart moved downward have been engaging in an intensive examination of conscience in regard to road design, vehicle safety, safety programs in general. The law cannot escape this examination of conscience.

However, we must make a cautious approach to the restriction of rights in spite of the high price tag attached to those rights. It is easy to say, "Let's change our laws," and difficult to change them for the better. It is easy to act quickly, and difficult to act wisely, but speed and wisdom must combine in our actions if 1966 and 1967 are not to record increases in motorized death equal to those of the past three years.

A recent article in the *Traffic Digest and Review* was a plea for proportion and perspective in dealing with the traffic accident problem. It criticized the American notion that the answer to all problems is, "We need a law," and pointed out that we now have laws that, if made effective, would solve much of the traffic accident problem.

To be made effective, the law must first be made intelligible. The Uniform Vehicle Code embodies the best current thinking of those who have been dealing with the traffic problem. Many legislatures have used it as the basis for revision of their traffic codes, but many could not resist the temptation to introduce exceptions, conditions, and "gimmicks" that have made the meaning of the law less clear. Every lessening of the meaning of the law reduces the law's influence on the actions of drivers. Engineers and lawyers, in their citizen-driver roles as well as members of learned professions, must take some responsibility for the elimination of the exception, the condition, and "the gimmick."

Some of our laws have necessarily been stated in terms that require individual interpretation by drivers. The authors of the article in *Traffic Digest and Review* point out that the leading causes of traffic accidents include failure to yield the right of way, following too closely, and speed too fast for conditions. But who has the "right of way"? How fast is "too fast for conditions"? How close is "too close"? These offenses are normally prosecuted only when they result in an accident. Can any objective criteria be established by which the driver may know what speed is too fast for conditions, and can these same criteria be applied by law enforcement officers and courts? How capable are drivers of comprehending whether there is one car length for every ten miles of speed between their cars and the vehicles they are following? How can these laws, the violation of which has such serious consequences, be made intelligible and meaningful to those who must abide by the law and those who must apply it?

It is easy to set a maximum speed limit, and comparatively easy with modern speed measuring devices to determine when that limit has been exceeded. But how many accidents are caused by exceeding that maximum limit and how many are caused by driving within the maximum speed limit but too fast for road conditions, or visibility, or conditions of traffic? We do not know, and in order to find out, police officers would have to collect another fact in accident reports and statistical summaries. Like all of us, police are concerned about the amount of time it takes to fill out reports.

Should we concentrate on enforcement and increase penalties for driving in excess of a set 50, or 60 or 70 mile-per-hour limit? Many would say yes, but others contend that while such enforcement might help in one respect, it leaves untouched another important difficulty with set speed limits: driving at the speed limit when conditions make such speed unsafe. They argue that more accidents are caused by driving 50 miles per hour in a 50 mile-per-hour zone when maximum safe speed is 30 miles per hour, than are caused by exceeding the speed limit when conditions are normal. Exactly what the facts are on this point is not certain.

Perhaps we will find out some day, but in the meantime, we must deal with today's problems on the basis of today's knowledge. The Uniform Vehicle Code is the best legal instrument for dealing with today's traffic problems. Just as it has been revised periodically in the past, so will such revisions continue to be made in the future as further knowledge becomes available. The Uniform Vehicle Code was originally drafted and approved in 1926, and last revised in 1962. It was drafted by the predecessors to the National Committee on Uniform Traffic Laws and Ordinances, a committee with about 100 members, including representatives of federal, state, and local government, industry, and organizations working in the field of traffic safety. The American Bar Association is represented on the committee.

The Uniform Vehicle Code is a comprehensive document that reflects the best of state traffic laws and other experience considered valid for this purpose. It embraces many facets of control and regulation of the human being as either driver or pedestrian, of the vehicle, and of the highway — the three principal elements of the traffic problem. It provides a legal foundation for almost every aspect of the highway safety activities now in operation.

The Uniform Vehicle Code establishes the guide lines by which state and local governments exercise their powers of regulation and control over the vehicle and the driver or pedestrian. It refers to the Uniform Manual on Traffic Control Devices — another excellent guide for traffic and highway engineers in signing, laning, and providing automatic signals.

The Uniform Vehicle Code does not set any guidelines on how to build highways or where to build them. It does take cognizance of the fact that there are 2-lane, 3-lane, 4-lane, 4-lane-divided, and 6-or-more-lane highways with or without a median strip. This it does by providing for different driving speeds appropriate for the particular types of highways.

The most important part of the Uniform Vehicle Code is Chapter Eleven, generally referred to as the "Rules of the Road." This includes regulation of speed, passing, right-of-way, turning, traffic control signals, pedestrian regulations, special stops, offenses of driving under the influence of intoxicating liquor, chemical tests for intoxication, implied consent to chemical tests for intoxication, driving while under the influence of drugs, hit-and-run, reckless driving, homicide by vehicle. It includes various laws relating to emergency vehicles, bicycles, and motorcycles, and to parking, accident reports, and duties of drivers, passengers, police, garage-keepers, and others after an accident occurs.

For all of these matters, there should be national uniformity of regulations on a paragraph by paragraph, sentence by sentence basis. These rules of the road are too important to allow any variations by the individual states. It has been stated that drivers who learn and form good driving habits and attitudes according to the Rules of the Road in one state may be judged poor drivers in another state in which different Rules of the Road are prescribed. Two different legal environments existing side by side do not promote safe driving.

The Uniform Vehicle Code provides other aspects of regulation and control. For example it provides for the establishment of one state agency to be known as a Motor Vehicle Department to deal with the registration of motor vehicles, issuance of registration plates, the examination of applicants for driver licenses, issuance and control of driver licenses, periodic motor vehicle inspection, financial responsibility, certificate of title, anti-theft measures, and other aspects. In these matters, it is only necessary that there be reasonable uniformity in functions and operations.

The Uniform Vehicle Code sets out requirements for an accident records system that is basic to the collection of good information. It requires reports of accidents by drivers, owners, police officers, garages, and bureaus of vital statistics. It establishes authority and responsibility for tabulation of accident reports, analysis of them as to causes of accidents, and other pertinent information.

The present Uniform Vehicle Code also sets forth provisions as to required equipment on vehicles and the performance required of this equipment. This section is implemented by the Vehicle Equipment Compacts that now exist in 44 states.

To guide the police and the courts, enforcement limits of the various section of regulations in the Code, particularly the "Rules of the Road," are set forth. These limits are essential for effective traffic supervision by the police. They are also necessary for intelligent and fair action by courts. The courts are required to report to a central agency all convictions for moving violations and all convictions pertaining to driver license violations.

The Uniform Vehicle Code adapts criminal procedures for police and courts to follow in the enforcement of traffic laws. It provides for money fines and days in jail, with increasing penalties for second and third offenses. It places the authority for the suspension or revocation of drivers' licenses in the Motor Vehicle Department. While the Code does not restrict the courts to money fines and days in jail, neither does it adopt any of the various corrective and educational penalties available to judges.

Development of exact uniform penalties for particular offenses is of questionable value since such penalties do not take into consideration other factors that decrease or increase the hazard present during the commission of a traffic offense. What is more needed than uniform, exact penalties is a uniform sense of justice among all judges. To encourage this sense of justice, extensive and frequent conferences are needed to provide judicial education for judges of courts trying traffic offenders. The American Bar Association Traffic Court Program devotes considerable time and effort to provide such judicial education.

The Code designation of traffic offenses as criminal offenses was adopted in 1926. A criminal offense is a violation of a public right. In this sense it is known as *malum prohibitum* offense — one that is prohibited because public safety requires it. California is making a move to take away the criminality stigma; New York did so in 1929 when it created a class of offenses known as "traffic infractions." Special care was taken by New York, however, to provide that the procedure applied to traffic offenses would be the criminal procedure. In New York the sole legislative intent besides removing the criminality stigma was to preserve for persons convicted for such offenses their creditability as a witness in other court cases, both civil and criminal.

New York preserved the constitutional requirement for a fair trial of traffic law violators in a court so constituted as to afford "due process" in the first instance. Some advocates wish to eliminate the fair trial concept insofar as most traffic cases are concerned. They also advocate an administrative agency as a remedy for court congestion. I think, however, that strengthening the existing court system, providing it with a tool like the Uniform Vehicle Code, and furnishing it with facilities and personnel for administering justice properly, is the sound remedy for our court problems.

The function of the traffic court within the legal environment is to inculcate respect for the traffic laws and for the traffic courts adjudicating the cases presented. It is within the power of these courts to correct and then educate the traffic violator, impressing on him the need to make a conscious effort to obey traffic laws. There are judges who are accomplishing this objective — but far too few. We need more such judges, especially those who can accomplish the desired objective despite inadequate facilities, inadequate court personnel, and inadequate laws.

To summarize, the Uniform Vehicle Code is the best available tool today to create the important features of the legal environment for travel on our highways and streets. However, no state has adopted the entire Code. Every state has adopted different parts of it, with the net result that the country as a whole has a hodgepodge of traffic laws that vary from state to state. This should be remedied as quickly as possible.

Another tool now available through the American Bar Association Traffic Court Program is a set of national standards for improving the administration of justice in courts handling traffic cases. No single court conforms to all of the national standards, but those courts approximating them are making a valuable contribution to traffic accident prevention. The judge of the traffic court is a key factor in all traffic accident programs; a community can lose the benefits of a well-conceived community traffic safety effort for lack of a judge who can command respect for the law and for the court. Conversely, the judge alone can improve the public attitude towards obedience to traffic regulations even in the absence of a traffic safety program and adequate laws. He does this by eliminating the "violate for a price" policy. He does this most effectively when all violators of moving traffic offenses are required to appear in court in person, receive adequate time and attention from a judge who may impose corrective and educational penalties.

The individual's "right to travel" has been restricted for the benefit of all persons using the streets and highways. The Uniform Vehicle Code is a workable document that needs greater acceptance. It must be interpreted intelligently by the courts and administered fairly and impartially by all who have official responsibility. Finally, the public must accept the obligation to seek good laws and then to respect and obey them.

DISCUSSION

Moderator, J. HERBERT HOLLOMON

ROSS NETHERTON: A judicial inquiry, whether it is civil or criminal, is a carefully controlled process of obtaining and presenting and screening data or evidence. How adequate are our rules concerning evidence?

MR. ECONOMOS: The rules of evidence, both on the civil side and on the criminal side, are constantly undergoing changes to take into account scientific advances and other improvements in the area of data gathering. This has been seen quite clearly by the acceptance of the results of chemical tests for alcohol where charges of driving under the influence of alcohol are made. There have been several cases recently where drugs have been involved, and the effects of the drugs have been brought to the attention of the court. Skid marks, radar, and other evidence of this nature can be used. As fast as scientific validity can be established, the courts will make use of even the oldest rules of evidence and adapt them for the admissibility of such evidence. The only question that remains is the amount of credibility to be attached to them, the weight to be given to them. Judgment on this point will, of course, vary from court to court. Some education for the judges to reduce extreme variations is needed.

MR. HOLLOMON: What evidence do you have that the variations from state to state in laws, codes, and enforcement procedures cause variations — actual reduction or modification — in either the accident rate or the damage rate?

MR. ECONOMOS: There has been no statistical study made in the area of uniform laws with reference to the comparison of one state that complies to the greatest possible extent with the Uniform Vehicle Code and one that varies completely from it. The important point here is that reduction of accidents is a complex problem that requires application of what is known to be a balanced, coordinated program for the enforcement of laws and obedience to laws.

We know of instances where a single judge, for instance, working under a poor law has been able to reduce fatalities and keep personal injuries in his particular county down to a level lower than that in any of the four counties around him. Researchers who have made an analysis of this particular situation have stated that the difference was the judge's attitude about application of the principles of good judicial performance.

This means that a poor law and a good judge might get the same results as a good law and a poor judge. Problems like this confront us all of the time when we try to make such comparisons.

MR. HOLLOMON: What is the statistical or scientific evidence that law enforcement has any effect on the traffic accident rate, and if it does, what is the degree of effect?

MR. ECONOMOS: Law enforcement is the quickest possible method by which you can achieve a reduction of accidents in any community. In Los Angeles, Chicago, Detroit, the State of Washington and many other places, there has been an increase in traffic law enforcement. Continuous pressure, not spasmodic or periodic pressure, has been brought to bear on traffic offenders, with an increase in the number of people cited to court. As a direct result of achieving what is known as a desirable enforcement index, these particular communities have achieved a noticeable reduction in fatalities and in personal injuries. It must be added that in those same areas there was a terrifically broad-gauged,well-organized citizen effort going on at the same time as the enforcement activity. The answer to your question comes down to this: Enforcement pays off.

JOHN GARCIA: In the study of fatality and injury reductions as a result of the law enforcement programs you just mentioned, were there controls? Were there comparable cities and comparable situations where no program at all was instituted, and was it shown that these cities did not have any changes, or comparable changes, in their accident reductions?

MR. ECONOMOS: In the cities I am citing, we have comparable situations before and after.

MR. GARCIA: That is not what I meant. In cities having these programs, there were changes, but were there comparisons with other cities where changes might have been due to other factors than the laws and their enforcement?

MR. ECONOMOS: There have been other cities that have achieved a reduction in traffic accidents, fatalities, and injuries through programs other than a good program of law enforcement, but no cities I have studied in the past 20 years ever achieved it without registering at least the minimum desirable level on the enforcement index. This is a quantity index that measures the activity of the police and the courts. A city must register at least the minimum on the index.

MR. HOLLOMON: I think Mr. Garcia's question has to do with whether or not there was both a blind sample and a positive sample treated under different conditions at the same time, so that a determination could be made as to the effect of the single variable of law enforcement.

MR. ECONOMOS: There has never been any organized research in this area.

MR. CAMPBELL: You implied that you were citing controlled studies that isolated the effect of enforcement. I am not aware that this has been demonstrated. It is very difficult to draw conclusions from a simple before-and-after study. A co-variant design is necessary.

This is not to assert that law enforcement has no effect, but like so many other things, the data to prove it in terms of scientifically demonstrable benefits are not available at this time.

JOHN EBERHARD: You indicated that the Uniform Vehicle Code had provisions or requirements for the vehicle itself. Would you elaborate on those provisions?

MR. ECONOMOS: The Uniform Vehicle Code has a special chapter covering lights, brakes, the kind of glass in the vehicle, how high it should be above the road, and so forth. It covers simple items of this nature, not complex things. In my opinion, these are minimal equipment factors as far as the Uniform Vehicle Code is concerned. However, such equipment factors have created a lot of problems because of non-standard, non-uniform provisions throughout the states; the Uniform Code helped improve the situation.

MR. HOLLOMON: Did you state that you felt it was necessary to have at least parts of the Uniform Code mandated uniformly across the country, or did you say it was just desirable for states to adopt it? What would be the legal basis of a federally imposed Uniform Vehicle Code?

MR. ECONOMOS: A possible legal basis for a uniform code might be the regulation of interstate commerce. This is an over-simplification in answer to your question. As a pressure on states, there is the suggestion that money for public roads be withheld until the state adopts uniform rules of the road.

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THE DRIVER AND SAFETY

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It is useless to wrangle over the relative importance of vehicle, driver, and highway in the total traffic safety picture. Even if it could be deduced that one factor was most important in producing accidents, it might be found that another was most important in preventing accidents, and still another most important in lessening the consequences of collisions. If the relative contribution of vehicle, driver, and highway is to be assessed, it should be expressed in an analytical form and based on observed facts in order to bring forth sensible responses to the traffic accident problem.

Causes and effects in traffic accidents are not simple and clear-cut matters; moreover the term "accident" refers to a complex of events, not just one event. Since there do not yet exist firm operational measures of either cause or effect variables in traffic accidents, we are presently not able to assert much more than a "systems" cliche, that elements of the traffic system interact in various ways. The principal data consist of a multitude of statistical variates such as the number of miles driven, location and speed distributions of vehicles on roadways, number of vehicles in accidents, and the number of persons killed or injured. Various indexes have been made up of ratios and products of these numbers, and the indexes in turn are often intercorrelated among themselves and with other observable features of the car occupants, the vehicles, and roads.

With all these complexities in mind, and with no intention of rating driver or vehicle as most important in traffic safety, I shall discuss first the control of the vehicle. Then I will discuss the strategy of driving, for there is more to driving then merely operating the controls in a car and making it go. In considering the strategy of driving, we might look upon the car as a tool used to accomplish an objective. Some personal factors that can influence both vehicle and

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driving strategy will be discussed. That will be followed by some biomechanical considerations in the design of vehicle components.

The driver as an element in the total vehicle control system does not perform as a fixed constant; he changes on demand as the situation changes. As a result of this considerable adaptability, the human factors research job becomes complicated. To seek those design configurations that are in some sense optimum, we have made tests in which experimental vehicles or system parameters were systematically altered; the resulting behaviors of the man, or of the man-vehicle system, were recorded, then compared. In such experiments, the researcher must cope not only with the usual variances in individual drivers and environmental conditions, he must also cope with non-stationary human characteristics.

I will describe some of our experiences in conducting these tests. Some time ago, we used a special test car with an electro-hydraulic servo link between the steering wheel and the front wheels. We asked, "What is the best steering ratio for a car?" The question can be expressed in explicit operational form, and therefore we hoped there would be a simple and precise answer obtainable from trying various ratios and observing the consequences in driver performance. We found, however, that making changes in the control characteristics did not lead to any easily measurable differences in the way the driver performed during relatively normal but challenging driving tasks. It was clear that the driver was adapting himself to whatever control system was being presented to him — within fairly wide limits. (Differences between widely different systems could be measured by comparing derivatives of yaw, or swerving, but not by comparing vehicle tracking errors, the principal criterion.)

In our next experiment in which we intended to study steering ratio and steering effort (kinesthetic feedback) together, we concluded on the basis of the previous experiment that we should measure system quality by the degree to which the driver had to exert himself to adapt to the system. Not knowing any way to tap into the driver in order to measure objectively the cost to him of his adaptation, we accepted his verbal report as that index. This is not a very novel technique; it is commonly employed by test pilots, for example, in experimental aircraft studies. We used a response-surface statistical experiment design to test seven different steering systems, which were systematic samplings of the design parameter space. We elicited quantitative judgments from drivers who compared systems two at a time under some specialized driving and environmental conditions. Figure 1 shows the least-squares solution to the preference ratios that were obtained from the test drivers. It forms a topographical contour map having a pronounced peak with rapidly falling contours away from the optimum region. This all seemed very clear; we had managed to obtain some indication of the best combination of steering ratio and steering effort for the specialized conditions of concern to us then. However, there are some real problems here.

We subsequently repeated the experiment with a much improved test vehicle, but now 15 different steering control systems were tried. These represented different combinations of forward gain, steering effort required, and forward control damping both positive and negative. With 15 different systems to examine, it was impractical to

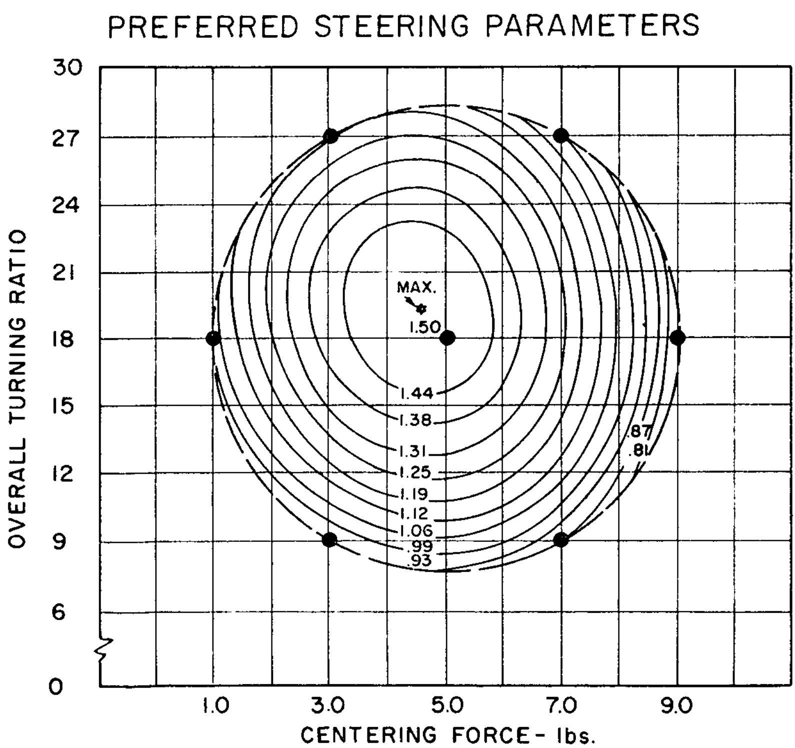

FIGURE 1.

have every driver try all possible pairs; therefore, we selected two very different members of the 15 systems as the constant references against which all others were compared. We divided the test drivers into two groups so that each group used one of the two selected systems for their reference. In this experiment we not only measured driver opinion regarding the comparisons each was making, we also reverted to measuring objective system performance, this time in simulated cross-wind.

As we had expected from our previous work, the objective performance did not show any great differences among the 15 different steering systems that were tried, except for a significant learning curve on the more unusual systems. The curve indicated that adaptation took three or four minutes rather than the few seconds one commonly sees with more ordinary systems.

However, upon examining the drivers' assessments of the systems, we found what, as psychologists, we should have been prepared to see; we were disappointed when we saw it, nonetheless. That is, there was a powerful gravitation toward that which had become familiar, namely the reference system. Thus, in the two groups of drivers, all of whom received the same 15 systems to evaluate, there was a strong polarization of acceptance in the direction of the reference system with which they had become familiar. In fact, most of the variance in preference measures could be attributed to using the two reference systems rather than to differences in the control parameters that were the main point of the investigation. Needless to say, we are still researching how to do this kind of research.

There are implications for engineering technique in this finding, for it raises some doubt about the ability of technicians to evaluate objectively, without instruments, those devices and systems with which they have become familiar. For the driver in the general public, it further reinforces the observation that control of most cars is quite simple, and that the driver will exert himself in whatever way is required in order to get the vehicle to do what he wants it to do; that is, he adapts to the equipment. And even though he develops an attachment to that equipment with which he has become familiar, he can readily readapt to a different situation.

The automobile is a reasonably simple mechanism to operate. There are only a few controls in it, and its dynamics are tighter than most other vehicles devised by man. Its directional response has a time-constant of less than a second, which is vastly less than that of airplanes, boats, and submarines, for example. Although there is only one stage of integration between a steering wheel input and vehicle directional response, the time-constant is so short that one scarcely notices that it is a second order system. (Human response bandwidth is only slightly wider.) But like most physical devices, the automobile can be driven into nonlinear response regions. Except for race drivers, very few persons have occasion to deliberately drive so far out of the normal range that they are near the edge of instability (skidding, for example). As a result, when unusual circumstances (ice, tire blowouts, unexpected behavior from other drivers) bring about a condition for which most persons do not have the experience background, they are not able to perceive quickly enough what is happening and to respond appropriately.

What are the implications for driver training? I view driving skill as having two components. The first is the ability to operate the controls and make the car go, which is so undemanding that nearly anyone can do it; the second is the strategy of driving, or comportment in traffic. Driver training should teach both of these aspects of driving skill.

It would be good if driver training could provide a sufficient amount of direct experience at controlling the vehicle in protected areas in difficult situations, such as in skids. There are many of us who have never learned how to control a car under all conditions. Many young hotrodders no doubt can control a vehicle better than I can, and the female cabdriver who brought me here this morning most certainly can. Questions may be raised as to how effective a course in driver training can be in altering or conditioning attitudes, since driving strategy may well reflect one's life style.

Unfortunately, there has not been any definitive study to determine the effectiveness of driver training programs. It is certainly our belief that driver training must be better than no driver training. There have been numerous comparisons of the traffic and accident records of persons who were in driver training courses against the records of those who were not, and these studies frequently show better performance by those who were in the training programs. One basic problem is that driver training facilities are generally insufficient for everyone to receive thorough, behind-the-wheel training. In places where students may choose to take or not take driver training, it has never been conclusively shown that those students who choose to take driver training are not different in their basic approach to life and to driving than those who choose not to take driver training. There is a lengthy longitudinal study in progress in Colorado in which comparison is being made between the latter-day traffic and accident records of students systematically excluded from driver training or assigned to such a program when they were in high school.

As for the strategy of driving, there are two main types of behavior among drivers. In most cases, drivers make decisions and adaptations to accomplish the primary objective of proceeding through the varying flow of traffic. In some cases, drivers may use the car and the traffic environment for expressing psychodynamic needs. That is, the driver's car may be used in the surrounding traffic as an instrument for the driver's psychological expression.

In discussing the first type of driving behavior, that is, adapting to traffic needs, it can be said that drivers are more adaptable in the pursuit of their transportation objectives, and their driving is more appropriately flexible than traffic regulations say they are allowed to be. When the posted limit is set too low for the circumstances, there is widespread violation of the speed limit. There have been some tests in recent years of motorists' willingness to cooperate with speed regulations. Traffic officials in some parts of Illinois, Nebraska, and Utah, for example, have tested this willingness by changing the speed limit in areas where there was gross violation of the posted speed. (Generally, the speed limit was revised to a value near the 85th percentile of the speed at which most motorists actually traveled on that highway.) A frequent result has been that the average speed of the traffic went down a bit after the speed limits were raised. As soon as the posted speed limit showed itself to be reasonable, motorists obliged by conforming to the requirement, and became good citizens instead of habitual lawbreakers.

Safe driving is a personal thing and does not necessarily relate to moment by moment rigid adherence to minor traffic regulations. For example, a recent study was done by the American Institutes for Research for the Public Health Service. In Washington, D.C., researchers took movies of 304 cars while following each of them in city traffic. Eighty-seven percent of them went over the speed limit, 63 percent did not stay in their lane, 20 percent changed lanes without caution, 17 percent followed too closely, 46 percent turned without signaling, 80 percent changed lanes without signaling, 15 percent rushed a traffic light, 6 percent passed improperly, 11 percent turned improperly, and 34 percent stopped improperly (usually in pedestrian walkways). They averaged nine errors each.

The main point here is that most drivers gage their driving behavior in accordance with the needs of the moment more than with rigid regulations that may not significantly apply. This instantaneous adaptability to traffic conditions, while optimizing one's own transportation objectives, is perhaps best seen in Rome. Traffic would probably be paralyzed if drivers and police did not take a congenial laissez-faire approach to traffic regulations, and view them more as advisory than binding. It is probably just such flexibility and adaptability of the driver that allow him sometimes to stray innocently over the hazard threshold into a collision, but which in most circumstances keep him safe and optimize the pursuit of his objectives. We call this skillful driving as long as nothing happens. However, those same maneuvers would be branded irresponsible and reckless if some unexpected interference were to cause a mishap.

Many accidents occur because drivers do not perceive and react quickly enough to the unexpected. A great deal of driving behavior, like other types of behavior, is based on expectation. We know from general psychological considerations that events having a low probability, and hence usually a low expectation, are often simply not believable when they do in fact occur. It takes a longer time to react to a transpiring event that we ordinarily consider to be very unlikely. For example, one does not expect to see a very slow-moving car going along an expressway; one does not expect to see a car coming the wrong way down a ramp. Corrective action on both occasions is often delayed long beyond the point when the signal first emerged.

Even though the visual and aural cues for such unexpected events are well above threshold and strongly salient, we often delay a long time before accepting the true situation. The basic mechanism seems to be a cognitive dissonance between what you "know" just can't be so and what the true state of affairs actually is. That is not to claim that you never believe what you see just because you're not expecting it. It means that it requires time to convince and alter your perception. The delay increases the probability of a collision. The Bayesian statistician will recognize this as similar to the problem of altering strong *a priori* personal probabilities on the basis of limited evidence. Actually, some persons never do alter their perception. Conflicting testimony and blame of others is very commonplace after such events.

Think for a moment about the general human characteristic of belief based on expectation and consider how this same human characteristic influences our approach to the hazards of traffic. Since we all engage in driving behaviors that, with a little further deviation, can easily cross over the hazard threshold and result in a collision, it is evident that expectation with regard to the risks that people are willing to take plays an important role in traffic events.

I think most of us get into our cars and drive away without any paralyzing preoccupation with the possible imminence of a personal disaster. Indeed it is the other driver who gets into accidents, not us. And when we do get into accidents, it's easy to blame the other fellow and we may well be right.

Accidents do not happen to us, they happen to the other fellow. Our own intuitive odds-maker tells us that is true every time we drive. As I have mentioned, our driving behavior is typically very flexible, almost continuously crossing over the theshold of narrow legalistic constraints as we encounter as many as 500 separate events and attend to them during every mile we drive. Perhaps 20 of these events may require that some important decision be made.

What effect does all this experience, day in and day out without any adverse results, have on the development of our expectational set? It is not surprising that most people have the expectation of safe trips, for they go and come without experiencing any tragedy. National Safety Council figures, converted into reciprocal form, confirm this expectation of safety. They measure personal risk as follows: A person could drive 40 mph for 16 hours a day every day of the year for more than 70 years between each vehicle or pedestrian fatality. Whereas some 17 million driving miles intervene between deaths, injuries are more frequent, with 430,000 miles intervening between them. These figures are the average for all types of drivers and all types of driving.

Of course, the "average" can be misleading. There is a wide difference between the majority of drivers and a certain small group of drivers in the population that skews the accident statistics badly. The result is that risks for most people are probably less than the nationwide average. In addition, most drivers have less to fear from their own performance than they do from the performance of the smaller, statistically more dangerous group.

Lest I be misunderstood, I will say that I cite these figures only to provide some measure of explanation for the lack of frantic concern for safety by most persons as individuals. I do not wish to leave the impression that I am minimizing our national traffic problem, or implying that society is getting off cheaply.

The cost to society of all the injuries and deaths suffered in traffic accidents has been considerable. In view of this cost, it is not surprising that there has been a considerable amount of moralizing directed at all of us about our driving practices, to the extent that I think we may be justifiably impatient with the accusations. Most people do not feel they need or deserve these harassing and punitive reminders, which often have implied an almost irredeemable guilt. It is no wonder that reaction to certain safety slogans has been hostile and non-cooperative. For the most part, we are good drivers; we are decently cooperative and courteous even if only for the pragmatic purpose of maintaining an optimum traffic situation. Safety campaigns have not been roaring successes. Many of the admonitions ring hollow.

An individual's objectives are usually pursued to the limit that he considers worthwhile and risk-free. This judgment varies from person to person, and probably covers a wide spectrum of benefits and costs. Although benefits and costs must ultimately be traded off against each other, I suspect the function is not necessarily linear or direct. It is more likely that one does not seek to optimize the ratio as such, but rather that one has some relatively fixed-cost threshold below which he seeks to stay; he may be conservative or he may be reckless about how close he will allow himself to approach the threshold, but in any case he seeks to increase his benefits to their maximum while staying within a "reasonable" cost. In the context of this symposium, benefits refer to transportation objectives, and cost to accidents.

One way in which a driver increases his benefits is illustrated as follows. There was a time years ago when, after six or seven hours of driving, one would be so fatigued that stopping for a rest was necessary. In recent years, car travel has been relatively easier, and most drivers are still fairly fresh at the end of six or seven hours. However, they usually press their advantage; instead of stopping and enjoying their rest and leisure, they continue driving until they reach about the same threshold of exhaustion as they did when driving was more difficult. Thus, for the same physiological cost, they have increased their benefits. In doing so, perhaps they are accepting a higher accident risk because of longer exposure.

One of the more interesting developments in recent years has been the accelerating emergence of mathematical formulations for describing traffic behavior. These formulations range from models analogous to the kinetic theory of particle motion to those that start with postulates based on likely human characteristics — such as human reaction time and sensory theshold for detection of changes in relative velocity. Some of these models have been formulated in terms of statistical decision theory for the description of errors in risk taking. There has already been practical application of some of these ideas of modulating traffic flow with control devices in order to avoid the generating of shock waves in the traffic stream. These shock waves, which are initiated by speed non-uniformities in dense traffic, propagate backwards in the traffic stream, leading to slowdowns and standstills, thus effectively decreasing the potential capacity of a road. A voluminous literature in this field is developing; it is commonly reported in the *Journal of the Operations Research Society of America,* and is largely the result of the new interest in finite mathematics and of the wide availability of high-speed computers. More and more papers on this topic are being presented each year at the annual meetings of the Highway Research Board.

I come now to the second approach to driving strategy, in which the driver may use his car in the traffic environment to express psychodynamic needs. There is no doubt that in some statistical sense a small fraction of accidents is in fact disproportionately caused by particular types of people. However, to demonstrate or study this in a practical way is not at all easy. There are the popular beliefs in accident proneness and predisposing traits but neither of these concepts has been firmly validated by psychologists. The accident-prone individual supposedly has some inner need to punish himself and thereby gravitates into situations where this need can be satisfied.

The individual with characteristic personal traits tending to involve him in accidents supposedly follows a line of judgment and behavior that puts him in a bad situation doing the wrong thing at the worst moment. There are psychologists today who reject the usefulness of the trait idea mainly because one commonly observes enormous variation in personal behavior from one situation to another.

Nevertheless the trait concept endures; in a broad sense, there do, indeed, seem to be personal predispositions for accident involvement, and it is also likely that some portion of the traffic safety problem will be found to be associated with certain human characteristics.

One group in the population accounting for a disproportionate fraction of the total accidents is the teen-age group. Youth still constitutes a minor proportion of the total driving public, perhaps 20 percent, but the size of the group is increasing. There will be a sizable jump in the number in the mid-70's. However, some 40 percent of traffic deaths occur to members of the 16 to 24 age group.

Is it just youthful high-jinks — predisposing traits — or lack of experience? The answer is not clear. Some studies show that among new licencees over age 20, the accident rate does not expand as it does among the younger licensees, and accidents seem to be conspicuously associated with young males, not girls. In a recent study of the teen-age driver in California, the conclusion was drawn that exposure, meaning the amount of time spent driving an automobile, was more important than the age of the driver in determining accident rates and violations. When equated for exposure, 18 and 19-year-old males had fewer accidents than younger males.

In regard to personal traits that predispose drivers to have or avoid accidents, there has been a variety of studies over the years showing that drivers who have been involved in accidents or violations tend to be more aggressive, cannot contain their hostility, are self-centered and indifferent to others, are resentful, and appear to take more risks. Dr. Malfetti of Columbia University a few years ago did a small study that suggested that many supersafe drivers were, on the other hand, superrepressed and superconforming. The characteristics that seem to make these drivers safe are not very valuable personally or in society, he felt, and he raised the question "whether we would wish to train people, even if we could, to possess these traits for the limited purpose of safe driving."

In a recent study at the University of Washington, a number of drivers who had been injured in traffic accidents were compared with a matched set of drivers who had not. As is often the case, in their psychological attitude test scores, the drivers evidenced no significant differences. Both groups ranked themselves close to expert drivers. However, when examining the histories of these persons a little more carefully, researchers found that the reports made by those injured in the accident were often different from the police reports, with the police reports frequently indicating recklessness. Those in the injured group also had records of significantly more driving offenses or difficulties in the past. They admitted having failed skill tests on at least one or more occasions; they had had their licenses revoked; and they had accumulated violations having negligence or drunk citations more frequently than the control group. This study reported that "the omens in careless or incompetent driving patterns for (many of) the now-injured had been gathering for some time."

Surveys made in Ohio and Michigan of drivers who had been in collisions revealed that about 80 percent of them thought that the other driver was to blame. Eighty percent thought they were good or excellent drivers and only one percent thought they were poor drivers. Would a refresher course in driving and safety help them? Only 5 percent thought their driving could be improved by that method and almost 40 percent said positively no. About half of them felt that there is nothing that can be done to avoid future accidents. Only about one in 20 believed that safety programs really teach anything about safe driving. Only about 2 percent of these people thought that courtesy is important.

Notice that careless or incompetent persons are potentially identifiable on the basis of their past history. However, they are not necessarily detectable before they have generated a past history; even after having generated a miserable history, they are not easily culled out by standard psychological testing instruments.

A number of studies have pointed to one principal factor among chronic repeaters: social irresponsibility, or poor citizenship. It could be said that a man drives as he lives. For example, among the chronic repeaters we find individuals who are more often seen in adult court for non-traffic reasons, who have more trouble with credit agencies, are more often in juvenile court, more often make appearances at public health and VD clinics, and more often have contact with social service agencies than the infrequent traffic violators.

This suggests that there are two solutions to this public safety problem: First, we could retrain the attitudes of these offenders; second, we could deny drivers' licenses to the worst offenders in the first place. It seems very unlikely, however, that any sort of retraining, or psychotherapy for that matter, will do much good for persons having deeply rooted personal characteristics of this type. There is no way to assess the effectiveness of such retraining since we are scarcely able to measure attitudes by standard psychological testing. Certainly present tests also are not reliable enough to spot the potentially unsafe driver and deny him license before he can build up a bad driving record. Using records from the courts, credit agencies, and social agencies as a basis for licensing to drive is also unreliable. Although a predominance of extreme repeaters may come from the socially irresponsible group, not all of that group becomes extreme repeaters, and psychometrics has not yet produced a testing instrument to make the discrimination among individuals in it who will be safe or unsafe drivers.

Some figures indicating the proportion of repeaters in traffic accident statistics were given recently in the Bureau of Public Roads study of 150,000 accident cases. It was found that 6 to 7 percent of all drivers have one or more accidents in any given one-year period; of these drivers, 90 percent did not have an accident in the year following the recorded accident, and 89 percent had not been in an accident during the year before the recorded accident.

The correlations between traffic performance and any measurable characteristic of the individual, whether it is an index based on the person's past traffic history or one derived from psychological testing instruments, have been disappointingly low — about 0.2, or so low that they scarcely have any predictive usefulness at all. Predictive efficiency is only 4 percent.

Figure 2 shows the oval-shaped envelope of the scatter of individual test scores plotted against subsequent driver performance. The horizontal dashed line divides the public into the 80 percent whose actual subsequent record proved them good risks as drivers, and the 20 percent whose actual subsequent record indicated they should have been excluded. However, while failing test scores would also exclude 20 percent, they would not exclude the same 20 percent who had poor subsequent driving records. By applying the vertical dashed line as a pass-fail cutoff, we have the following makeup for the 20 percent excluded by the test: a large group "A," subsequently proven as good drivers; a smaller group "B," subsequently proven as bad drivers. Group "C," subsequently proven as bad drivers, would not have been detected by the test.

This shows the near hopelessness, with present general techniques, of selecting only good drivers for licensing. However, there are two exceptions to this. First, for the limited business purpose of selecting good drivers from a large pool of applicants for a small number of jobs, one can afford to disqualify falsely many good applicants to

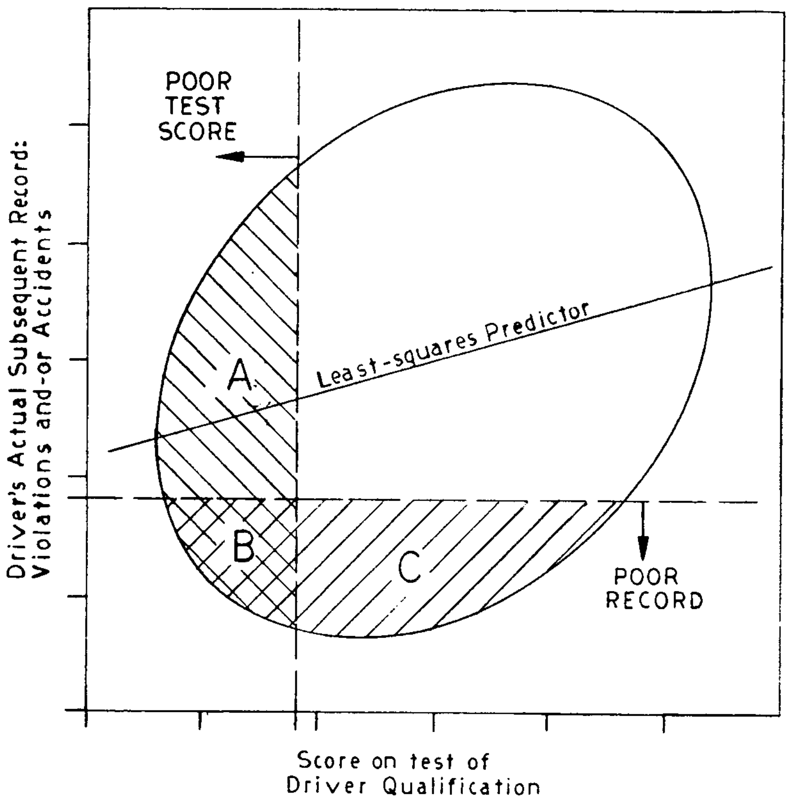

FIGURE 2.

assure that no bad ones remain; second, and most important, one can narrow down the field of disqualification in order to find the grossly aberrant.

One important group of drivers whose personal traits and aberrant behavior have a definite bearing on traffic accident statistics is the alcoholic group. Recent studies offer undeniable evidence that alcoholics are responsible for a high proportion of traffic fatalities. In the past five years, several studies, largely sparked by Dr. William J. Haddon, Jr., have been carried out in various states. These studies have pointed to a single conclusion: As many as *half* of the drivers who are killed in single-vehicle accidents have blood alcohol levels of greater than 0.15 percent (weight per volume) concentration. Single-vehicle accidents are those accidents in which no other driver is likely to be to blame; more deaths result from these than from collisions of two or more vehicles.

That figure, 0.15 percent, has been the legal standard of intoxication across much of the nation. It is quite a standard: It would take about eight drinks on an empty stomach over a period of about an hour for a 200-pound man to show that kind of concentration in his blood. Alcohol is oxidized and eliminated from the body very slowly. In one experimental test, a man took eight drinks spaced over four hours. It took about two hours from the time he started drinking for his blood alcohol level to reach 0.15 percent. And it stayed above this level for nine hours. Fourteen hours after the last drink his blood level was still at 0.09 percent.

In the newly emerging understanding of very severe accidents, it is apparent that they involve an uncommon number of aberrant situations in the driver, the car, or the road. Often all three are aberrant — for example, an aggressive drunk in an old rattle-trap driving too fast toward a wet slick on a curve lined with a deep ditch or big trees. The aberrancy of the driver is most often alcoholism and social pathology, or sociopathy. Notice the emphasis here is not alcohol itself, but alcoholism and social pathology.

Recently, Selzer and Weiss at the Michigan Neuropsychiatric Institute studied 72 drivers who had been judged guilty in the deaths of 87 persons. They found that half of these drivers were near-alcoholics or full-blown alcoholics. More than half had psychiatric disorders other than alcoholism, usually paranoid thinking; a quarter of them had fits of uncontrollable violence. A driver of this type can easily be aroused to vengeful or pre-emptive aggression toward other drivers for imagined personal slights. He is usually immune to the ordinary threats and appeals. Punitive measures commonly applied to other drivers with some probable degree of effectiveness tend to make individuals with sociopathic disorders more hostile and tend to reinforce the aberrancy rather than reduce it.

If we could remove such drivers from the road, how much would it change the total accident picture? It is uncertain, although some studies done in California by Dr. Julian Waller, when taken with the mounting evidence elsewhere, have led to a crude estimate that perhaps as many as 25 to 35 percent of all traffic fatalities may be due to alcoholics or sociopaths. Alcoholics make up about four percent of the country's population.

Dr. Waller's studies also reinforce the statistics that in about half of our traffic fatalities, the party at fault had been drinking alcohol. As I said before, pathological drinkers are responsible for about a quarter of the fatalities, which means that social drinkers are responsible for another quarter. Of the drinking group blamed for fatalities, nearly 75 percent had blood levels in excess of the legal limit of 0.15 percent. In this group, 62 percent had cirrhosis of the liver. Interesting too is that among the adult (25 years and over) drivers and pedestrians who were not drunk but were at fault in traffic fatalities, an unprecedented number, 15 percent, had cirrhosis of the liver.

How much do the medically deficient and physically disabled drivers contribute to traffic accident statistics? Only a small fraction of the traffic fatalities can be shown to have resulted from medical events such as heart attacks and seizures. These are essentially unpredictable, and it is hard to make a case for limiting the driving of those persons who might be susceptible to such medical events.

The physically disabled seem to perform in traffic much as they do in jobs in industry, that is, much better than one might imagine. Dr. Richard Domey of Harvard did a statistical study of matched pairs (sex, age, experience) of disabled compared to non-disabled Massachusetts drivers. The physically disabled had only about half as many traffic citations and accidents as the representative sample of non-disabled drivers.

In the consideration of the vehicle and the bearing its design has on the performance of the driver, an important biomechanical fact is that functional ability to operate the major controls is affected by the placement of the occupant inside the car. Good placement is not a simple thing to accomplish because of the very wide range of sizes of people who must be accommodated. To accommodate the frequently conflicting requirements of both the fifth percentile female and the 95th percentile male is not easy. This range in the civilian population is unusually wide, unlike that for military requirements. Thus, to provide visibility over the steering wheel for the lower percentile drivers creates problems in regard to pedal reach for them, and more problems for leg clearance under the steering wheel for higher percentile drivers. This is further complicated by the desire to keep the wheel reasonably close to vertical for best crash-loading. As a result, various schemes have been repeatedly looked at for adjustable controls; most have thus far seemed to provide more problems rather than any solutions. To design a vehicle for both operational safety and injury protection is a challenge. Operational effectiveness requires, for example, that controls be widely spaced and very prominent. On the other hand, occupant protection requires that the controls not be prominent, that they be out of occupant impact zones but within reach and consequently bunched close together. Now with shoulder belts coming in, interior design to maintain an adequate reach for a broad percentile range of body sizes is further challenging.

In many respects, anthropometric studies in the automotive industry have moved beyond what had previously been the most reliable sources: military data. Not only have data on females been sparse, but more basically, traditional anthropometrics, the measure of man, is not directly applicable to the vehicle design problem. Anthropometry has been oriented toward the comparison of peoples, and consequently the measurement of persons was tailored to that purpose. When persons were measured, they were placed in standardized postures that facilitated the measurement. However, these postures and measurements are often not directly relevant or usable for automobile design purposes. We have for years been using information of this sort, collected mainly by the military and most recently as part of the new National Health Survey. However, we are finding more and more that it is necessary to determine not the probability distributions of people-size, but the probability distributions of functional dimensions and acts. For example, from photogrammetric data on 2,300 drivers, we have developed trivariate distribution contours for the location of drivers' eyes on a fixed car-body coordinate system, without reference to standardized anthropometric posturing nor to manikins. These contours have been adapted to an algorithm for visibility percentile specifications.

There are many areas in which in-house anthropometric research is aimed at establishing relevant functional relationships; static dimensions pertaining only to abstractions are appropriate for anthropology textbooks but not for vehicle design.

Another important area for research in biomechanics concerns vehicle design as it relates to the injury of passengers involved in automobile crashes. There has been a developing technology in the method of evaluating through laboratory tests various vehicular surfaces and structures for their injury potential. There has not been sufficient original research associating the size and quantity of physical blows to the organism with the resulting levels of injury. But once some approximations have been obtained as a result of tests using animals, cadavers, and sometimes even live volunteers (for the minor impacts, of course), there still remains the problem of devising a suitable laboratory test and procedure that can be reliably and validly applied to various vehicular surfaces and structures.

Cadavers and animals and live volunteers cannot be used for the routine day-in, day-out testing to assess the degree of injury potential of structures of various designs. Artificial devices must be contrived for this purpose. The devices must have dynamic characteristics either reasonably similar to the organism, or at least mathematically relatable. They should be of such a character that physical parametric measurements leading to a numerical value can be obtained. Some confusion occasionally results because force levels for equal injury severity are not nearly the same when testing with a cadaver as when testing with a laboratory rig. It is a matter of calibration, but extrapolations and generalizations are still difficult to make, with the result that testing techniques often must be improvised for the specific circumstances being examined. I state these truisms because not everyone recognizes that the state of the art in this field is still largely empirical and far from routine.

Specification of the input waveform is of use mainly to standardize the testing procedure; it does not necessarily bear any direct relationship to the response waveform. Since we are dealing with impulses, the response waveform must somehow be rationalized into some kind of numerical criterion. Thus far, the results of limited cadaver testing have led to what are mainly empirical rules for evaluating the response waveform. For example, acceleration peaks of one or two milliseconds have come to be regarded as relatively unimportant in head injury. Sometimes only the peak accelerations or forces are deemed important, such as in evaluation of potential injury to the knee or thigh or hip; in other instances weighted integrated functions of the waveform seem to be more appropriate. For puncture-type injury, there has not yet been developed any sucessful criterion for injury potential based on kinetics alone, and ad hoc experimental and clinical accident data must be relied on.

There has been a fair amount of human body tolerance information developing in recent years, but it has mainly referred to the head. Unfortunately, most of this information has been obtained from impacts of the forehead, with only recent and limited attention having been given to the face. There is an enormous amount of individual variation. The injury variance from point to point on fleshy parts of the face and head are as great as the variance from skull to skull.

It is amazing how much attenuation takes place when the soft tissue of the body, such as the scalp, is hit and deformed. For example, a skull with the soft tissue removed can be made to fracture at about two or three foot-pounds of energy when striking a flat unyielding surface, whereas it would take under the same conditions 35 to 60 foot-pounds to fracture the skull covered with intact soft tissue. Much of this information has been summarized in SAE Information Report J-885a.

To summarize, the driver is not an invariant, stationary, linear system of fixed constants. He adapts himself to the parameters of the vehicle-traffic-road-objectives system in which he finds himself. He controls his vehicle and comports himself mainly by his expectations, which were developed through experience and which directly affect his perceptions. There are probably some personal characteristics that mark some drivers as essentially aberrant, and the foremost among these seems to be pathological use of alcohol. Efforts to cull out problem drivers, other than those grossly aberrant types, seem unlikely to succeed with the present state of the art of psychological testing, at least insofar as the general traffic safety problem is concerned. Techniques for measuring the trauma potential of vehicle structures are still being developed, pacing basic biomechanical rcsearch findings.

DISCUSSION

Moderator, J. HERBERT HOLLOMON

JOHN REECE: Many states as a matter of legal policy, including the Uniform Vehicle Code, exclude from licensing those groups of people described by statute as alcoholics or narcotic addicts, plus those who are described as "habitual users of other drugs to an extent that would impair their driving ability." Might we conclude, in view of your remarks, that such policy decisions in law are not really rational, and that if those statute requirements were modified, or conceivably even eliminated, they would not affect the accident picture to any great extent?

MR. VERSACE: Do I understand you to say that if these people were allowed to continue to drive that the accident picture would remain substantially the same?

MR. REECE: Yes. Is there any evidence that this is true? I am trying to research the point as to whether it is truly rational for statutes to exist, unsupported necessarily by scientific data, prohibiting alcoholics from driving. I suspect that such statutes are based on simple, general prejudice that drunks should not drive. From recent research of a scientific and psychological nature, this general conclusion in fact cannot be substantiated, and therefore if we let all alcoholics and drug users drive, we don't necessarily distort the accident picture.

MR. HOLLOMON: As I understand what both Dr. Haddon and Mr. Versace have said, there is clear evidence that the chronic alcoholic is in fact a disproportionate cause of fatalities with respect to accidents. It that correct?

MR. VERSACE: Yes. Perhaps two of the facts mentioned might seem contradictory. The first concerns psychological testing. Using the test as a stringent way of weeding out those in the public at large who are going to be problem drivers is unsatisfactory. There are no good tests for doing this. That is what I tried to demonstrate in Figure 2, a very poor scattergram. However, if exclusions are limited to a very highly specific and very visible type of character, such as the obvious alcoholic, then you can at least eliminate him and save the people he might kill. The second fact I mentioned, one attributed to recent studies in California, was that 25 to 35 percent of fatalities are caused by alcoholics. Even though I repeated that figure, I don't think that alcoholics make a tremendous contribution to the total accident picture. Not directly knowing the evidence on the question, I would take a rather conservative position on it. Still, I think if you can identify habitual alcoholics and narcotics users — and that is the big job, positively identify them as such before they have actually killed themselves or killed other people — then it would be desirable to get them off the roads.

Perhaps Dr. Haddon might want to make some further remarks on that.

DR. HADDON: I think your answer is very much to the point. As a nation, we have long tended to assume that because we have passed a law to define some group that is to be excluded from the highways, that group is actually excluded. There is substantial evidence from a number of directions that many individuals who should be excluded under such regulations do in fact get licensed, and perhaps the overwhelming majority of them are licensed.

To take it a step farther, there is substantial evidence that after they are licensed and are caught violating the law, their licenses may be suspended or revoked but they continue to drive. If you doubt this, look at the statistics on persons in various types of illegal situations, such as drunken driving, who were found to be driving on revoked or suspended permits. This is one of the areas in which we must have a great deal of research to find out whether laws to exclude certain groups have any effect.

Getting back to the primary point, I agree with Mr. Versace with respect to the distribution shown in Figure 2. He makes the point very well that from a cost-effectiveness standpoint or cost-benefit standpoint, we would have to exclude far more individuals than it is practical to do, at least with the exception of very aberrant groups, which are just now being identified.

MR. ECONOMOS: As a matter of information, the Uniform Vehicle Code was revised in 1962 to make the upper limits of the chemical test for alcoholic concentration 0.10 instead of 0.15 percent. There are four states that have already recognized it, and more will adopt it as time goes on.

A. C. BLACKMAN: Have there been any studies comparing the general car-driving population with the commercial fleet operators? In general, they have a much better overall record, on a mileage basis, I believe, than the general public. Has there been a comparative study of these two groups to see whether there are any factors that are different, factors that might affect the driving records of the two groups?

MR. VERSACE: I recall seeing a number of studies of this sort, which do in fact ascribe to the commercial operators a significantly better performance than the public at large. There are a couple of things operating here. First of all, when a person is performing as an employee, he has somewhat different motivations, I think, than when he is pursuing his own objectives. Second, selection procedures for employees can be extremely stringent, whereas it is not practical for them to be so stringent for general licensing. For example, taking the same plot, Figure 2, we can arbitrarily make the acceptance score very high for job selection purposes. Of course, we are excluding a tremendous number of perfectly capable candidates for these driving jobs, but what do we care? If we have 150 applicants, and need only seven drivers, we can pick the cream of the crop. Under those circumstances, even a poor testing instrument can be used effectively.

In a number of instances, tests have been used successfully in the selection of drivers for commercial purposes. Commercial drivers so chosen may well be a substantially better group of drivers than the general public as a whole.

DR. HADDON: One of the problems here is what you count. It seems very likely from a good deal of evidence and inference that the truck driver, for example, is less likely to be injured in accidents, or killed in accidents that injure or kill persons in small passenger vehicles. This is very obvious in collisions between large trucks, tractor-trailer combinations, for example, and small cars. The odds are based in physics and are heavily weighted against the people in the passenger car. If accident rates are defined in terms of injuries or deaths, there is a built-in bias that may be substantially misleading as to the rate of involvement in essentially similar accidents from a force standpoint.

THE VEHICLE AND SAFETY

ROY HAEUSLER
Chief Engineer for Automotive Safety
Chrysler Corporation

What is the relationship of motor vehicle safety engineering to the nation's traffic toll? Before considering this question, I would like to review some of the causes of accidents. Dr. Haddon and his associates have provided evidence strongly suggesting that half of all our highway fatalities can be ascribed to drunken drivers or drunken pedestrians. These are not merely people who have been drinking, but people who are found to have blood alcohol concentrations representing intoxication. Dr. Melvin Selzer and his associates at the University of Michigan Medical School have found strong indication that half of the drivers held responsible for fatal accidents in which they were involved while intoxicated were not merely drunk at the moment; they had previously given clear indication of being pathological drinkers — alcoholics.

Another cause for traffic accidents has not been mentioned. Many studies have given clear indication that driver inattention has played a very large role in millions of automobile accidents. Most of us, I think, have frequently seen near-misses that obviously were the result of at least momentary inattention. The near-misses cannot always be expected to be misses. Some are hits.

In regard to alcohol and inattention, we could well ask what steps are being taken to keep drunken drivers off the highways, and to correct or exclude those drivers unable or unwilling to commit themselves adequately and sustainedly to the driving job when they are behind the wheel. I think if we were to make an inquiry, we would surely find that driver license applications are not given the benefit of an investigation or test procedure that would identify seriously inattentive drivers, or drivers that are alcoholics.

Can changes in automobile engineering help to cope with these two causes of accidents, alcoholism and inattention? The first reaction may be to say that little can be done to keep drunks or inattentive persons from having accidents if they persist in driving. However, we must take a more constructive view, one that goes beyond fault, blame, penalty, and punishment. Instead of dwelling on causes, we can work on modifying the consequences of traffic accidents. At least the other driver, the potential victim of the drunk, will appreciate whatever provisions have been made to help him pull himself out of a precarious position — provisions such as tires, suspension, and brakes chosen for the shortest stopping distance and for straight controlled stops without swerve; tires, suspension, and steering mechanism chosen for precise directional control under conditions of evasive maneuver; and a power plant chosen for maximum usable acceleration within the full range of normal driving speeds. If a collision or rollover does occur, he will appreciate all measures that have been provided to minimize his risk of serious injury — interlocking doors latches, seat belts, and interior cushioning, for example. This is the approach that has been receiving more and more attention.

In line with this approach, cars are being designed to be progressively more forgiving — forgiving of driver error, driver inattention, driver inebriation. If better car design does not prevent an inattentive or drunk driver from going through a red light or crossing the center line into opposing traffic, at least better car design may reduce the seriousness of the injury in the ensuing accident. It can correctly be said that millions of drivers have been successfully avoiding the red light crasher and the weaving driver for years, but many others — perhaps millions of others — do not avoid him. Every year, there are ten million traffic accidents in which two million people are seriously injured and 50,000 others lose their lives. This is reason enough to warrant our evaluating all design proposals that show promise of further protection against traffic accidents or injuries. Accordingly, it is appropriate for the automotive engineer and his associates who do research, styling, product planning, and design and development to consider all feasible remedies, without undue reference to underlying traffic accident causes, if maximum progress is to be made toward a safer car.

What is a "safe" car? The term "safe car" has been widely used, especially in the popular, non-technical press, without any serious effort at definition. It should be obvious that it is not really possible to build a "safe" car if the terms are intended to mean a car in which no occupant will be injured to any degree, even in the most severe collision. Neither is it really possible to build a car that will cause no injury to pedestrians so unwary as to step into its path.

Another definition, one somewhat more realistic, could be based on specified performance requirements. However, it has critical weaknesses too. One car can be said to be "safe" if it is just within the specified performance, while another car might be condemned as "unsafe" because it is just outside the limits. If the limits, inevitably chosen arbitrarily to some degree in any case, are shifted slightly in one direction, both cars might register as "unsafe." Shifting the limits slightly in the opposite direction could make them both "safe." Such specious rating would serve only to remind the discerning thinker that safety is a relative condition, unlikely ever to be attained, and varying as a continuous function. Yet, while it is impossible to build a completely "safe" car, it is entirely feasible to build a *safer* car, and this is being done, not merely at the design level but in production as well.

With regard to safety orientation, automotive engineering programs have had the following aims:

More protection for the passengers against injury in the event of a collision or rollover.

Visibility improvement for the driver.

Improvement in the driver's ability to remain attentive to the driving task.

Improvement in the driver's ability to communicate with other drivers and with pedestrians.

Improvement in the ease and precision with which the driver can control the vehicle.

Improvement in the vehicle's ability to follow the driver's lead in terms of the qualitative as well as the quantative adequacy of the response.

Further reduction in the risk of abrupt failure of any vehicular component that could precipitate or aggravate an accident.

The following illustrations give greater definition to the first of these aims, that of providing more passenger protection against injury.

This type of latch was adopted more than ten years ago as standard equipment on all American cars as a result of the finding of Indiana State Police Crash Injury Research that risk of serious injury in an accident was greatly increased when the car occupant was thrown out. Typically this ejection occurred as a consequence of the door's coming open. Cornell Crash Injury Research was later able to show that in traffic accidents, only half as many doors came

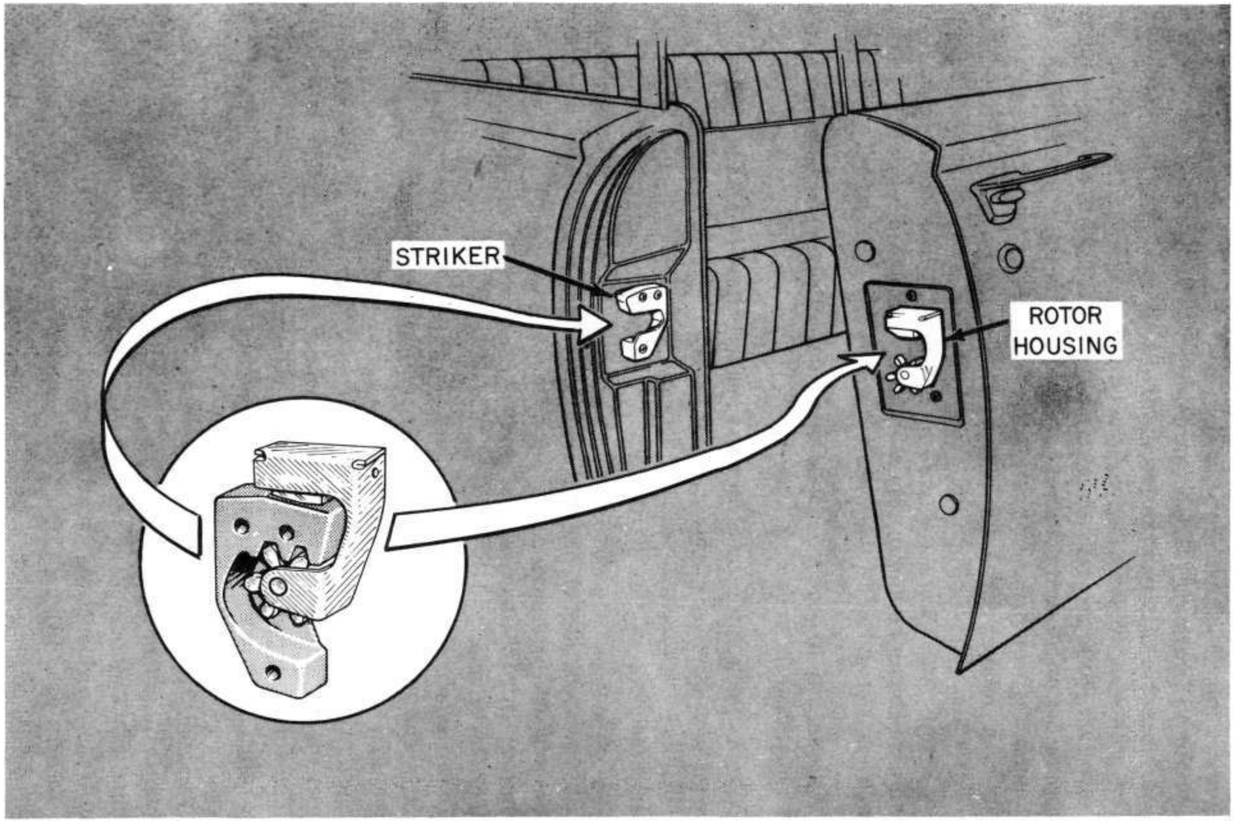

FIGURE 1.

open when they were equipped with the new type of latch shown in Figure 1 as did doors equipped with the previous type of latch.

Outside door release levers, buttons, and handles have been designed to provide minimal risk of accidental unlatching during side-swipe or rollover. Flush pull-out handles and guarded push button releases on the outside of doors are in widespread use. Risk of the door's opening through operation of this outside control during an accident has been reduced but not eliminated. However, the outside control is most unlikely to release the door if the door is locked, another good reason for routinely locking all doors from the inside. Other reasons for locking doors from the inside are to keep youngsters in and intruders out.

In the effort to keep doors shut in accidents, an interior door release lever of the type shown here has been designed. This lever is nearly flush with the door paneling. Its design makes it unlikely that the passenger will grab for it as a handhold during an accident, thereby inadvertently opening the door. The illustration shows how the lever is operated when release of the door is desired. (Fig. 2.)

Locking all four doors of a four-door sedan normally means pressing down four buttons as shown here, one on each door. The ones away from the driver may be hard for him to reach, especially those to the rear of front seats equipped with headrests. Locking all doors can easily be accomplished by the pressing of a single button close to the driver when cars are equipped with power door locks. The doors will not be locked any more securely than can be done with the individual lock buttons, but at least under some circumstances the job is more likely to be done when it can be done with a single convenient button. (Fig. 3.)

The rear seat in any sedan is generally the safer place for children. In four-door cars, both rear doors are equipped with locks of such design that two operations are required before the door will open. First the lock button must be raised, then the door lever must be pulled. The lock buttons on rear doors normally have the same mushroom head as was shown in the previous illustration, and these buttons can readily be grasped and raised by an adult, thereby unlocking the door.

This is difficult for a small child to do, but it may be possible for some. To guard against a child's pulling up the lock when he should not, a lock button shown here has been designed without a mushroom head. It is the Child-Guard design, intended to thwart

FIGURE 2.

FIGURE 3.

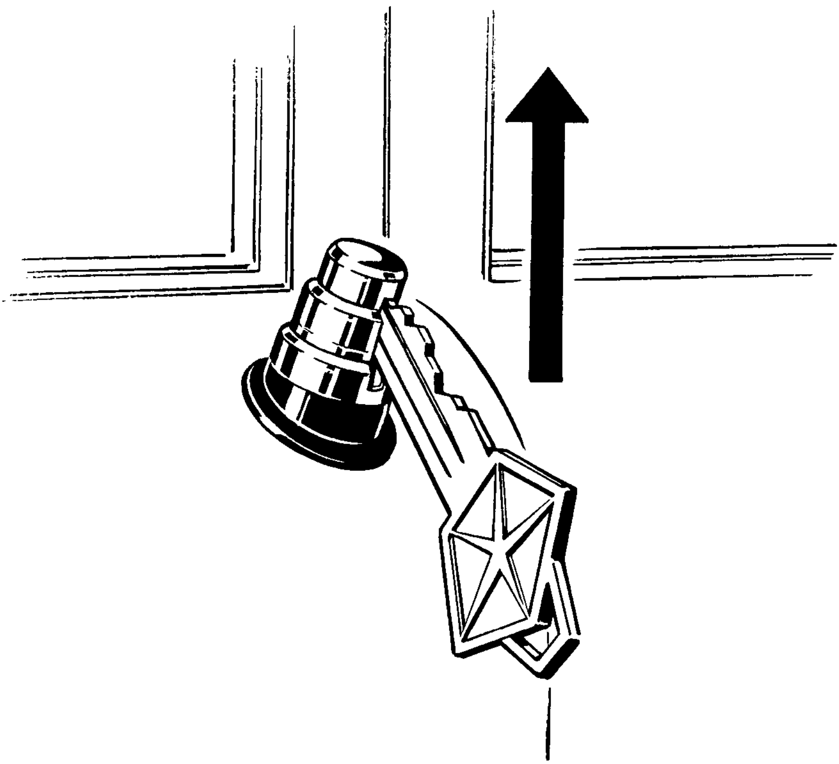

FIGURE 4.

the mischievous child who might try to undo what a parent has done in locking the door. (Fig. 4.)

With the Child-Guard door lock button pressed down into the locked position, there is no opportunity for the child's fingers to raise it again. In order to raise the button and unlock the door, a key must be inserted in a slot in the side and used as a pry or lever. Considerable finger strength is needed, making it unlikely that a child could manage it even if he used a key.

Seat Belts have been standard on every American car built during this model-year. (Figs. 5 and 6.) The great need has been to get universal usage.

The availability of the shoulder belt has been extended greatly during the past year. All evidence to date from such researches as

FIGURE 5.

FIGURE 6.

those of the Cornell ACIR group and Drs. Huelke and Gikas at Ann Arbor strongly indicates that a substantial reduction in risk of injury or death can be expected with the use of the shoulder belt in addition to the lap belt. However, simply equipping the automobile with the belts and mentioning them in the owner's manual will not be enough to assure their acceptance and use. We badly need a supplementary driver instruction program for all motorists already licensed and on our highways.

This type of shoulder belt is currently offered by two domestic automobile manufacturers. It is completely independent of the lap belt, thereby minimizing the risk that it will cause the lap belt to be pulled up or to move up into the soft abdominal area during a collision. The main disadvantage of having two independant belts is that they require the weaver to fasten and release two buckles instead of one. On the other hand, the wearer can adjust each belt to its optimum snugness; he does not have to accept the same belt tension for the entire system. (Fig. 7.)

One recommended installation for shoulder belts is shown in this drawing. This arrangement provides additional assurance that, under load, the shoulder belt will stay down on the shoulder, away from the side of the head and neck. In extending to the rear of the back seat for anchorage, however, this shoulder belt blocks access to

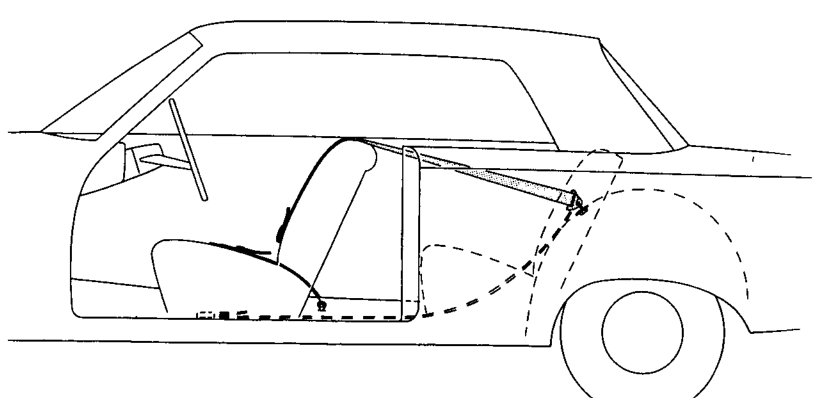

FIGURE 7.

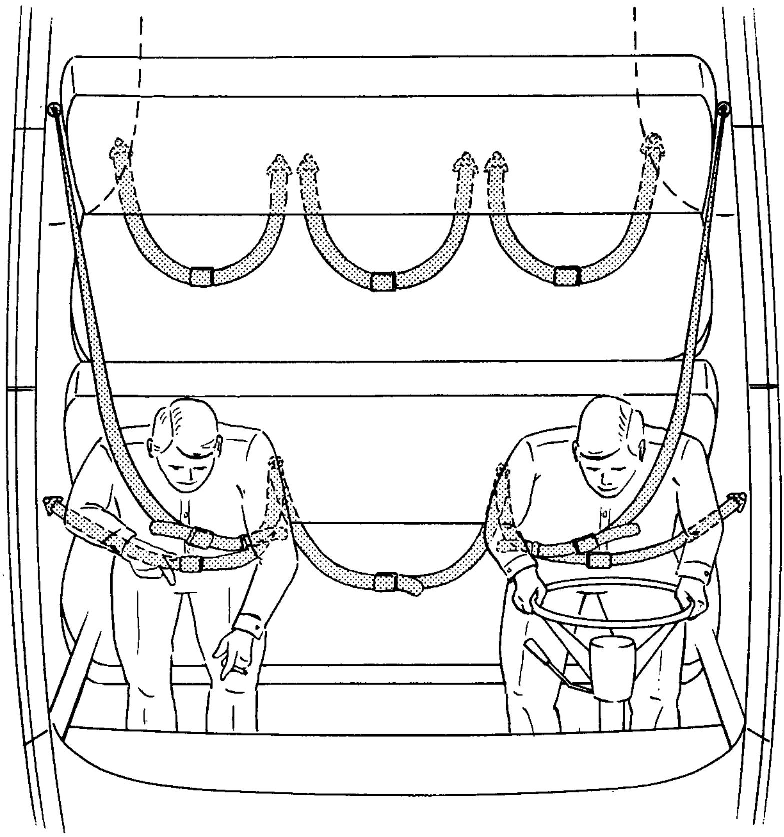

FIGURE 8.

and from the rear seat area when being worn. The belt can be unlatched and dropped to the dotted-line path along the body sill to allow rear seat passengers to enter and leave.

This car is equipped with all standard belts and those additionally available from the car manufacturer. The full complement of belts — lap belts for each of the six passengers, plus shoulder belts for driver and passenger on the far right — warrants our earliest acceptance and our regular use. (Fig. 8.)

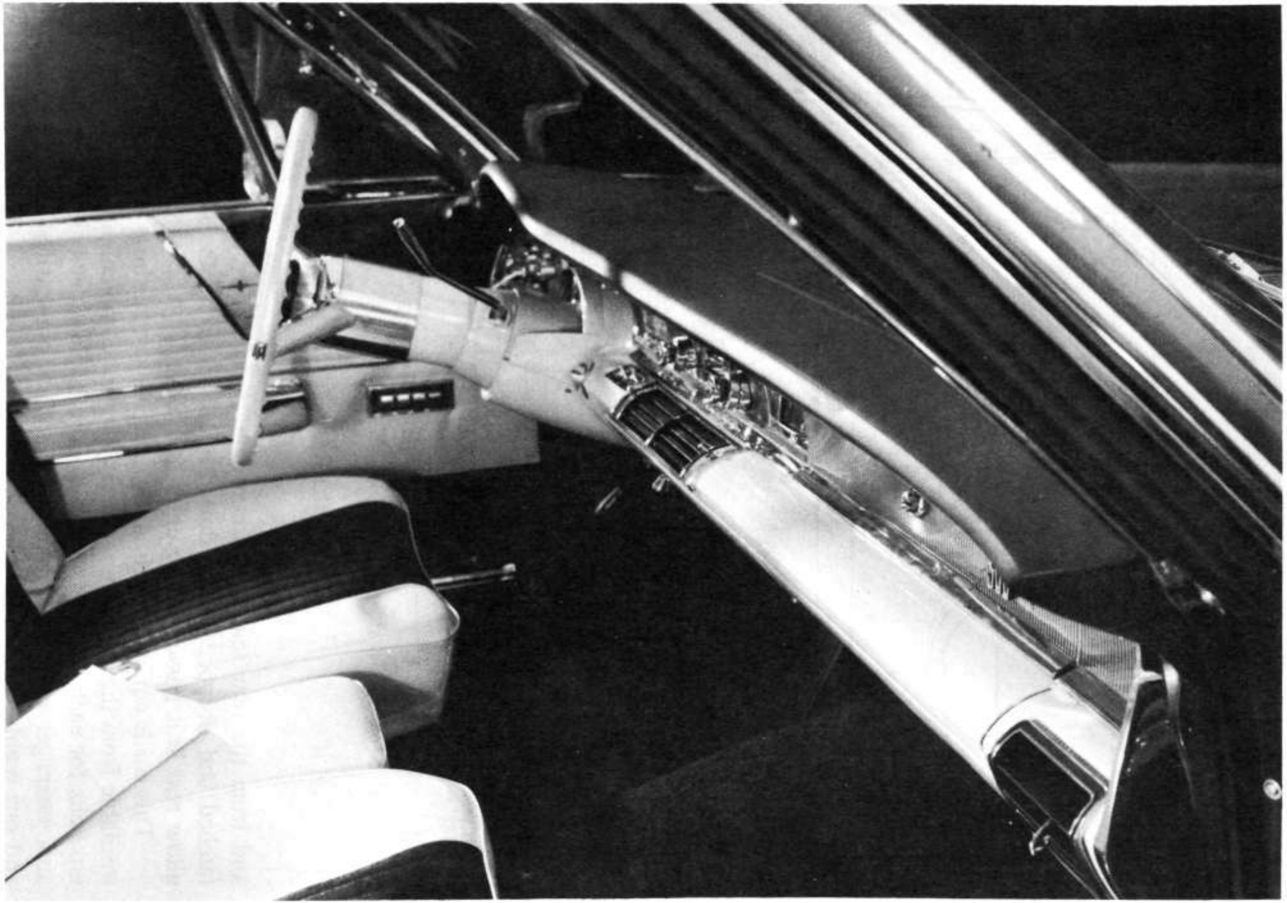

FIGURE 9.

FIGURE 10.

Instrument panels in all domestically manufactured cars are now cushioned and panel structure has been further modified in a manner to reduce head injury. Ideally all controls should be readily accessible and operable, even by the gloved hand, but inaccessible to the head in the event of a collision. Figure 9 illustrates one type of compromise between these two safety requirements. The controls are located in a valley under an over-hanging instrument panel brow whose gently contoured upper surface enables it to meet the GSA 515/2 requirement for impact energy absorption. While the recessing of controls into a horizontal valley has been a substantial step forward, much more can be expected in this area of protective design.

This view also illustrates another aspect of safety consideration in design. It should be noted that the top surface of the instrument panel is almost non-reflective in reference to the windshield glass.

All sun visors are now cushioned, but further improvement is needed and work on new designs is underway. (Fig. 10.)

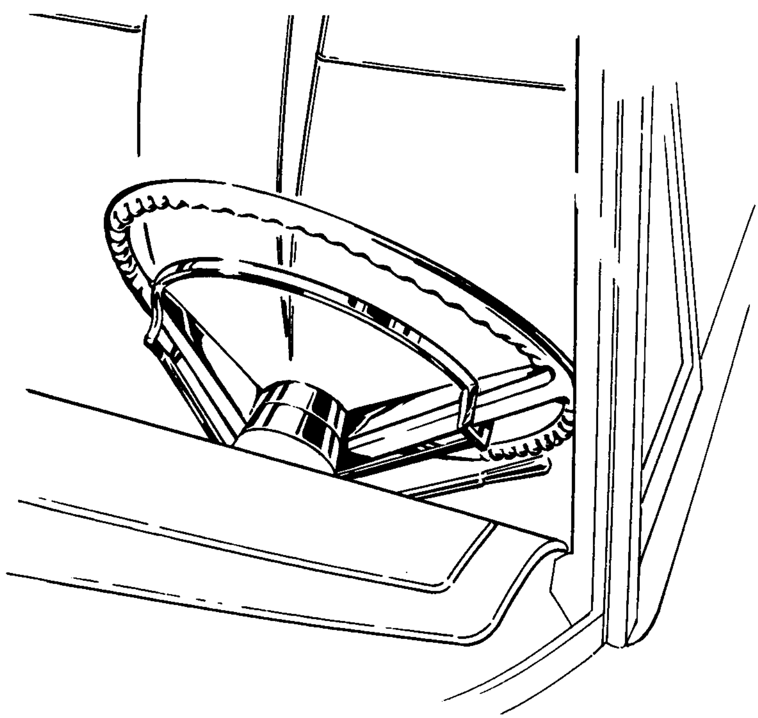

FIGURE 11.

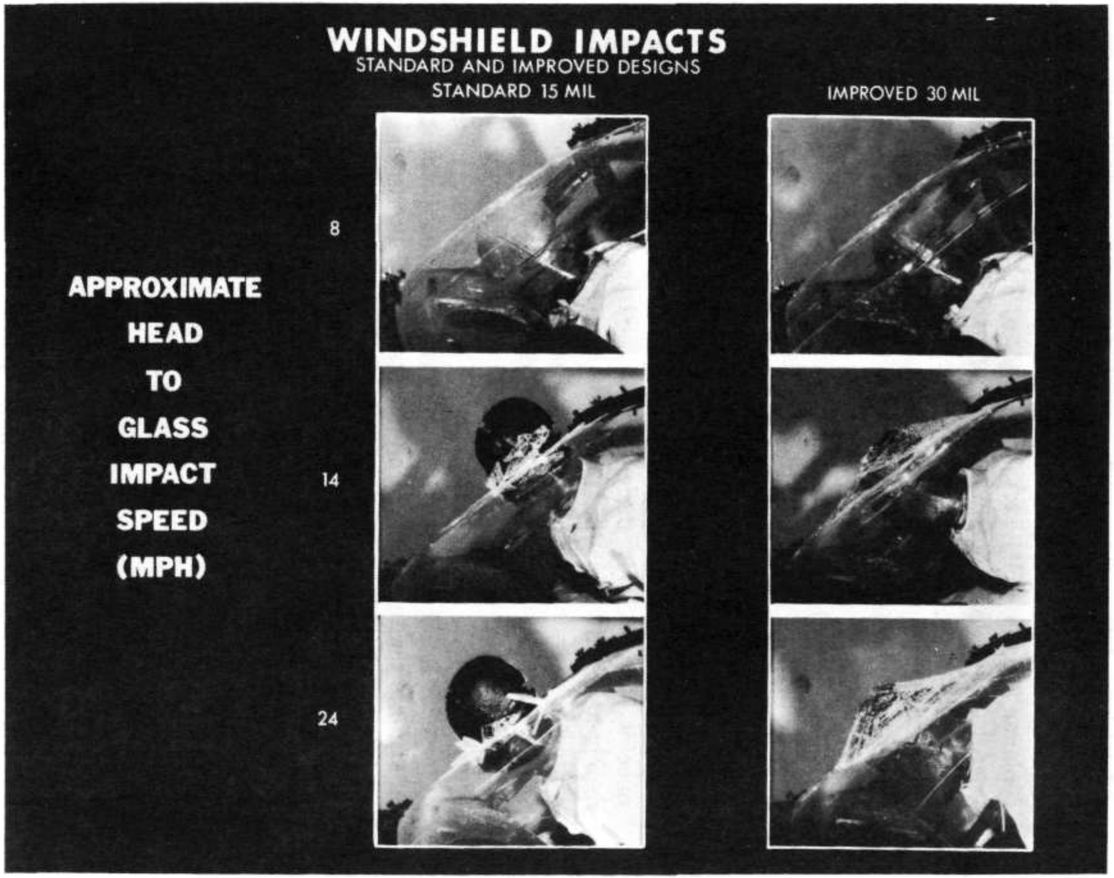
WINDSHIELD IMPACTS
STANDARD AND IMPROVED DESIGNS
STANDARD 15 MIL
IMPROVED 30 MIL
APPROXIMATE HEAD TO GLASS IMPACT SPEED (MPH)
8
14
24

FIGURE 12.

In the hope that driver chest injury could be reduced in forward collisions, this design of steering wheel with recessed center has been used in many cars recently. The wheel is supposed to yield under impact load, but thus far studies such as those at Cornell have been unable to show significant reduction in injuries for drivers thrown against them as compared with drivers striking against more nearly coplanar designs. (Fig. 11.)

All 1966 domestically manufactured cars are being equipped with windshields made of glass having much more penetration-resistance than glass used in previous years. The new glass will withstand, without head penetration, impact speeds twice as great as those the old glass could withstand. Note that the speed referred to here is the impact speed of the passenger's head into the windshield in the second collision, and not the car's speed in the first. The new glass is made by loosely bonding a double-thickness plastic interlayer to the glass; on impact, the plastic peels away and acts more like a net than its predecessor in decelerating the impacting head. (Fig. 12.)

"Headrest" is an unfortunate choice of name for this device, since it is specifically designed to discourage the passenger from resting his head against it. It could be more correctly designated anti-whiplash restraining device. Its purpose is to provide protection against whiplash injury to the neck and back in the event that the vehicle is struck from the rear. Such head restrainers have become more widely available, and can be expected to become standard equipment in the near future despite low acceptance from the motorist. In many an instance that has come to my attention, the motorist has not tolerated the restrainer's presence even though it is located out of the way of the motorist's head in normal sitting position. Apparently motorists feel a kind of claustrophobia. The potential value of head restrainers in rear-end collisions and their low acceptability to motorists constitute quite a challenge to the designer. (Fig. 13.)

Rather than going on with more illustrations of activity in automotive safety design, I would like to suggest some of the next steps in this field.

First is improving present designs to obtain greater protection, and to obtain greater acceptance and more active cooperation from the motorist. Those who feel impatient with the way designers cater to motorists' reactions or attitudes must remember that our best engineered devices and equipment will provide no benefit if the motorist will not tolerate them in his car, or if he is uncooperative

FIGURE 13.

and refuses to wear, adjust, service, or take the trouble to operate them.

Second is developing and adopting designs providing protection but requiring no additional active cooperation from the motorist. Among such changes are increasing the resistance of passenger compartments to penetration and crushing; decreasing the passenger compartments' acceleration during front and rear collisions; and increasing the energy absorption capabilities of the compartment interiors.

Third is accelerating the program to develop additional safety performance standards. This will be a major feature of the program directly ahead of us. Safety standards already exist for instrument panels, steering wheel and column assemblies, door latches, seats, seat belts, and seat belt anchorages, but some of these will need to be more comprehensive. Additional standards concerning other vehicle features are also needed.

In developing additional safety standards, as in developing additional safety improvements, we must continue to abide by the following precepts: First, merit must be judged by performance, not merely by claims based on design intent. Second, performance of the vehicle must be measured under actual operating conditions, both normal and abnormal. The latter can be expected to include near-miss situations as well as actual collisions and rollovers. Simulations will be acceptable only when there is adequate correlation with actual operation and events.

DISCUSSION

Moderator, J. HERBERT HOLLOMON

MR. WEIDMAN: The chest belt in Figure 7 goes back across the door and into the back seat of a four-door sedan. Wouldn't it be equally feasible to incorporate the anchor of this chest belt into the structure of the back of the front seat, thereby accomplishing the same purpose without impeding traffic to the back seat? Has this been explored?

MR. HAEUSLER: It has, indeed, and merits further exploration. The problem is that the loads imposed during a collision are very much greater than loads that the seat has been designed to hold under normal circumstances. If the belt is to hold and the restraining job done, a totally different seat is required. Designing a suitable seat for this purpose has obvious merit. We cannot long allow the belt to be a nuisance to passengers. Until a front seat can be designed strong enough to do the job, however, it is of great importance to use what is available. Even though I am looking forward to a better solution, at the moment I feel grateful to have for use the belts shown in Figure 7.

ALAN M. NAHUM: Mr. Haeusler mentioned the new windshield, which is certainly a revolutionary change, and we hope will be one of the improvements found in the next car models. By what method is the industry evaluating the live performance of this new windshield? I mean its actual performance out on the road.

MR. HOLLOMON: The basic question is how do you determine the real effectiveness of a design or piece of equipment after the vehicle is in the hands of the user, and is involved in an accident.

MR. HAEUSLER: This bears directly on the last point I made, which was that we are going to have to judge merit by vehicle performance tests under actual operating conditions. In short, no one can know for certain what the merit of this device is until traffic accident statistics are available. Testers in the laboratory do their best to simulate as closely as possible actual operating conditions, but statements about merit are reported as merely tentative until they are confirmed by motorist experience. It is obviously difficult, if not impossible, to obtain by any other means a realistic measure of the effectiveness of a device intended to prevent major head injury in actual collisions.

DR. NAHUM: I understand the difficulties attendant upon determining in advance how well the new windshield will work. What data collection process is now in effect to find out how well the new glass is working or not working?

MR. HAEUSLER: The data collection process available, studies such as yours, Dr. Nahum, and studies on a statistical basis such as those of Cornell, are obviously beset with difficulties in that we did not make half of the new model cars with the old type windshield and half with the new. There will be some opportunity for comparison of old and new type glass in those instances in which a car body produced in 1965 has been continued in production in 1966, and in which features other than the windshield were left essentially unchanged with regard to design. Of course, other controls will also have to be exercised so that similar accidents and similar situations are being compared.

MR. CAMPBELL: We at the Cornell Project are intensely interested in evaluating this new glass. However, '66 models with the new windshield come into our sample only by dribbles. It was seven months from the time these automobiles were first offered to the time we receive our first photographs of one of them with a cracked windshield. This is simply to show that our evaluation is based on a slow case-by-case monitoring process. At the current rate, it may be a couple of years before we have enough cases to be able to draw a conclusion. Of course, other agencies could have much higher volume of statistics on this matter.

MR. BRODERICK: Has any attempt been made to provide for energy absorption on the outside of the front end? Are there any plans for big improvements there? Also, have you done any studies of new designs, unfamiliar designs, for instance, doing away with the steering wheel and perhaps substituting something else?

MR. HAEUSLER: There is nothing I can talk about with regard to proposed designs, but studies that have been done indicate that there is some benefit available through front energy absorption devices. It has been demonstrated, for example, that a car with front-end sheet metal in place absorbs more energy than one without it. It is inappropriate to suggest that extra sheet metal is about as far as we can go in front-end absorption of energy. There is more energy that needs to be absorbed, and it is quite conceivable that a more effective job can be done.

With regard to steering equipment, the experiences several of us have had in research with steering devices other than the steering wheel have led us back to the steering wheel. The wheel seems to be the best way to enable the driver to maneuver and control the car during both normal driving operations and in emergency situations.

MR. VERSACE: We are continuing studies on the possibility of using a guidance control other than the steering wheel. There are big problems with the steering wheel, as you know, anthropometric problems if nothing else. Accommodating the total range of drivers from the fifth percentile woman to the 95th percentile man presents unavoidable conflicts. It is impossible to optimize simultaneously visibility over the wheel and accessibility under the wheel.

There are other problems in regard to the general shape of the wheel and its energy absorption properties. However, in radically different systems such as the so-called wrist-twist system with which Ford has been experimenting a lot, there are other questions. It has superlative characteristics for easing the driver out of unfortunate circumstances. However, it is not yet clear whether the wrist-twist system might make it easier to get into unfortunate circumstances, and if the advantages outweigh the disadvantages. We do not find any obvious difference in performance with it; that is to say, drivers immediately adapt to the new system and drive just as they would with the ordinary wheel. Despite the impact hazard of the steering mechanism, it nevertheless does offer an upper torso restraint for the driver during an impact. How to provide restraint for the driver when other systems are used will have to be explored.

DR. VAN IRWIN: I am concerned with the safety of the rear seat passenger for whom only a seat belt is provided. The improvement in design of the front passenger compartment is perhaps quite adequate, but when the rear seat passenger comes face to face with the back surface of the front seat during a crash he would appreciate, I think, a softer cushion than was shown in Figure 3. That seat had a rather sharp, metallic, menacing surface on its back.

MR. HAEUSLER: We heartily agree that it is very desirable to provide energy absorption surfaces for the rear seat passenger's head in the event he is thrown forward and strikes the front seat. This is a proposal under consideration now as part of the GSA standard.

In addition, I think shoulder belts are just as important for rear seat passengers as for front seat passengers. When the whole subject of shoulder belts was broached, it was decided to offer them for the seats most frequently occupied, and get them going. However, I believe that the shoulder belt is important for the rear seat, too, and it will be there.

R. B. SLEIGHT: What is the industry doing relative to research on enhancement of public acceptance of safety devices?

MR. HAEUSLER: We engage in "consumer research." For example, we determined ahead of time what our problems might be in gaining acceptance of the new door release lever with its rather unconventional position. We think that such research is quite important in helping us determine the manner in which to present such items to the public in order that they will have the maximum chance of acceptance. I am sure this is another field that will get a great deal more attention in the years immediately ahead. Such consumer research needs to be done.

THE HIGHWAY ENVIRONMENT AND SAFETY

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The magnitude of the highway transportation segment of the United States economy is such that it has become one of the most significant factors in shaping and evolving American societal goals and requirements. President Johnson, in his message to Congress on March 2, 1966, concerning the proposed Department of Transportation, noted that in 1964 American transportation moved 1.5 trillion ton-miles of cargo. He also noted that in 1965 the transportation segment of our economy accounted for $120 billion or approximately 15 percent of the gross national product. In accomplishing this total transport function, Americans traveled 1.5 trillion passenger-miles, 90 percent of them in motor vehicles on our nation's highways, according to figures based on National Safety Council estimates.

The tragic side of what otherwise would be a monumental achievement is the annual motor vehicle accident toll of approximately 50 thousand deaths and 1.8 million disabling injuries. The serious nature of this toll is evident when it is noted that this represents nearly 50 percent of the total number of deaths and 17 percent of the total number of disabling injuries that resulted from all types of accidents in the United States in one year. It amounts to one death every 11 minutes and one disabling injury every 40 seconds. It represents the major cause of death among persons from one to 24 years of age. It is the fifth most prevalent cause of death in the United States, following heart disease, cancer, vascular lesions, and pneumonia, which, for the most part, are diseases of the aged.

From these data and from considerably more detailed information available concerning the economic impact of the automobile accident, it is evident that traffic safety is one of the primary problems of society in this decade. One is immediately led to ask what corrective measures are being taken about such a tremendous problem. Unfortunately, the answer is that almost no corrective measures are being taken. The American public and, more specifically, the scientific, engineering, and political sectors still believe the folklore that accidents occur only to others and that they are Acts of God over which we have no control. This fatalistic, passive attitude will never lead to an elimination of the annual highway tragedy.

The few individuals who are attempting to solve the accident problem have not been able to attack it on a level consistent with its severity. With a total expenditure of, at most, a few million dollars annually, a coordinated, well-thought-out attack is not possible. Secretary of Commerce John T. Connor in his March 17, 1966, appearance before the House Interstate and Foreign Commerce Committee regarding the proposed National Traffic and Motor Vehicle Safety Act of 1966 stated, "Our survey of present highway safety efforts throughout the nation clearly shows that federal, state, and local efforts have proceeded separately with little or no coordination and that major gaps and weaknesses exist in the programs that are underway." As a result of this lack of coordination, most so-called traffic safety research presently underway can be classified either as moderately large spectacular projects designed to indicate to the public that work is being done on traffic safety, or as small operationally oriented and, in many cases, panacea-seeking projects with little or no possibility of immediate application or payoff. Relatively little competent research has been directed toward seeking the true underlying causes of the motor vehicle accident and with few exceptions no research has been undertaken to determine and develop adequate safety standards for roadways or vehicles.

Before discussing the highway environment, its part in the traffic safety problem, and some highway environment considerations meriting safety-oriented research, it is necessary to view the highway environment aspect of the traffic safety problem in its proper perspective. Many safety researchers have trichotomized the problem into these basic components: (1) the highway environment, (2) the driver, and (3) the vehicle. It is obvious that the entire answer to the traffic fatality and injury problem will not be found by studying only one of these components. For example, it would be absurd to design a very expensive "death-proof" automobile before at least considering the possibilities of improving the environment in which present vehicles operate, or improving driver capabilities through training or selective licensing. Even if a completely safe vehicle could be designed for the present set of environmental and driver conditions, it would not necessarily be the optimum or most expedient solution to the highway safety problem. Furthermore, the cost and size of such a vehicle could be of such magnitude that society would be unable to allocate adequate resources to provide for its construction and operation in the quantities necessary to satisfy transport requirements.

It would be equally absurd to approach highway safety only from the aspect of the highway environment. Certain classes of accidents such as leaving the roadway, striking fixed objects, head-on and side-impact collisions, could, it is true, be eliminated for the most part, or at least their severity reduced to an insignificant level, entirely through roadway design. This approach, however, would most likely require the construction of roads with a 500-foot buffer zone on both sides of each direction of travel, with no signs, abutments, railings, trees, or any other object or projection in this buffer zone. Carrying the environmental solution to this extreme obviously would be economically infeasible.

Finally, it would be impractical to direct all attention to the driver, eliminating from the road all drivers with marginal skill in handling the vehicle or in making the complex decisions required in the driving task, and drivers who will not obey the driving rules. This, of course, would be impossible to achieve since many of the driver characteristics contributing to the accident syndrome are not known while many that are known are not measurable. For example, how can we determine in advance how often a given driver will drive when he is too tired, too intoxicated, too emotionally upset, or under the influence of judgment-impairing drugs? Furthermore, exactly what constitutes being "too tired" or "too intoxicated," and what amount of judgment impairment can be tolerated? These terms must be defined if such conditions are proposed as a basis for restricting or revoking licenses. Even if standards could be developed, the difficult problem of enforcing the restriction, the suspension, or revocation would still exist.

The fact is that no single approach will lead to a Utopia in which traffic deaths and injury are completely eliminated. Only a coordinated program encompassing all three aspects, namely, the driver, the environment, and the vehicle can possibly lead to a reliable, efficient transportation system in which deaths and injury are reduced to a minimal level.

In order to provide the basis for this coordination and to establish a design-alternative decision-making process, a performance-standards method of planning the total transport system must be devised and implemented. That is, minimum performance levels for the driver, the vehicle, and the roadway must be established and adhered to in designing vehicles and highways, and in the licensing and periodic retesting of drivers. These performance standards must consider safety, convenience, and system efficiency as well as time and cost of implementation. Furthermore, the standards must not be static since technological advances will create changes in the transport requirement. The decision process must be dynamic and sensitive to the evolving transport requirements and must receive feedback from the operating system, from societal goals and values, and from the engineering and scientific community.

Before discussing traffic environment safety research, an overview will be presented of the general problems concerning traffic safety today. In attempting research into any aspect of traffic safety it is imperative that all concerned keep constantly aware of the interaction between the vehicle, the environment, and the driver. In the past few months, many of us have become concerned with an apparent over-emphasis on the vehicle during what might be considered an attempt to make it and the automobile industry the scapegoats of the traffic safety problem. This is a dangerous way of thinking, not only because it centers attention on only one aspect of the problem to the exclusion of the other two, but also because it may lead to the establishment of hastily-conceived, rigidly enforced, and possibly dangerous vehicle design standards that are not supported by carefully planned and executed research.

Ralph Nader in his book *Unsafe At Any Speed* has focused on the pathetic state of affairs in the automobile industry's approach to vehicle crash-worthiness. He also shows how the relevant federal agencies have abrogated their responsibilities to the public by being parties to inadequate safety standards and meaningless safety programs. He did not mention that equally pathetic situations also exist with regard to inadequate environmental design of highways, inadequate driver licensing and testing programs, poor highway design standards, improper traffic enforcement procedures, and judicial laxity in dealing with traffic law violators. These critical aspects of highway safety have not yet been brought to the public's attention. A Nader-type book could and should be written on these topics.

The often self-appointed traffic safety oracles and investigating committees should make themselves aware of the share of blame chargeable to government agencies for lack of leadership, lack of direction, and lack of coordination among themselves in establishing traffic safety criteria. The public must also be rebuked for its lack of interest in already established safety principles and devices.

Finally, the scientific and professional communities should do some deep self-examination. For far too long, they have helped maintain the status quo by reporting only the noncontroversial results of their work, or by writing in abstract, hard-to-comprehend jargon that completely obscures the significance of their findings. Furthermore, they have not helped matters by taking the attitude that it is the duty of others to interpret their research results, that others should develop new system or procedures for implementation of the results, and that others should evaluate the expected benefits that will result from them. It is absurd to expect the general public and its political representatives, most of whom have no technical background in traffic safety, to interpret properly the significance of research results and to formulate action programs from those interpretations.

The traffic safety problem requires all the concerned individuals, groups, and organizations to contribute their unique skills and experience relevant to the problem. It is the responsibility of the researcher to translate his results into understandable language, to propose implementations, even though they might not be perfect, and to produce rational estimates of cost-benefit relationships for alternate solutions. Furthermore, it is the responsibility of those who sponsor the research to make sure that implementation of results is accomplished. It is the responsibility of the federal, state, and local governments to select the appropriate actions from the possible alternatives and to provide the means for introducing and incorporating them into the transport system. It is the public's responsibility to demand safety improvements, to support the additional costs that might be required, to accept any necessary changes in driving habits, and to accept restrictions on individual rights if such restrictions are required to insure the success of improvements. If these responsibilities are not accepted, any expenditure on traffic safety research becomes a waste of public funds, for the research will amount to no more than meaningless exercises.

One of the most significant underlying problems of traffic safety research today is project selection and funding. The total dollar allocation to highway safety research from all sources is insignificant when compared to funds allocated to other social problems of equal or less importance. Estimates of traffic research support run from as little as two million dollars to a high of perhaps $100 million annually, depending on who is doing the estimating and what is counted as traffic safety research. The actual amount spent on research that is closely related to the traffic accident problem is probably in the neighborhood of five to ten million dollars. This amount is relatively minor when compared to the hundreds of millions being spent each year on research related to high mortality diseases. It is insignificant when compared to the annual expenditure of the $120 billion for transportation.

Traffic research funding is further weakened because the limited funds available come from a multitude of uncoordinated government and private sources such as the National Safety Council, Automotive Safety Foundation, Bureau of Public Roads, Public Health Service, automobile industry, the insurance industry, state governments, or National Cooperative Highway Research Program contracts using funds primarily derived from the one and one-half percent research allocation of the federal aid highway construction program. In this scatter-shot method of funding, there is total lack of coordination between the various sponsoring agencies. Even more serious is the small dollar magnitude of most of the contracts. A few projects have annual support in the $100 to $200 thousand dollar range, but most funding ranges from $2,000 to $50,000 annually.

Small contracts or grants are especially discouraging to competent researchers for a wide variety of reasons. He can not provide staff continuity, he is forced to use mickey-mouse equipment, he is limited to totally inadequate sample sizes, he must ignore many significant variables, and so on. The usual results of research done with such inadequate statistical data are conclusions that must be qualified so much that they have no practical application. Even worse, the researcher has dissipated much of his time — time that is in short supply since there exist only a limited number of trained traffic safety research professionals, time that should have been spent attacking the research problem with proper facilities, instrumentation, experiment design, and staffing.

Further hampering the small-grant researcher is the volume of paper work he is required to produce; often it is equivalent to paper work required for projects in the hundred thousand dollar class. In many instances, sponsoring agencies have required quarterly progress reports, interim reports, and as many as 100 copies of a final report on contracts amounting to only a few thousand dollars. With such absurdly large requirements and absurdly small funding, the research effort is little more than a report-writing exercise.

We can no longer afford to tolerate safety-oriented research contracts that are so small, so underfunded, and so limited in scope that their results cannot be related in a meaningful fashion to safety action programs.

The elimination of inadequate funding for research can be accomplished if a concerted effort is made by all research sponsors to coordinate their activities. Along with coordination, an increase in available funds of at least a factor of 50 must be achieved. This would provide an annual traffic safety budget of $250 to $500 million. Some of these funds must be allocated for the creation of adequate research facilities with sufficient instrumentation and personnel to insure that safety research projects are efficiently run and statistically sound. At that point, it will become possible to attack the problem of traffic safety in a responsible way and on the broad front it deserves.

To assure efficient and expeditious progress toward the solution of the traffic safety problem, it also will be necessary to develop methods of evaluating the potential benefits of each proposed research project. Cost-effectiveness procedures must be established so that each project can be evaluated in terms of expected benefit, ease and cost of implementation, time required to accomplish the research, time required to implement the results, feasibility of this implementation, and so forth. Those projects that show promise of producing the greatest benefits in the least amount of time must be undertaken first. Similarly, cost-effectiveness analyses must be used to evaluate alternative solutions to each traffic safety problem. The cost and time to implement changes, the expected benefit, and social acceptability trade-offs of changes in vehicle design, highway design, or driver performance requirements in the solution of a specific problem, must be evaluated before a commitment is made to proceed with any change.

The highway environment has three categories of factors directly related to the traffic safety problem. First, there are the complex interactions between the environment and the driver that may lead up to an accident-producing driving error. Second, there is the physical interaction of the environment with the vehicle and the driver during the occurrence of an accident. Third, there are the operational problems associated with providing post-accident care for the injured, removal of damaged vehicles, and repair of highway facilities.

Included in the first category are factors such as signing messages, congestion, sight distance, speed limits, lighting, weather, road condition, intersection placement, geometric design, and law enforcement. Factors in category two influence accident severity and include bridge abutments, sign structures, light standards, median dividers, other automobiles, pedestrians, median and shoulder geometry, building placement, and maintenance. The post-accident factors of category three include accident detection, emergency equipment availability, methods of removal of injured, and ease of reaching the scene of the accident.

Each of these factors will provide the basis for many potentially productive research activities, some of which will be discussed here. However, there are many factors that are not directly linked to the environment that may, because of their fundamental nature, be even more productive as research subjects. They include means for accurate data collection, the assessment and improvement of driver capability, improved driver training and licensing, effective and efficient inter-governmental cooperation, the evaluation of exposure to traffic or accident potential, effective and just convicting and sentencing of traffic law violators, and forward-looking metropolitan planning.

This discussion of category one, pre-accident environmental factors, will be limited to factors related to highway signing, to freeway ramp placement, and to traffic information feedback to the driver.

As of now, only a few aspects of the highway signing problem have been researched scientifically. One research project on the problem of the wrong-way freeway driver was recently completed by the California Division of Highways and the Institute of Transportation and Traffic Engineering at UCLA. A system of special on-ramp signs for alerting the wrong-way driver to his error was developed and evaluated in the laboratory, using the UCLA driving simulator. This system of signs is presently being installed throughout the state of California for long-range evaluation. Unfortunately, however, signing is only a part of the wrong-way driver problem. Another survey of such drivers showed that upwards of 60 percent were too intoxicated to be aware of any signing messages, while others were actually driving the wrong way intentionally! Additional research to study these problems and devise solutions for them obviously needs to be undertaken.

In general, however, signing standards have not been adequately researched. Most existing standards are based not on objective research but on the personal experience and opinions of professionals in various highway departments, industry, the research community, and the government. Since there almost always is diverse opinion as to what standards should be established, and since no supporting data exist, the loudest voice or the best oratory generally prevails.

Similarly, ramp placement is more a matter of armchair expertise and local option than of scientific study. As a result there exist many signing and ramp placement practices that are extremely questionable. The following are examples of signing and ramp placement problems of extreme importance.

Ramps in the Vicinity of Freeway-to-Freeway Interchanges

The present practice of placing on and off ramps in the midst of freeway interchanges often requires for the high speed driver almost impossible decision-making and subsequent maneuvering of the car to carry out decisions. He is first presented with an array of signs to understand; then he must locate his route from among as many as four alternative routes; finally he must get into position to make his maneuver. Frequently, all these actions must be carried out within a one-half mile distance. Even with light traffic, it is not possible to make such decisions with safety, particularly if freeway speeds are maintained and if lane changes are required. The impossibility of properly signing within a one-half mile distance such complex situations is readily apparent. Further, lane capacity is substantially reduced when complex route-choice decisions are required. As a result, totally inadequate operating efficiencies prevail at nearly all major urban freeway-to-freeway interchanges. Considerable congestion and numerous accidents are the net results.

Ramp Signing

One present standard prohibits the signing of a freeway off-ramp to a road running parallel to the freeway. This practice often confuses and inconveniences the driver, particularly when the parallel artery is the usual destination of drivers exiting at that ramp. It becomes absurd when the exit ramp signing indicates the name of non-existent streets, cross-streets located a long distance from the exit, or cross-streets of very little interest to the exiting driver. This is an example of a standard that does not consider the driver and his needs, but only attempts to create uniformity for its own sake.

Special-Interest Ramp Placement and Signing

The present policy of not signing or providing ramps to serve special interest groups is obviously in opposition to the best interest of traffic flow and traffic safety. In the case of service, food, and lodging, the policy seems appropriate; however, when carried to the extreme of not providing ramps or destination signs to major traffic-drawing points, it becomes absurd. Major tourist attractions, such as Disneyland in California, are denied signs on the basis that it would be showing favoritism and therefore is discriminatory, even though at the freeway off-ramp nearest Disneyland nearly all of the traffic is bound for this attraction. Similarly, when no direct connections to nearby freeways are provided for major industrial centers or for public service facilities such as airports, universities, or stadia, the result is considerable congestion and confusion on the surface arteries inter-connecting the freeway and the facility. Warrants need to be developed that enable highway authorities to resist the signing demands of communities and other special interest groups; at the same time, the warrant should provide for signing to large traffic volume destinations.

Directional Signing

The present differences among the techniques for signing highways at freeway-to-freeway interchanges, at surface streets to major artery intersections, and at surface streets to freeway intersections are almost unbelievable. Some of the unresolved questions are:

1. Should the freeway name be long or short?
2. Should the freeway be named for a destination or not?
3. If the highway at a particular interchange runs north-south but is nominally an east-west route, which cardinal directions should be indicated on the signs?
4. What color should be used for the lettering and the background of signs, and should color coding be used?
5. Should surface streets that cross major arteries have signs that can be read before the intersection is reached? If so, how far before the intersection, and what size should the signs be?
6. How many cities should a given destination sign include, and how far in advance of the decision point should they be placed?
7. Should the signs giving distances to freeway off-ramps in urban areas utilize mile and quarter-mile increments, or should they state distances in mile and tenth-mile increments?

For this last question the present standard of providing quarter-mile increments is based on the unproved assumption that it is easier for the driver to judge distance to a quarter of a mile than to a tenth of a mile. Automobile odometers are calibrated in tenths of a mile, however, making it necessary for the driver to perform a complex mathematical analysis if he wishes to predetermine the odometer reading for his exit. Furthermore, when ramps are close together, or when signs for some reason must be located close to the ramp, drivers can be misled by a quarter-mile sign into thinking that there is a quarter of a mile separation between sign and ramp when in fact there may be as little as a tenth of a mile.

In regard to traffic information feedback to the driver, considerable effort has been expended in discussing the subject for many years, but the only tangible results thus far have been a few crude changeable-message sign systems, some automatic radio communication systems, and elementary prototype automatic control systems. No widespread use of these devices has been attempted.

Benefits of information feedback to the driver could be substantial in areas such as the following:

1. Detection and warning in the event that fog or other conditions of poor visibility have slowed vehicles ahead.
2. Detection and warning of unsafe vehicle-following distances.
3. Detection and communication of icy road conditions.
4. Alternate route advice when congestion exists.
5. Automatic vehicle-speed control.
6. Warnings concerning the aberrant actions of drivers immediately ahead.
7. Early warning of impending slow-moving traffic.

A considerable array of research activities can be easily devised to study these and other similar driver information needs. Some of these possibilities are presently being investigated to a minor extent; however, lack of funds and facilities prevent their being studied in a scientifically controlled experimental environment. The basic technology to provide information feedback to drivers is now in existence and has been for a considerable number of years. What has been lacking is the effort to apply the devices to the traffic situation. For example, radar detection devices to tell drivers the relative velocity and distance of cars ahead have been possible for at least 25 years. Present techniques now evolving in micro-miniaturization of electronic circuits, laser technology, and in the field of fluidics make it feasible to create highly reliable units capable of automatically warning the driver when he is approaching stalled or congested traffic situations. It has been estimated that such devices could be built and installed in a car at a cost as low as $5.

In discussing category two, during-accident environmental factors, only roadside obstructions and median and shoulder geometrics will be considered. Since about 30 percent of all automobile deaths result from accidents in which the vehicle leaves the roadway before it collides with any object, it is evident that considerable improvement in highway safety could be brought about by directing attention to roadside environmental factors. Recent studies by General Motors, Cornell Aeronautical Laboratories, the University of Illinois, the California Division of Highways, and the Texas Transportation Institute all have shown that substantial reductions in severity and incidence of single-car accidents will result when highway shoulders and medians are encroachable and unobstructed. Other studies have shown the usefulness of various types of median planting to stop out-of-control vehicles.

In looking at the present standards for median and shoulder width, sign and light placement, use of guard rails, and ditch and embankment configurations, it is evident that very little consideration of safety has gone into their establishment. One of the key underlying reasons for this situation is the conflict within State Highway Departments between design and operations engineers; neither group appears willing to consider the other's requirements. The end result of this conflict is unsatisfactory roadside design. The following are some examples.

Median Width

Because narrow medians have been designed and constructed, it has been necessary to install median barriers to reduce accident severity and prevent head-on collisions. The result has been a substantial increase in number of accidents.

Sign Structure Design

The immovability of posts that support overpasses and the usually fatal consequences of colliding with such posts have resulted in the installation of guard rails in an effort to deflect vehicles from a direct impact with the posts. This has not been too effective in eliminating serious vehicle-post collisions and has increased the incidence of minor accidents due to the presence of the guard rails.

Sign Structure Placement

Massive structures are often located in off-ramp gores at precisely the point where driver-error frequently occurs. Last-instant lane changes at high speeds often result in a collision with such structures.

Shoulder Obstructions

Signs, lights, delineators, milepost markers, and trees are often so close to the edge of the pavement that a minor driving error can result in a serious collision with one of the obstructions.

Bridge Abutments

These are usually placed close to the edge of the pavement, thereby creating a serious hazard. Present standards permit short bridge spans, and the cost argument is used as the justification for keeping and using such standards.

Shoulder Design

The standards for road shoulder design are so poor that a high-speed vehicle leaving the roadway frequently rolls over or strikes an embankment or ditch.

Guard Rails

When guard rails are installed as a matter of routine without regard to whether their presence will result in lower accident frequency and severity as compared to no guard rails at all, an environment is often created that is both costly and dangerous.

In order to establish adequate design standards for these and other physical roadway characteristics, research investigation of such factors as the following will be required.

1. Median and shoulder widths, with or without barriers or guard rails.
2. Energy-absorbing devices for bridge abutments, sign posts, and other fixed objects.
3. Breakaway posts for signs and lights.
4. Distance from edge of roadway to signs and bridge abutments, lights, delineators, guard rails, and other fixed objects.
5. Contours of highway shoulders and embankments to allow encroachment without collision with obstacles and without vehicle roll-over.
6. Shoulder surface treatment and planting to minimize vehicle damage and passenger injury and to provide an environment for decelerating the out-of-control vehicle.
7. Development of cheaper, perhaps mass-produced, bridge structures to enable the construction of longer spans.

The post-accident factors of category three include detecting the accident, bringing emergency equipment to the scene, and removing the injured. In many cases the congestion resulting from an accident creates an environment in which many secondary accidents occur. When traffic density is high, the unwarned driver approaching the end of a queue of stopped vehicles is forced to make a dangerous panic-stop, often resulting in a secondary accident. Similarly, congestion resulting from the presence of highway maintenance crews creates a hazardous accident-producing environment. Since on many heavily traveled highways no adequate alternative bypass routes exist, it is not possible to shunt traffic safely away from such temporarily and unexpectedly congested areas. The congestion frequently requires difficult and time-consuming effort for the medical, investigative, and clean-up teams to reach the accident scene. These problems suggest research into the following subjects:

1. Median and shoulder design to provide space for the movement of emergency vehicles.
2. Location and practicability of emergency entrances and exits to enable traffic to bypass the accident area.
3. Automatic changeable message signs and/or radio communications systems to provide information indicating alternate bypass routes around accident-blocked highway sections.
4. Deployment by air of investigative, medical, and clean-up teams to reduce the time required for accident investigation, emergency care and removal of the injured, and removal of damaged vehicles.
5. Highway designs from the standpoint of providing for maintenance and repair of highway facilities without creating conditions that produce accidents and congestion.

Even though the implementation of the results of studies such as these may not lead to the prevention of many primary accidents, it could easily lead to a substantial increase in the rate of survival for the injured, and, through more expedient elimination of congestion, to a significant reduction in the number of secondary accidents.

Three factors of a general nature indirectly related to the highway environment safety problem urgently require substantial research and improvement. They are (1) intergovernmental cooperation, (2) land use and transport planning techniques, and (3) accident exposure, data collection, and statistics. Each will be discussed separately.

In regard to intergovernmental cooperation, the present government structures of nearly all large metropolitan regions are fragmented to such an extent that inter- and intra-governmental cooperation amounts to little more than good intentions. Politically inspired decisions at all government levels commonly compromise sound designs. Coordinated transportation planning is impossible as a result of the diversity of land use and roadway design standards existing within the various cities. In many larger cities, there is no way to coordinate the planning, the traffic, and the engineering design departments to insure that land use plans are in balance with proposed transport system plans. Superimposed on this jumble of departments are the superagencies such as the mass transit districts, transportation authorities, various state and federal agencies. Each pushes for its own interest, often without full understanding of or willingness to cooperate in a coordinated systems approach.

As for the second group of factors, land use and transport planning techniques, one must observe that planning techniques in use today are so crude that they are worthless. These techniques are characterized by oversimplified assumptions, personal opinion, and hypothesized or guessed-at data. When actual data are used, even in impressively massive amounts, they are usually crude and meaningless collections of non-related observations. Many factors such as socio-economic and demographic stratification of the population and of jobs, and the non-linear relationships between traffic density and travel time, cost, safety, and convenience are ignored. Data concerning land use, job availability, population density, and traffic flow often are estimated or based on statistical distributions obtained by combining non-related data. Techniques must be developed that will adequately consider these factors.

Nearly all consulting firms in transport planning today are guilty of making use of these inadequate and inaccurate techniques. Their approach to transport planning allows them to provide for any given plan a report supporting any preconceived, desired result. In route-selection studies, it is not uncommon for planners to choose in advance the route they wish to have and then set about to prove that it is the optimum choice. This is easily accomplished by placing the selected route along existing highways or low cost right-of-way areas, while routing alternatives through relatively expensive, intensively developed real estate. Astronomically large changes in route costs can be achieved by merely shifting a given route a few hundred feet one way or the other. Political expediency to avoid going through the property of particularly troublesome or influential persons or organizations, vociferous protesters, schools, churches, and cemeteries, often creates longer routes far removed from the optimum location and frequently containing excessive curvature. The end result for the public is lost time, increased accident potential, and more costly and less efficient transportation facilities.

The federal government requires every city to provide land use and transportation plans if it wishes to qualify for its share of the federal and highway construction funds. Thus, nearly every large city is guilty of using such non-scientific techniques to produce transportation and land use plans that often feature unworkable, expensive mass transit systems, absurd highway routes, and improper land utilization. These results border on fraudulent expenditure of public funds by city officials, governmental planning agencies, and consulting firms.

The third group of factors indirectly related to the highway environment safety problem includes accident exposure, data collection, and statistics. The present practice of collecting traffic accident data without devoting adequate attention to the conditions under which they are collected and without establishing and using a statistically sound and coordinated data storage and retrieval system has provided researchers, public officials, and the general public with a worthless set of non-factual, misleading statistics. For example, the use of passenger miles, vehicle registration, and driver registration as measures of accident exposure when computing comparative safety statistics for the various transportation modes, ignores many exposure-influencing factors that are perhaps much more significant. If a measure as simple as passenger miles traveled is adequate, then a trip to Mars by an astronaut in a spacecraft traveling on an impact trajectory would be considerably safer than auto travel on earth, since only one passenger would die for about 50 million miles traveled as compared to 5.7 passengers per 100 million miles calculated for highway travel in the United States.

A further complicating factor with the passenger-mile exposure measure is the crude method used to obtain the estimate of total passenger miles for automobile travel. Present estimates are based on gas tax receipts, estimates of average vehicle gasoline consumption, and estimates of the average number of persons in the vehicle.

It is not uncommon for offices handling traffic statistics to change the exposure index, depending on what safety conclusion is to be reached. For example, the present "scare technique" used on holiday weekends measures exposure on a time base, that is, number of deaths per holiday period instead of the usual exposure measure of number of deaths per 100 million passenger miles; thus, it appears that driving on a holiday weekend is considerably more dangerous than at any other time. The fact is, not only is the actual number of deaths per day for the holiday weekend no higher than for the non-holiday weekends, but the rate when related to other measures of exposures may be substantially less. For example, if exposure is taken to mean passenger-miles traveled on holiday weekends, it is easy to show that the holiday period is the *safest* time to travel.

As a result of the inadequacies of present accident statistic procedures, a group of California safety researchers, meeting at UCLA in 1965, discussed the problem of accident exposure measures and concluded that no satisfactory measure existed. Over a hundred different conditions affecting exposure were listed by these researchers in about 20 minutes: age and sex of driver, hours since last rest, driving experience, traffic density, potential vehicle contacts per mile, time of day, percentage of persons with no blood alcohol, vehicle age distribution, vehicle make distribution, highway width and grade, sight distances, etc., etc., etc.

Because of this complexity, a meaningful measure of exposure can be developed only by undertaking a massive sensitivity study of each one of the exposure factors and determining which ones are significant contributors to accident causation. Based on a UCLA-ITTE research project looking into adapting industrial quality control chart techniques to accident statistics, it has been concluded that until an adequate accident exposure measure is developed, exposure should be dropped from primary statistical treatment of accident information, and used only in later secondary analysis of specific problems once high accident locations have been identified.

One must conclude that each of the highway environment problems just discussed, as well as the many others that have not been mentioned, interact with each other to a substantial extent. The potential research activities mentioned only begin to scratch the surface of these problems. The cost of implementing design alternatives resulting from research will reflect topography and the degree of urbanization present in the region for which they are being considered. Thus, it will not be possible to establish a rigid set of design standards for each physical aspect of the roadway, applicable to all conditions. Instead, it will be necessary to establish mandatory roadway safety performance standards. With these as a design objective and with the use of cost-effectiveness analysis, the trade-offs between alternative design possibilities can be evaluated.

The primary purposes of this presentation have been to stimulate the thinking of those who are involved in, or plan to become involved in highway safety research, and to help officials and the public realize that no simple solution for the traffic accident problem is possible merely through the indiscriminate expenditure of massive sums of money. Instead, the attainment of an efficient, reliable, economical, and safe transportation system will be possible only if users, researchers, and public officials dedicate themselves to creating and implementing a traffic safety research program that is adequately funded, instrumented, and staffed. Entrenched special interest groups and inefficient governmental agencies must be disbanded or at least divested of their influence in this vital area. Regulatory and enforcement procedures and standards must be established according to objective facts, enforced with justice and uniformity, and modified as warranted by new conditions and new knowledge. Those engaged in the development of science and technology must carry their work in traffic safety to the level of practical applicability. Advances in instrumentation, communications, and control techniques must be exploited. Test and evaluation facilities must be created and funded so that new systems, devices, and design standards, as well as proposed remedial changes for existing facilities can be evaluated for reliability, cost effectiveness, and societal acceptability.

A giant first step in this direction will be possible through establishment of the proposed Department of Transportation and through enactment of the proposed National Traffic and Motor Vehicle Safety Act of 1966. All who are dedicated to finding and implementing a solution to the traffic safety problem must support these proposals. For the first time we are faced with a golden opportunity — one that may never again come our way. Not only has public interest in the traffic safety problem reached its highest level in history, but financial support of a magnitude commensurate with the problem is also being considered. While this is a heartening turn of events, vigilance is required lest lack of planning, coordination, and careful allocation of funds permit this opportunity to slip away. If substantial federal money is made available it must not be dissipated on the study of insignificant problems with results that promise no practical applicability; the money must not be handed over to governmental or private organizations that do not demonstrate ability to use it fruitfully; federal funds must not become a means of perpetuating ideas, traditions, and, indeed, organizations that have lost their usefulness.

DISCUSSION

Moderator, RAYMOND L. BISPLINGHOFF

ROGER MC INTYRE: There is an article in a current magazine describing a language used primarily by truck drivers to warn other drivers about accidents that have occurred in the road ahead, and about other hazards. Do you think that anything can be done to educate the automobile driver in such a language of the road?

MR. MOSHER: I think you mean, can we in any way teach the driver to allow an adequate safety margin in his driving habits, so that he will not become involved in secondary accidents? First, I do not believe that the safety margin approach could entirely solve the secondary accident problem. It is relatively easy to visualize how a person should drive to avoid such accidents; however, to get him actually to drive in this manner is not too feasible. For example, it is easy to define driving at reasonable speed and following distance for roadway conditions that might unexpectedly be encountered. The driver will not, however, accept the same following distances for normal roadway conditions. Furthermore, he consistently overestimates his abilities to perceive and react to driving conditions, normal or unusual. I believe that to overcome these problems, it is necessary to develop and place in the vehicle various instruments and devices for alerting the driver as he approaches congestion, accidents, slow-moving vehicles, or other potential hazards. An approach such as this, together with education, will probably be the only effective means of communicating to the driver on the road so that he will be capable of making adequate responses. If we rely entirely on driver-to-driver signals and attempt to train drivers to look for such signals, we will be creating a very difficult driving task.

MR. VAN IRWIN: You mentioned planting on the sides of the road versus a 500-foot free space on either side of the road. It seems to me that planting with bushes would be much cheaper and more beneficial. No grass mowing would be required and the bushes would have the ability to absorb vehicular impact energy. In the northern part of the country in the winter, I have seen snow piled up along the side of the roads in banks, and these banks would envelop a vehicle running off the road and decelerate it at a very comfortable rate. Bushes would serve the same purpose all the year round.

MR. MOSHER: There are many facets to the roadside planting issue. There are several arguments for and against each type of roadside planting practice or proposal. Practices such as planting near the roadway trees that will grow to substantial trunk diameters are obviously poor from the safety viewpoint. Trees, of course, are not too comfortable to plow into. Even though appropriate roadside planting can reduce accident severity substantially, it does not provide the open space that sometimes could prevent the accident from happening at all. We cannot approach roadside environment improvement only from the standpoint of embankment planting to decelerate vehicles more comfortably. Instead we must look at it as an alternative treatment and compare it to other alternatives such as wide, unobstructed shoulders. This latter alternative, for example, offers an environment where a driving error such as an unsafe lane change, which often requires a following driver to swerve in order to avoid a collision, will not result in an off-the-roadway accident. Some of the more obvious benefits of unobstructed shoulders are reduced primary and secondary accidents and less accident-caused congestion and delay. The primary disadvantage is that of increased right-of-way cost.

MR. BISPLINGHOFF: We have been told that 50,000 people lose their lives each year in traffic accidents. What fraction of the fatalities occur on the highways between cities as compared to accidents on highways or streets within cities?

MR. MOSHER: In 1964, according to the National Safety Council, 70 percent of all highway deaths occurred in rural areas. This amounted to 33,000 persons of which about half were killed in night-time accidents.

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ENGINEERING STUDIES OF MOTORIST INJURY EXPOSURES FROM REAR-END COLLISIONS

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At the University of California, Los Angeles, 16 years of intensive research has been directed toward the problem of reducing motorist injuries. Most of the findings from this Auto Crash Project are related to improvements that can and should be made to the automobile. These well-documented findings have been widely published. In addition, the UCLA Auto Crash motion picture films have provided a public education service finding use in most of our driver training classes within the United States, and enjoying international recognition.

Our published findings point out general areas and specific conditions in which passenger vehicle design improvements will save lives. We also identify categories of alleged improvements that fall short of intended goals.

The progress in making use of these findings has been slow; in some instances there has existed a conspicuous lack of any progress. Quite understandably, I am encouraged by the recent public awareness that some deaths and injuries can be avoided through improvement in the design, manufacture, assembly, and, incidentally, the maintenance (which is in some measure up to you and me) of the motor vehicle.

The auto industry has been creditably cautious about implementation of quickly conceived, inadequately evaluated notions on ways to eliminate passenger car collision induced injuries. Most of us who are experienced in collision research have been humbled, at one time or another, by the realization that a pet concept or device failed to provide the measure of motorist protection expected, and in fact introduced a new hazard to driving a vehicle.

The scope of this paper has been narrowed from the subject "The Vehicle, The Impact, and The Damage" to "Engineering Studies of Motorist Injury Exposures from Rear-end Collisions." I hope to demonstrate that an intensive study is required to provide preliminary findings in a limited category of passenger protection worthy of consideration with respect to changes in automotive design.

This presentation will be limited to findings from three series of rear-end collision experiments conducted in 1954, 1958, and 1966. These experiments are illustrative of an engineering approach to the solution of one aspect of the complex problem of motorist safety.

Most authorities concede that automobile collisions will continue to occur regardless of accident prevention efforts. This is not a defeatist attitude, but a proper recognition of the many complex factors that produce interruptions in the orderly flow of motor vehicle traffic. In the accidents that do take place, if we can learn what happens to the passengers within a car during each type of collision, we will have a sound basis for engineering design revisions that can lessen the consequences of especially hazardous collision exposures. It has long been observed that not all automobile accidents cause injuries; some quite severe collisions occasionally result in only minor injuries for one of the occupants. Finding out the reasons for such a minimized effect should indicate ways to increase the safety of all motorists.

Automobile crashes may be characterized as double events. The first occurs as the vehicles (or vehicle and fixed object) collide, and the second occurs perhaps a tenth of a second later as the motorist strikes his car interior or is thrown outside the car.

It is this second event to which engineers at UCLA's Institute of Transportation and Traffic Engineering (ITTE) have devoted most of their attention. In most collisions, occupants are hurled against the car interior a fraction of a second after the car strikes an object. Exposure to injury varies according to the kind of crash. In order to observe closely and to measure scientifically what happens to passengers in various types of crashes, it has been necessary to simulate experimentally each principal type of collision.

The following types of collisions have been conducted by UCLA-ITTE: two-vehicle head-on, read-end, intersectional or side impacts; one-vehicle roll-overs or upsets, collisions with pedestrians, and with fixed objects. This paper is confined to the significant data and findings from three series of rear-end collision experiments.

The low-speed, rear-end collision is one of the more common types of urban automobile accidents and it is probably the most misunderstood and underestimated. Unlike other types of collisions, the rear-end collision frequently results in minor car damage and major bodily injury. However, unlike most injury-producing accidents, there is generally no visible sign of the injury the victim receives in rear-end collisions. He may not be immediately aware that he has suffered an injury that will require weeks or months for recovery.

An initial study of rear-end collisions was made in 1954 by conducting five experimental collisions at speeds ranging from seven to 20 miles per hour. Human subjects were used in both the front and the rear vehicles when collision speeds were believed to be non-injury producing. An anthropometric dummy was also used in the front car at these lower impact speeds to provide control data for subsequent higher speed impacts involving only the dummy. The human and anthropometric dummy subjects were instrumented by electrical accelerometers; the automobile was instrumented by mechanical accelerometers. High speed photography was used to facilitate micromotion analysis of subjects and vehicles.

The first objective was to determine the nature and extent of the force systems on both the human occupants and the vehicle structures of two automobiles involved in rear-end collision. Another objective was to present the findings so that they might be used (1) as a first approximation for engineering revision of the automobile to make it safer for the occupants during a rear-end collision, and (2) to facilitate a keener discernment of the neck injuries common to this type of impact.

The test facility, equipment, methodology, and instrumentation are described in ITTE Reprint Number 40, which was an article first printed in the *Canadian Service Medical Journal.*

Observations from collisions like that shown in Figure 1 provided data presented in Table 1.

The permanent deformations of the struck car in relation to impact velocity, and the relationship of vehicle deformation and impact velocity to head whip is shown in Figure 2. The rotational and translational component forces applied to the head by the angular and linear accelerations of the head, and their resultant forces, are also shown.

The 10-mph collision produced a higher resultant force on the head than the 20-mph collision. In the latter collision, increased

Table I

Run	Front Car						Rear Car			
			Acceleration, G						Acceleration, G	
	Pre-Impact Velocity	Subject	Head	Shoulder	Hip	Car Body	Pre-Impact Velocity mph	Subject	Head	Car Body
1	0	Dummy	2.5	3.0	10.0	1.5	7	Human		
2	0	Human	5.0	4.0		2.0	8.2	Human		3.4
3	0	Dummy	11.3	4.6	5.1	4.0	9.9	Human	8.0	3.7
4	0	Human	2.9	2.7		2.5	9.4	Human		2.7
5	0	Dummy	11.4	3.7	6.5	6.3	19.8	Human	8.0	5.0

Table I. Data from observations of collisions like that shown in Figure 1.

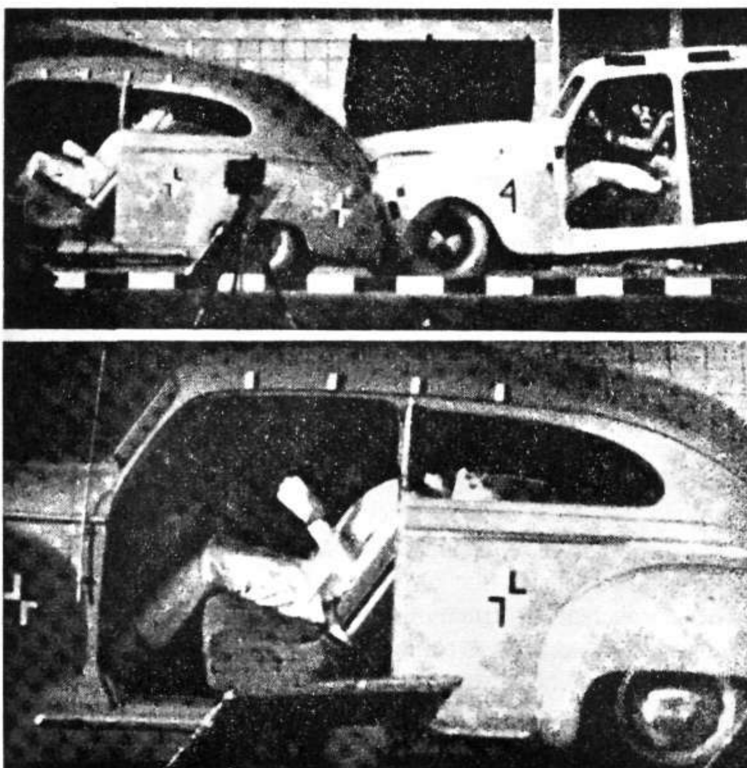

Figure 1. Rear end collision with striking vehicle moving at 20 mph. The upper photograph from high speed motion picture film shows 1/10 second after impact; the lower shows 2/10 second after impact.

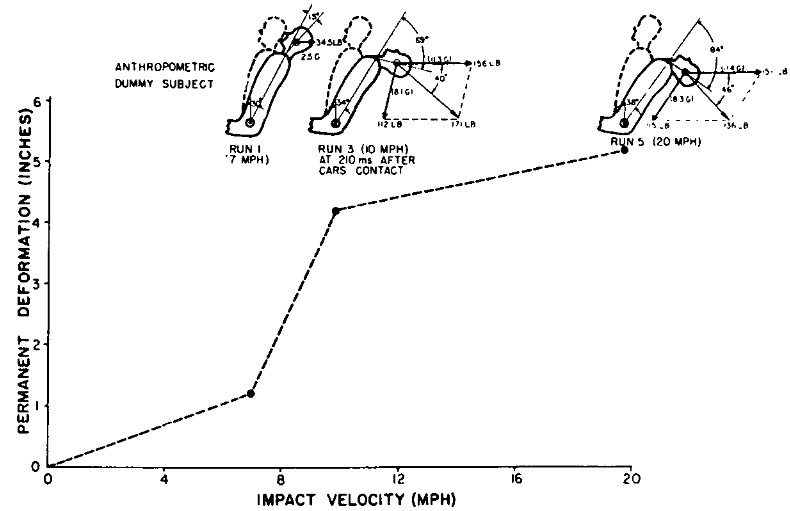

Figure 2. Permanent deformations of struck car in relation to impact velocity, and the relationship of both to head whip.

seat flexure placed the body in a sufficiently reclined position to enable the head to be flexed back far enough so that the horizontal component of acceleration (linear acceleration) partly offset the angular acceleration. Increased seat flexure, under the higher collision forces, served to moderate some of the force transmitted to the occupant. Consequently, the resultant force applied to the neck for the 20 mph impact (136 pounds) is less than the resultant force (171 pounds) for the 10 mph impact. Seat flexure reduced the injury potential by (1) extending the head acceleration period and reducing the resulting peak acceleration or force, and (2) positioning the upper torso in a more reclined attitude so that the forces of acceleration applied to the head operated through a reduced bending moment. The acceleration and related data at several reference positions for the head of a motorist in an automobile struck on the rear by another vehicle traveling 20 mph faster than the struck car is shown in Table 2.

During the initial phases of the period when the motorist is beginning the forced movements of whiplash, the two cars are undergoing the velocity changes shown in Figure 3.

Whiplash injuries may result from accidents other than rear-end

Time Milliseconds*	Acceleration, G	Response of Subject
20	0	Head erect
100	—1.0	Head reaction due to force application below body centre of percussion of the subject for seated position
235	+8.3	Extreme dorsi-flexion of head
287	0	Head has accelerated to car velocity so head velocity becomes constant with head flexed 86° rearward on its way forward
370	—4.0	Head 11° aft of erect, swinging forward with increasing acceleration due to restitutional forces of seat-back and neck
580	—3.0	Head strikes visor above windshield
960	0	Body is thrown back against seat
1030	4.5	Seat-back re-accelerates body to cause a second but less severe head-snap

* Time is measured from zero time, the instant the cars made contact.

Table 2. Chronology of events during whiplash.

collisions; they occur, for example, in intersection and upset accidents. It is the frequency of rear-end collisions and the potential severity of resulting whiplash injury that has focused attention on reducing such injuries.

A head support was designed and built into the back-supporting section of the front seat (passenger side) of an automobile. Experiments were carried out to evaluate its effectiveness in minimizing whiplash injuries from rear-end collisions.

The structure of a standard seat back was extended ten inches above its normal height. The extension was restricted to ten inches to avoid interference with rear vision. The added seat height supported the head's normal position. The seatback extension was padded to minimize injury to a head thrown against it during a

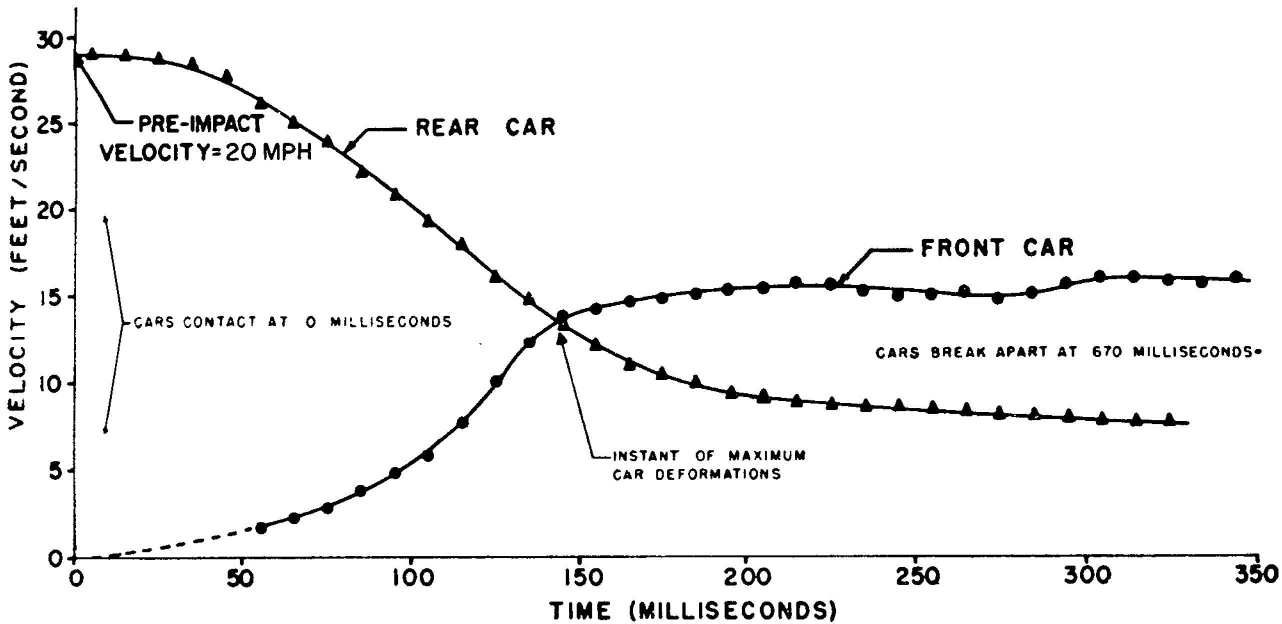

Figure 3. Velocity changes for two cars in a rear-end collision.

rear-end collision. Whiplash is characterized by an abrupt longitudinal acceleration of the upper torso; a differential velocity develops between the supported upper torso and the unsupported head. The accelerating shoulders leave the head "behind" and abruptly place the neck in an extended and flexed position. The human head represents approximately seven percent of the total body weight, which, for a 200-pound man, represents a 14-pound mass that must be accelerated by the only connecting link, the neck. In an extended and flexed position, the neck is poorly oriented to bring about acceleration of the head without developing injury-producing forces along the spine.

This extended and flexed condition is apparent in Figure 4, which shows the anthropometric dummy during a 23 mph impact. In the rear-end collision, the shoulders are accelerated by the seatback, but the unsupported head is accelerated only through its neck connection.

When a head support or seatback extension is provided, both the shoulders and head accelerate at essentially the same time, thereby eliminating differential velocities and the attending forces characteristic of the whiplash injury. The effect of a head support is graphically portrayed in Figure 5.

The head, whether supported or unsupported, accelerates in due course at about the same *rate,* but the supported head accelerates at the same *time* as the shoulders. Contrariwise, the unsupported head accelerates independently and, of course, at a later time than the shoulders, as shown in Figure 6.

When the supported head accelerates at the same time as the shoulders, negligible bending and shear stresses are applied to the

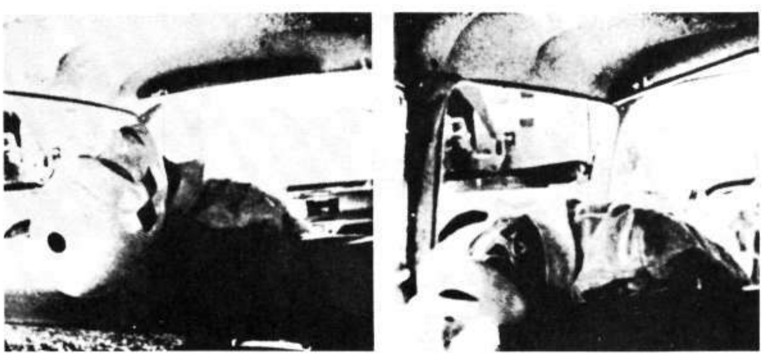

Figure 4. Whiplash during a 23 mph rear-end collision.

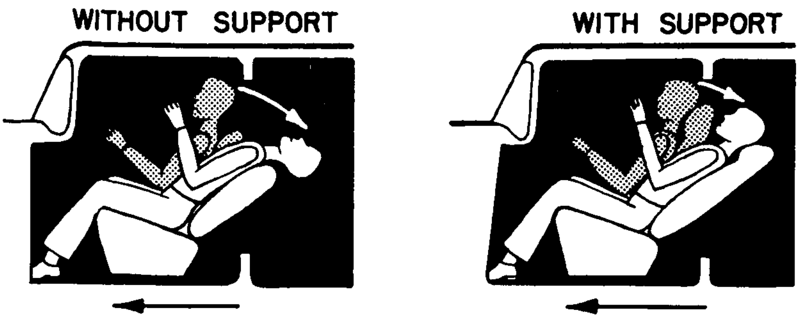

Figure 5. Effect of a head support.

spine, whereas the unsupported head is accelerated only by such delayed forces as are transmitted through the neck during the acceleration period of the head.

These findings have led to the conclusion that most injuries sustained from rear-end collisions could be eliminated by the use of a properly designed head support for the motorist. Unlike a safety belt, which must be fastened by the motorist in order to be of value to him, the head restrainer provides continuous protection against whiplash from rear-end collisions without relying on the motorist to make a conscious effort to utilize it.

In Figure 7, peak accelerations for the struck vehicles in ten rear-end collision experiments are compared with impact velocity. It may be noted that age and type of car structure are secondary in importance to the influence of velocity on impact acceleration peak values.

Considering the speed of impact, the rear-end collision generates *relatively* little permanent deformation for either the striking or struck cars because each car is opposing the crushable structure of the other car and the struck car is abruptly accelerated out of position before greater intrusion can occur. For comparable speeds of impact, damage to cars colliding with fixed objects will be relatively extreme because the opposing structure does not collapse correspondingly and is not moved as the impact gets underway. For collisions with fixed objects, the collision energy must be dissipated in a split second by the crashing car, as graphed in Figure 8.

Figure 8 also illustrates the variation in permanent collapse for vehicles of different construction; deformation for unit-body con-

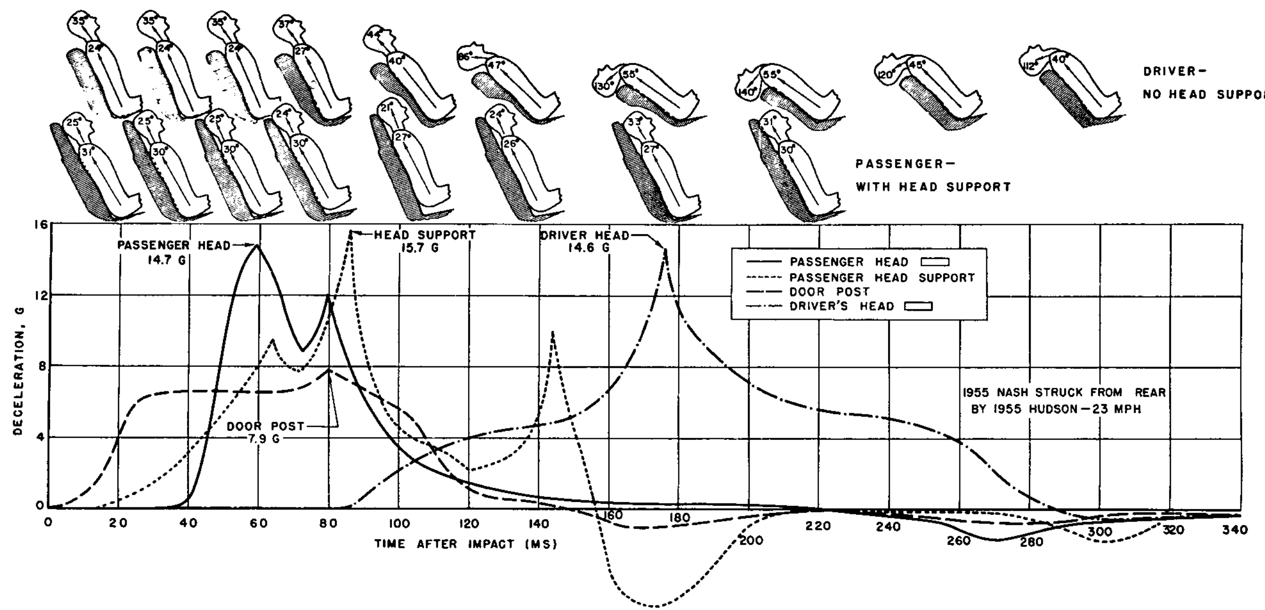

Figure 6. Kinematics of the supported and unsupported head in a 23 mph rear-end collision.

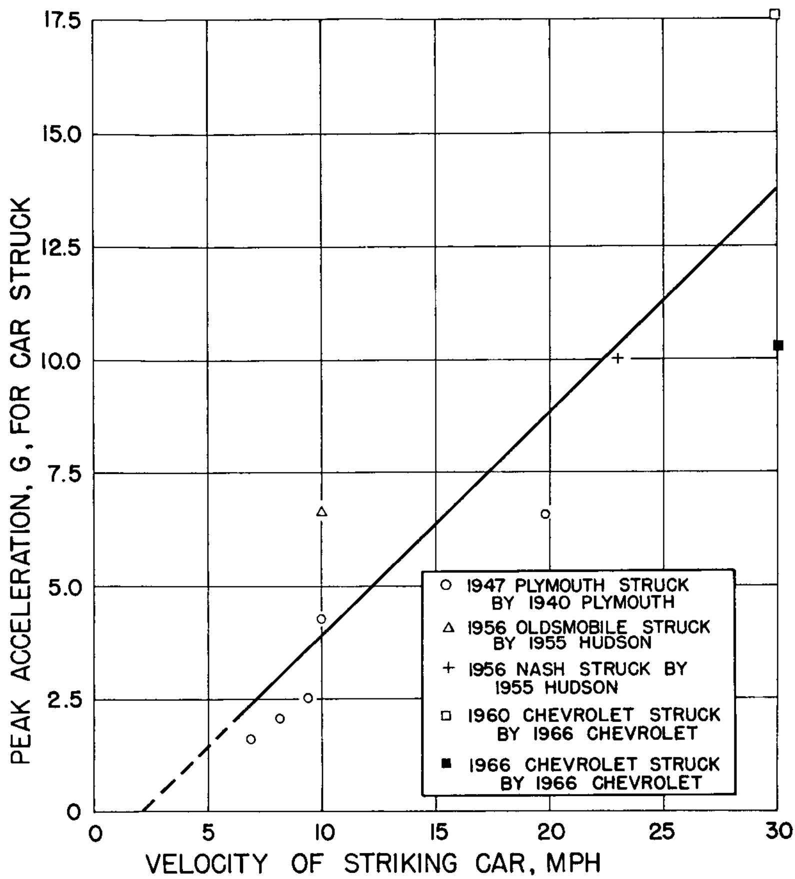

Figure 7. The effect of striking car's velocity on the peak acceleration of the struck car.

struction compared to frame construction is shown for comparable collision exposures.

Head and torso stresses were analyzed in one of UCLA's experiments involving an anthropometric dummy seated behind the wheel of a stationary car struck by another car traveling 23 mph. Rotational force on the driver's head was measured at 308 pounds, synchronized with an 84-pound translational force. The resultant 320 pounds acted through the center of the mass of the head with a mechanical advantage substantially greater than would be implied

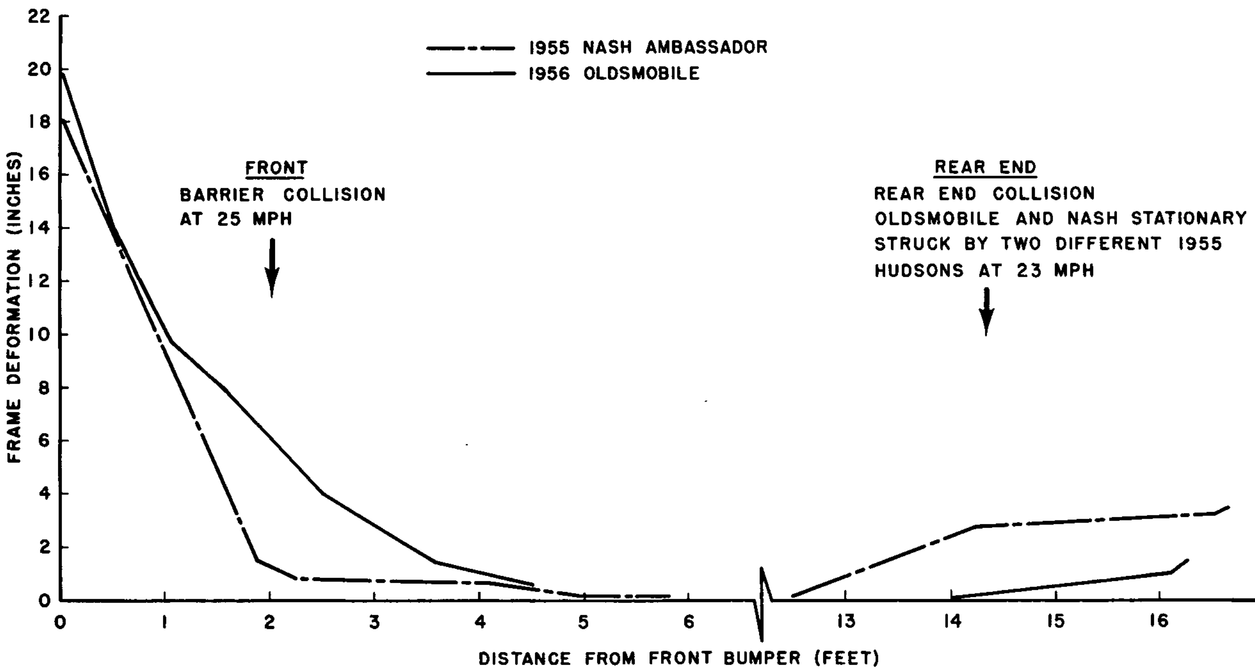

Figure 8. Frame deformation, longitudinal axis, of two types of automobiles.

by the 18-inch bending moment from the center of the head's mass down to the top of the seatback.

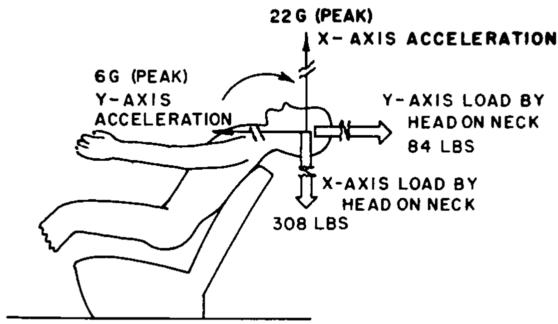

Figure 9. Motorist's head acceleration and force vectors during a rear-end collision experiment; striking speed, 23 mph.

The inertia effect of the lower limbs tends to pin the hips against the seatback; center of pressure of the seatback during collision acceleration is situated above mid-back; the mass of the arms and shoulder girdle augment the inertia effect of the head. During impact, the torso slides up the inclined seatback and rotates rearward, as shown in Figures 9 and 10.

Under these conditions, the low seatback of present-day cars, unlike seatbacks in older cars, cannot apply support throughout the back but instead act as a fulcrum for the body as it moves backward.

Forces acting on the vertebral column are shown schematically in Figure 11. The inertia force of the legs and hips (F_i) acting through the hip-girdle may be resolved into the transverse component (F'_i) and its corresponding vertebral compressive component;

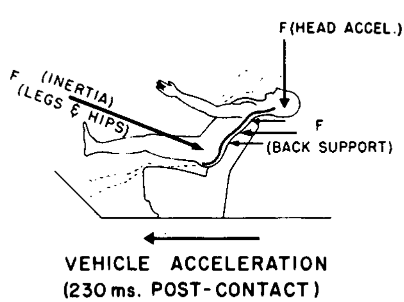

Figure 10. Motorist's force vectors during a rear-end collision.

the forces of the fulcrum-like back support ($F_{b.s.}$) are shown with distribution limited to the upper mid-back; the inertia forces from head acceleration ($F_{h.a.}$) may be resolved into a transverse component ($F'_{h.a.}$) and its corresponding vertebral compressive component.

A small downward (frictional) component exerted by the seat-back produces an additional compressive loading to the vertebral column. The force components of the head, seatback, and lower limbs constituting vertebral compressive forces predispose the vertebral column to buckling. The normal "S" curvature of the spine makes it even less able to sustain compressive forces than would be true if the spine were naturally straight. In the interest of brevity, the aggravation of injury by these factors will not be discussed here.

Assume the torso to weigh W pounds per foot, uniformly distributed along its spinal axis. Assume further that this spinal axis is a simple beam, supported by the fulcrum action of the back support force $F_{b.s.}$. The transverse force components F'_i and $F'_{h.a.}$ augment the forces of the distributed torso load. A study of the variation in shear stresses and bending moments along the beam simulating the vertebral column provides a clue to the mechanism of back injuries from rear-end collisions. No attempt will be made to quantify shear stresses and bending moments, except to indicate relative orders of

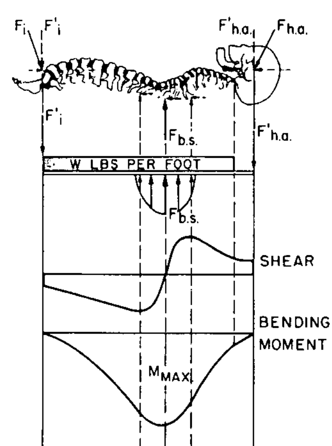

Figure 11. Analysis of patterns of stresses on the vertebral column during a rear-end collision.

their magnitudes distributed along the vertebral column during collision acceleration.

The shear diagram (third from top of Figure 11) is a curve for the beam shown above it in which the abscissa represents distances along the beam and the ordinates represent corresponding vertical shear stresses.

The vertical shear at the left end of Figure 11 increases from the abscissa an amount representing the shear stresses applied to the junction of the base of the spine with the hip girdle by F'_i. The vertical shear progressively increases for vertebral sections to the right because of augmentation by the lower trunk mass to the onset of back support forces, $F_{b.s.}$. As the back support forces increase to maximum for analysis of sections farther and farther to the right, shear stresses decrease to zero and then increase in the opposite direction as the back support forces diminish to zero. When $F_{b.s.}=0$, the inflection point in the shear curve is reached for the second time and thereafter the contribution to vertical shear by the distributed load of the torso diminishes until the distributed load reaches zero. This point represents the beginning of the neck, assumed to be negligible weight (3 percent of body weight). Shear stresses remain constant, therefore, for sections farther to the right and terminate at the center of mass of the head.

The moment diagram (lowest curve Figure 11) is a curve with distances along the abscissa corresponding to positions along the beam above it and ordinates representing bending moments for corresponding sections of the beam. Considering sections once again from left to right, the bending moment at the left end is zero because F'_i operates through a moment arm of zero length.

Moments for sections progressively to the right increase because of contributions from the distributed load and from increases in bending moment distances, augmented by the concentrated force F'_i to the onset of back support forces. As the section approaches the center of pressure of the back support forces, the bending moment is maximum and decreases thereafter by the offsetting effect of the distributed load and $F'_{h.a.}$ to the right of $F_{b.s.}$. The bending moment decreases linearly from beyond shoulders to zero at $F'_{h.a.}$ for reasons (assumed negligible weight of neck) described in connection with the shear diagram.

The vertical alignment of certain sections of the curves, considered with the diagrams of Figure 11 suggest the following:

(a) Substantial shear forces prevail at the junction of the spine and hip girdle during a rear-end collision, but appear insufficient to cause injury. Bending moments are zero or negligible.

(b) At the center of pressure of the seatback, bending moments have increased to a maximum but shear stresses are zero or nearly zero.

(c) On either side of the seatback center-of-pressure zone, there exist combinations of maximum shear stresses and near-maximum bending moments that may readily reach injury-producing magnitudes.

(d) A substantial residual shear stress prevails at the base of the skull.

The above statements may help explain the presence of mid-back and low-back injuries from rear-end collisions even though that section of the back was supported by the seatback, at least prior to impact.

Variables that operate to alter conditions from the above simplified evaluation include such factors as individual differences, the non-uniformity of the strength of the vertebral column, and the non-uniformity of weight distribution of the torso.

In the most recent series of automobile rear-end collision experiments conducted at UCLA, 1966 automobiles were used, and the stationary car was struck in the rear at 30 mph. The peak acceleration forces are shown in Figure 12. A 1966 automobile was also used to rear-end a 1960 model at 30 mph, as in Figure 13. The values of acceleration and restraint-tensiometer loadings shown in Figures 12 and 13 should be regarded as preliminary until the comprehensive report on this series is published.

The slightly more collapsible structure, characteristic of automobile designs of the mid-60's, is illustrated by comparing the 10.2 G peak acceleration attained for a 30 mph impact by the 1966 vehicles with the 8 to 10 G peak acceleration obtained respectively for the 1956 unit-body automobile and the 1956 frame-body automobile, each rear-ended at 23 mph. The potentially higher repair bill for the 1966 car collision is a small price to pay for lower

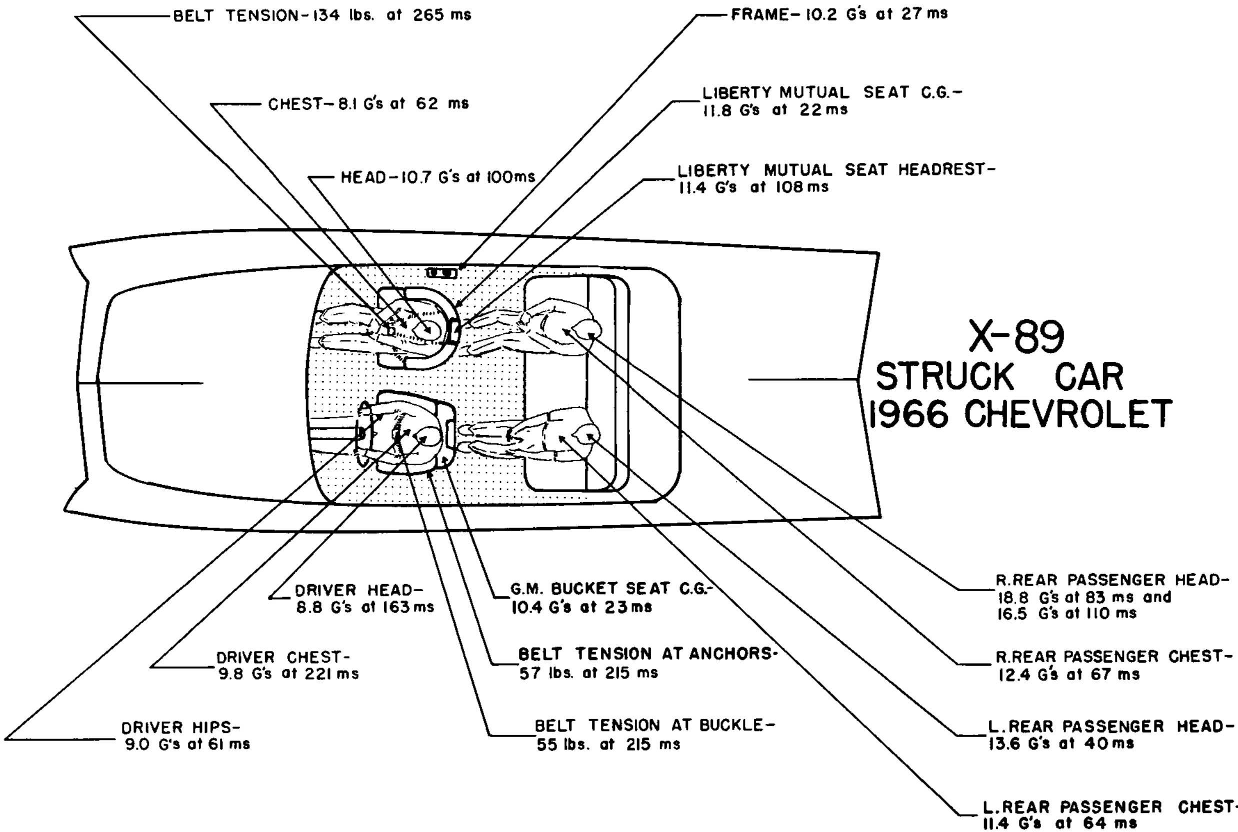

Figure 12. Resultant peak acceleration for a 1966 automobile rear-ended at 30 mph.

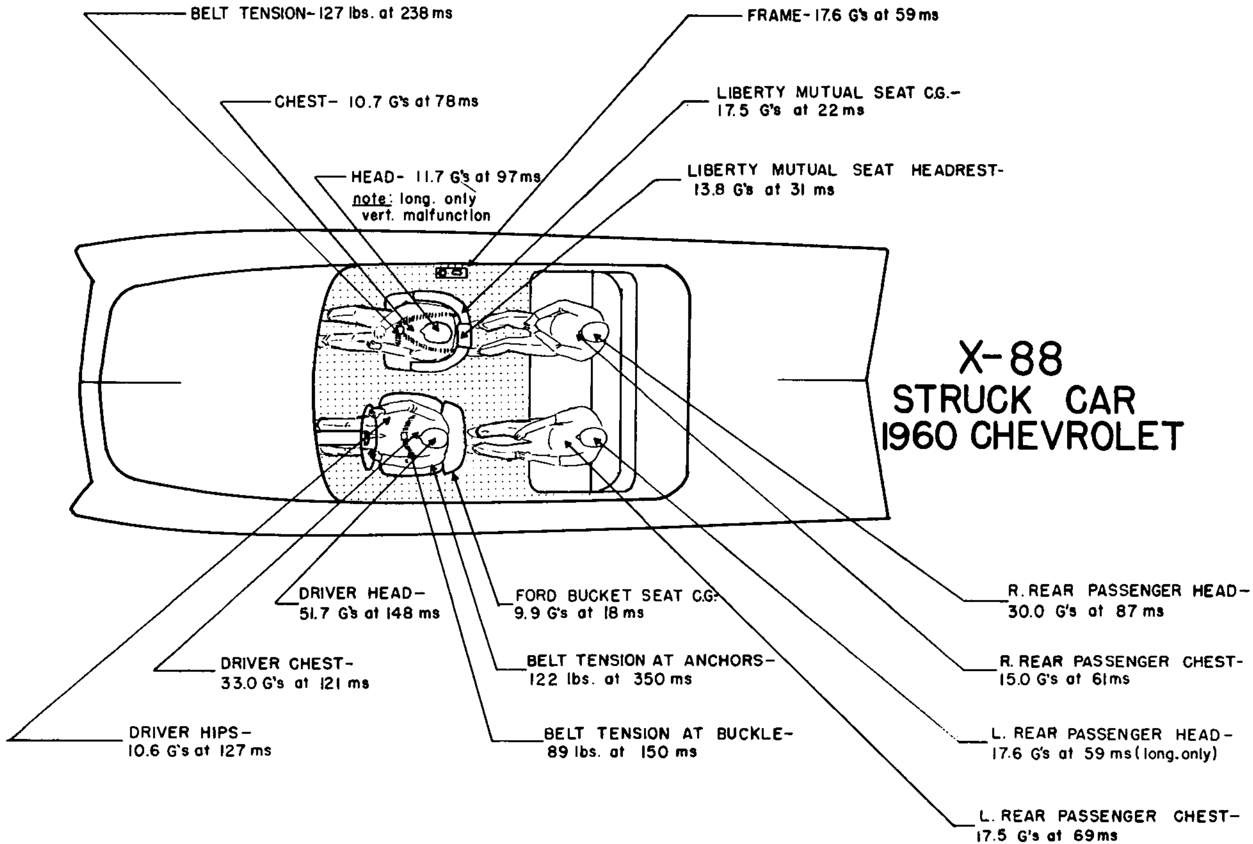

Figure 13. Resultant peak acceleration for a 1960 automobile rear-ended at 30 mph.

collision acceleration and reduced injury exposure experienced by the motorists.

The increase in passenger safety resulting from greater collapsibility of the vehicle structure should be augmented by the presence of built-in head supports. Automotive manufacturers can best handle this complex problem of seat design. Head support designs made by well-meaning but naive individuals often have resulted in devices obviously more hazardous than no head support at all. Such devices have not been designed according to the loads they may be called on to withstand; their failure to sustain these loads in actual collision often expose the head and neck to the steel bars used in the supporting bracketry. Furthermore, the steel bars used to support these accessory head restrainers become a hazard whenever the rear seat passengers are pitched head-on against them.

The automobile industry must be looked to for its engineering capability, both as to new head support designs and for safe and practical head support accessories for cars manufactured and sold without them.

I will summarize here the principal findings from this series of UCLA-ITTE experiments concerning rear-end collisions.

First, the motorist's body, when it is not supported or restrained, involuntarily moves as if it were completely independent of the automobile during the time the cars are crushing together. When the motorist's body fails to move at the same speed as the car body during collision, a velocity difference develops; the difference is cancelled abruptly as the motorist's body strikes obstacles or absorbs accelerating forces.

Peak accelerations attained for vehicles struck on the rear at speeds between 7 and 30 mph are approximately proportional to impact velocity. The effect of vehicle age and type on peak acceleration tends to be subordinate to impact velocity.

The struck car's body essentially completes its acceleration before the passenger shows significant evidence of being affected by the impact. Then the passenger's hips, shoulders, and head, in that order, begin accelerating.

The body posture and state of preparedness of the motorist at the time of impact may influence the acceleration pattern of the body components. Therefore, the injury potentials of a given collision may vary from one motorist to another.

The second major finding of the UCLA-ITTE experiments confirms and describes in detail the action called "whiplash" by medical scientists. In the 20-mph rear-end collision, for example, a dummy's head pitched backwards to an extreme position and then forward to an extreme position and back toward a normal position.

Rotational and translational forces act on the head, and the subsequent stress on the neck is related to the inertia the head mass offers to acceleration. When the two forces are combined into a single (horizontal or linear) force, they may augment or diminish each other depending upon their relative magnitude and the posture relationship of the head and torso.

As the head is pitched backwards, an angular acceleration develops in addition to the horizontal or linear acceleration. Since the angular acceleration, like the linear acceleration, applies its inertia load to the neck as the latter flexes rearward, both angular and linear accelerations should be considered when appraising the forces applied to the neck by the whiplash action.

The third major finding of our experiments is that the whiplash injury pattern can be significantly influenced by any or all of the following factors: (a) contact speed of the two vehicles; (b) height and strength of seatback; (c) mass and collapse characteristics of contacting sections of the cars involved; (d) human body variations including height, weight, and age of the individual, as well as his posture; (e) defensive action taken by the motorist when forewarned of imminent collision.

In regard to (a), it was shown experimentally that the 10-mph collision produced a higher resultant load on the head than the 20-mph collision. Increased seat yielding, by flexure of the seatback for the 20-mph collision as compared with the 10-mph collision, accounted for horizontal head accelerations being approximately equal for the two collisions, and the resultant head load for the higher impact speed being *less* than that of the lower impact speed. This increased flexure provided an additional 30 percent distance for the head to accelerate.

In regard to (b), the factor of seatback height and its influence on whiplash, experiments showed that the initial downward acceleration of a car struck from behind, while not of primary importance, does expose the passenger to possible increased back and neck injury by elevating his position about three inches relative to the seat. The area of his back supported by the seatback is thereby reduced.

As for factor (c), the influence exerted on whiplash patterns by mass and collapse characteristics of the contacting sections of the cars involved, experiments showed that the slight increase in the collapsibility of bumpers of late-model cars reduces slightly the peak acceleration during collision, and thereby tends to reduce the injury exposure the passenger will experience. Frame type cars absorb higher collision accelerations better than unit body cars, but unit body cars absorb lower collision accelerations better than frame type cars.

Some of the collapsing by car structures during a rear-end collision frequently is not evident following the collision. Combined plastic and elastic deformations for the 20-mph collision amounted to 24.4 inches, of which the permanent deformations for the front and rear cars were 5.2 and 6.1 inches respectively.

The car-to-car rear-end collision represents a relatively elastic impact when compared to one in which a car strikes a fixed, unyielding obstacle.

Concerning the influence of factor (d), the motorist's posture, and factor (e), motorist's defensive action, on whiplash pattern, experiments showed that a relaxed motorist, such as one waiting for a traffic signal to change, not forewarned of an impending rear-end collision, could have his head subjected to abrupt loadings in excess of 100 pounds for a collision under 15 mph.

The fourth major finding of our experiments details the value of the safety belt for passengers in the striking car, and the head support for those in the struck car. The motorists restrained by the shoulder-loop-and-lap safety belts when they were driving the striking car reported no discomfort during impacts of 10 and 20 mph. This is indicative of the value of these devices when they are properly designed, manufactured, installed, and used. In the 20 and 23-mph collisions, the neck of the restrained passenger sitting in the striking car did not flex forward dangerously because flexion was limited by the action of his chin striking his chest.

In the struck cars, the passengers having head supports benefited from the reduction of injury-producing forces. The head support maintains normal head and torso postures during collision acceleration, thus preventing the rotational component from developing and eliminating the injury-producing aspects of the longitudinal component.

The fifth major finding from our experiments concerned injuries other than whiplash that occur in rear-end collisions. Engineering analysis of the patterns of stresses to which the vertebral column of the human body is subjected during a rear-end collision indicates the reason mid-back and low back injuries often occur, while injuries at the junction of the spine and hip-girdle do not usually occur. Injuries occur when there is a combination of maximum shear stresses and near-maximum bending moments. The points at which the two are most adversely combined are on either side of the seatback's center-of-pressure zone. Individual differences, the non-uniformity of the strength of the vertebral column, and the non-uniformity of weight distribution of the torso account for the variation of back injuries.

A rear-end collision victim may also suffer facial injuries, and the front of his body may show other evidences of trauma as a result of his being piched forward into the steering wheel or onto forward surfaces such as the instrument panel and windshield. There is some suggestion that in rear-end collisions at speeds below 10 mph, the driver may be less exposed to injury than a front seat passenger because of the significant head and upper torso support the driver may derive from grasping the steering wheel. However, in collisions at higher speeds, the steering wheel may traumatize rather than support.

The sixth major finding of these rear-end collision experiments is that crash features such as the head support should be built into the automobile by the manufacturer. Automobiles should be rated on their collision performance as well as their acceleration and braking performance, with a high rating reflecting how well the car manufacturer has equipped the vehicle with long overdue safety devices. Automobile manufacturers should also develop adequate retrofit units for the millions of cars currently in need of these devices since most retrofit head supports currently being manufactured increase rather than decrease the possibility of injury for many rear-end collisions.

DISCUSSION

Moderator, RAYMOND L. BISPLINGHOFF

DR. HADDON: One of the weaknesses of engineering studies related to human beings, as well as other biological material, has been the tendency on the part of engineers to use average values. For example, in collision experiments, dummies of average size are used, whereas if one considers the variation in human size, weight, and so forth, one finds that "average" omits a very large portion of the distribution of the real material in the real world.

Would you comment on this in connection with testing, especially from the standpoint of how far up the distribution scale of human body size vehicle designs should be aimed to accommodate.

MR. SEVERY: The Air Force finds it necessary to use the 95th percentile as the upper limit for cockpit design. That rules out only the extremely tall and extremely obese person. The auto industry is not that liberal, and I don't feel it should be. If it were, difficulties would occur for the smaller body sizes. For example, if a shoulder harness attached to the door post is too high for a small person, it may cause severe lacerations of the neck during certain kinds of side impacts. The human neck structure is quite sensitive to this sort of abuse; such trauma can be fatal. Obviously if there is a fixed anchor point for the upper torso restraining belt and there are persons of varying height using the belt, there will be quite a range in the effectiveness of the belt's performance. Adjustability is needed in some situations, and this adjustability must be designed into the car.

I look forward to seeing a car with a seat that will adjust up and down and is strong enough so that restraining belts can be attached to it. Belts anchored to the seat should be much more able to accommodate the size-range of people who will be using them. Seat controls should include those that will move the seat forward and rearward as needed to bring the accelerator, the brake, and the steering column within comfortable reach of the driver, regardless of his size.

One serious problem we have not discussed adequately is the extension of the steering column against the face and the chest during front-end impacts. We identified that problem at UCLA as early as 1951; it is still with us. For some models of cars it is an even more serious problem now than it was in 1951. We must do something about it. I am not making any recommendations on how the problem should be solved since its solution can readily be designed by almost any engineer.

In our UCLA experiments, we have quantified it in terms of forces transmitted to the driver during impacts. It does not take more than a 20 mile-an-hour head-on collision to kill a driver as his torso is pitched forward to meet the rearward thrust of the steering column. Some people are more susceptible to a given traumatic exposure than others, I am sure. The steering column, striking the abdomen, can chip the liver or cause other serious, even fatal, internal injuries. There are reported cases of death of the driver after very minor impacts. Autopsies reveal the driver bled internally as a result of the high sheer stresses on his body as it came into contact with the steering wheel or column.

The automotive engineers have the data on this serious problem and they certainly know how to design a solution, but apparently there has not been enough attention and complaint focused on the hazards of steering wheels to bring about a design change. Changing designs to allow a five-inch thrust by the steering wheel column into the cabin area is not an acceptable solution — although I recognize we have to take a first step before we can become more rigorous with our design criteria. Deaths by steering column spearing has troubled me deeply for the past 16 years because this senseless waste of human lives could be so easily eliminated.

The need for head supports also has long needed attention. Our studies reporting on head supports appeared in 1954; no action was taken then, and little has been taken since. Much misery can be eliminated by the addition of head supports to the automobile seat. Another problem we should work on is the automobile door latch. Latches are not strong enough. The industry has done much to improve them, at least within the United States, but the situation is very bad in regard to some of the imported cars. Take, for example, the Rolls Royce with its gold-plated price tag. You can almost kick its doors open. In a collision at 20 miles an hour, the Rolls' four doors have been known to pop open as well as the trunk and the hood. The Porsche and Volkswagens offer no better protection.

We should not limit our interest to domestic cars when our citizens have an equal opportunity to buy imports that are far more unsafe in many respects. Our domestic cars are not safe enough but they provide a safer environment than the imports.

MR. MC INTYRE: Have you done any work on or considered the use of energy absorption devices? I am thinking of the work done by John R. McGehee of the National Aeronautics and Space Agency at Langley Center, Hampton, Virginia. There is also the work of Bernard Mazelsky of Aerospace Research Associates, West Covina, California; he has devised a Taurus ring to attach to the car bumper.

Has UCLA done any engineering studies on the possibility of incorporating such devices in the front or rear ends to absorb impact energy? The Space Agency has come up with some rather clever solutions.

MR. SEVERY: Yes, they are extremely clever, very efficient, and lightweight. We have had them delivered to our laboratories, and we have looked at them. We are impressed with their potential performance features. I regret to say we have not tested them. Actually, I think their application is limited. Within the structure of the automobile, anything that yields during impact provides a trade-off. It is hazardous to have much yield in the restraints for motorists. As collision forces build up, the various restraints we have now yield too much anyway. Flesh compressibility, the realignment of the seat belt harness, the stretch of the harness, the buckling upwards of the floor pan are all built-in yield factors. To include still another feature such as the Taurus Ring tends to provide too much yield, sufficient to allow the motorist to be forced against the windshield. Therefore, there is not too much incentive for applications of this nature. By using a yield device on the back of the front seat (if it has a strong enough anchorage system), it might be possible that individuals reaching the front seat back from the rear seat will receive some energy absorption.

As a matter of fact, quite unintentionally the car manufacturers have provided energy-absorbing features in the front structure, and they are very similar to those developed by the aerospace industry. The automotive industry, in providing the present-day vehicle with the strength or structural rigidity necessary for it to function in the manner required, has it so happens, also provided a bumper system with the intrinsic resistance to collapse that corresponds closely to good built-in energy absorption. It has been suggested that features such as the modulated hydraulic shock absorber device should be incorporated into the bumper system. While this shock absorber is an engineering masterpiece, I challenge the practicality of installing it on automobiles. It is an expensive mechanism for a collision event that is not highly probable. It is a mechanism requiring careful maintenance, and to add such a device to the front of the car seems to me quite impractical. The car should be designed for crashworthiness so that when the collapses occur, regardless of direction of impact there will be a minimum amount of intrusion into the cabin structure. Simultaneously, the collapse action should moderate the impact forces efficiently.

It should be emphasized, however, that no matter how well the car structure moderates the impact forces during a collision, the passenger will not be spared injury if he is not restrained sufficiently. There is too much slack in almost all present restraint systems. After all, a human body cannot be bolted directly to the car and therefore, as the onset of collision forces occur, he cannot decelerate with the car. There is at least one-tenth second in almost every collision exposure during which the car's deceleration has preceded the deceleration of the occupant. This means that there is a practical limit as to how much can be done to restrain the motorist. He must be restrained as much as possible, however, in order to benefit from structures moderating the impact forces. A lot more can be done to moderate these forces.

MR. VERSACE: With regard to the head rest and the anthropometric question that Dr. Haddon raised, what has happened to the controversy about the necessity for the head support's being directly against the back of the head? Can the support be effective if there is a space of six, seven, or eight inches between it and the head? This is important because that is about the amount of space we have found in the middle 90 percent of the population; there is a great variation in the location of heads on top of shoulders.

MR. SEVERY: As far as I know, this question remains unanswered. However, we have some ideas about it. In the rear-end collision exposures, the main problem is the differential velocity developed by the head as contrasted to the torso. Head inertia causes the neck to be flexed rearward. When the head's rearward movement is checked by impact with a head support, head-to-torso differential velocity is stopped before the neck makes an excursion beyond the normal limits of the human anatomy. That is the protection a head support is intended to provide.

When appropriate experiments are conducted, and we plan to do some, I think it will be found that a reasonable space between the head and the head support will not alter the effectiveness of the head support.

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THE ACCIDENT AND THE INJURIES

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It is possible to prevent the majority of deaths and injuries that result from traffic accidents. This can be accomplished in the near future. It can be accomplished without attempting to stop traffic accidents. My main hypothesis is that many accidents cannot be prevented, but most traffic deaths and injuries can be.

Physicians have a unique opportunity to evaluate the current status of the traffic accident problem. A look at any busy hospital emergency room and the roster of daily admission figures should be enough to convince anyone that we have completely failed to decrease the number of deaths and injuries that are the most unfortunate result of traffic accidents.

One of the reasons for our failure, and the one I would like to stress, is the gigantic misconception fostered in the mind of the motoring public — namely that it is necessary to prevent traffic accidents in order to prevent the resulting injuries and deaths. Nothing could be farther from the truth. In fact, the majority of deaths and injuries from traffic accidents can be prevented — and in the foreseeable future.

Because of this misconception, great efforts in terms of dollars and manpower have been spent in the attempt to identify and control the many variables that finally culminate in a traffic accident. The more the subject of accident causation has been researched, the more confusing it has become and the more apparent that the problem is extremely complex and will require more years and money and man hours before it is understood. It may be impossible to obtain any significant decrease in the number of traffic accidents in the near future.

We are in the midst of an uncontrolled epidemic — an epidemic of collision injuries and deaths. The story of the polio epidemic and its control, as seen in Figure 1, holds the clues to a possible solution. The polio epidemic was controlled not by destroying the virus, not

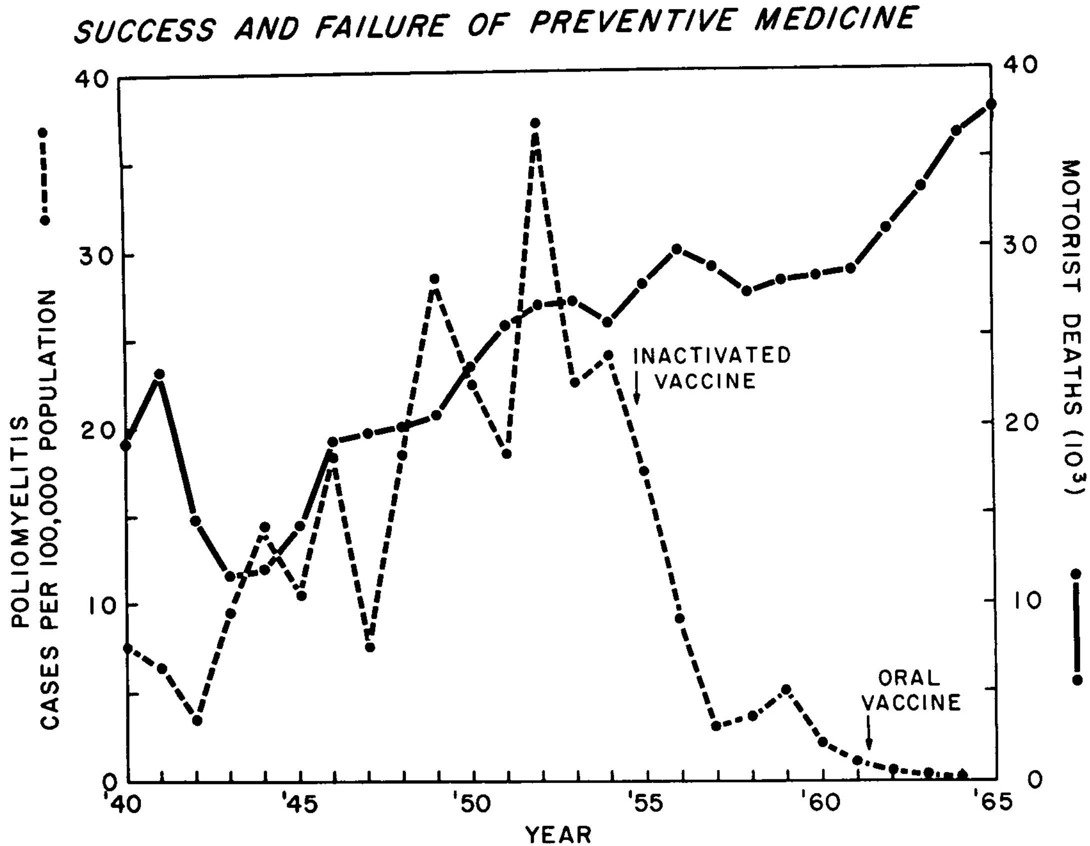

Figure 1. Success and Failure of Preventive Medicine.

by preventing people from being exposed to it, and not by developing newer and better methods of treatment; the polio epidemic was controlled only when it was possible to prevent patients from being injured by the virus despite unavoidable exposure to it.

In a like manner, it is impossible to prevent people from riding in cars, it has proven difficult to improve radically the care of people who are injured. However, it is possible to prevent death and injury from occurring as a result of the accident even when it is impossible to prevent exposure to the accident. This is the most promising area for concerted effort.

To understand why the traffic collision and the traffic injury are separate events, and why the injuries can be prevented even when the collisions occur, it is necessary to understand the dynamics of an auto collision.

As the diagram in Figure 2 shows, the first stage of a collision is the contact between the vehicle and the object it hits, usually another vehicle or part of the highway environment. During this sudden collision-stopping of the car, the passengers continue in motion only to come to a crushing stop some fractions of a second later when they hit the inside of the vehicle. This has been called the secondary collision. There are two separate and distinct collision events — injury and death occur in the second collision and not the first. It is possible to modify that second collision to prevent, in most instances, the severe injury or death that can result from it.

A study is currently underway at the UCLA School of Medicine to identify the causes of injury to motorists in auto collisions. A team has been formed consisting of physicians, engineers, photographers, and statistical analysts who work together as shown in the diagram in Figure 3. A detailed examination is conducted of all persons injured in selected traffic accidents. These data are combined with detailed information on the accident and a careful engineering analysis of the vehicles in which the injuries occurred. The final result is a description of the accident and how the accident occurred.

When a vehicle is involved in a collision, the massive forces of kinetic energy inherent in the moving vehicle are suddenly released and dissipated, usually by crushing a part of the vehicle. Up until the peak of this deformation, nothing has happened to the occupants of the vehicle — they are still unharmed. However, just after the

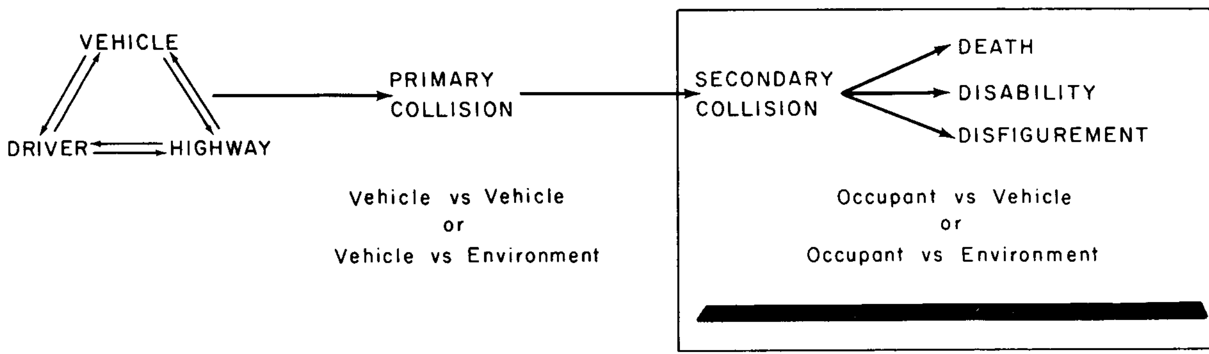

Figure 2. Sequence of Collision Events in Traffic Accident.

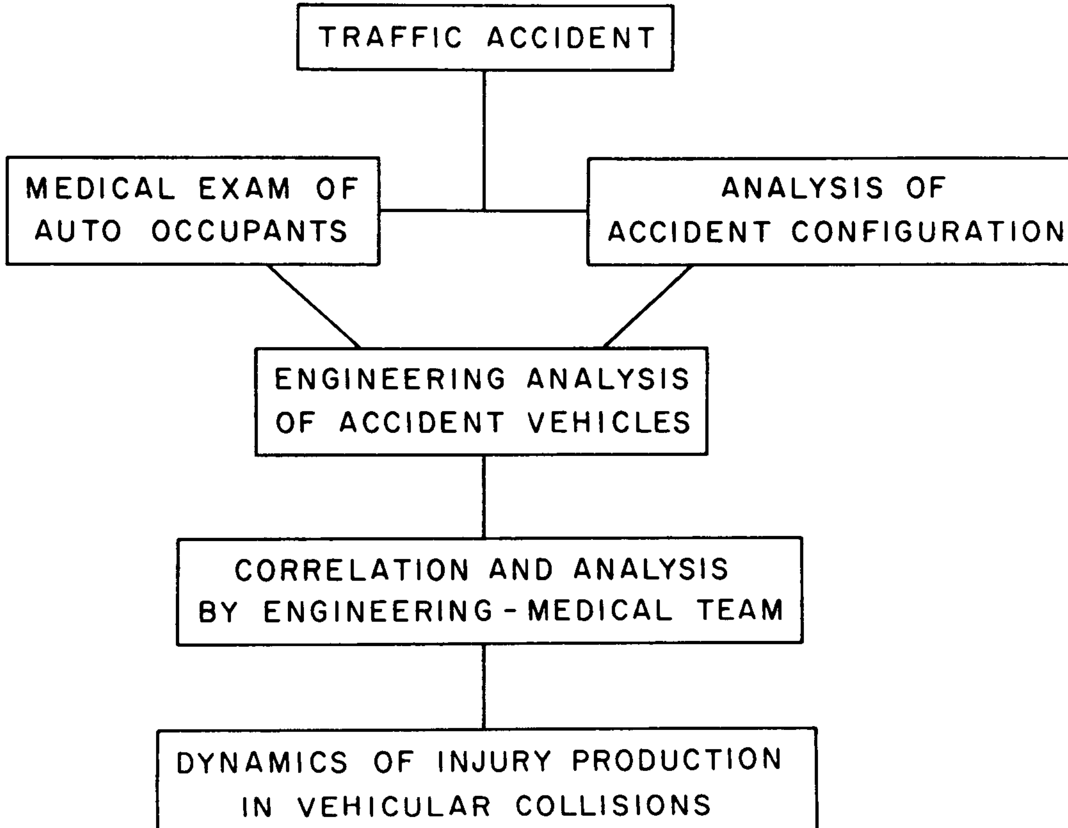

Figure 3. Organization of UCLA Vehicular Trauma Research Group.

vehicle comes to a stop, the occupants who are still in motion crash against the inside of the vehicle, unless they are ejected.

Being ejected from the vehicle is almost always more dangerous than remaining inside. Motorists are much safer if they remain inside — in fact, if the motorist cabin remains intact, most of the injuries sustained inside the vehicle could be prevented.

The final injury that a car occupant receives is also dependent upon the way in which the forces described act upon the body. The important factors here are the following:

(1) The total magnitude of the force.

(2) The area of the body that is struck. Head injuries, for example, are more life-threatening than leg injuries.

(3) The rate of onset of the force, or how long it takes for the peak force to be reached. The slower the rate of onset, the less the likelihood of injury.

(4) The duration or length of time that the force must be withstood. The shorter the duration, the less the injury.

(5) The total area of the body over which the force is distributed. Obviously, the greater the spread of the forces, the lower will be the harmful concentration in any one body area. For example, a knife and a fist could deliver the same amount of force, but the latter would be preferable because the force would be spread over a wider area and thus be less likely to cause serious injury. The seat belt and upper torso restraint distribute the forces over a wider area and over areas better equipped to withstand these forces.

Most passenger injuries are due to collision with some area inside the vehicle. The area of the motorist compartment that is struck is usually a function of (1) the direction in which the vehicle and occupants are moving, and (2) the seating location of the passengers.

For this reason, a trained engineer can often look at a vehicle and describe exactly in what direction the occupants moved and what structures inside the vehicle injured them.

The data presented here were collected in an analysis of 150 accidents in which at least one severe survivable injury occurred inside the vehicle. The accidents studied were selected from a total of 3,308 accidents that occurred last year in California. A total of 496 severe injuries were sustained by the occupants in the vehicles involved. Each was tabulated in regard to the exact object inside the vehicle that had produced the injury. The causative agents in order of importance were (1) the steering wheel and column, (2) the instrument panel, (3) the windshield, (4) the doors, (5) the A post or support between the windshield and door, and (6) the roof over the windshield. (See Figure 4.)

The body areas most frequently injured were, first, the face 32 percent, then the head 19 percent, chest 16 percent, legs 13 percent, arms 10 percent, abdomen 8 percent, and neck 2 percent. (See Figure 5.) The vulnerable face, head, and neck area suffers 53 percent of the injuries. Many of these injuries could have been classified as fatal, because the resulting disability and disfigurement ended or severely hampered the useful lives of these people. Many of them wished that they had died in the accident.

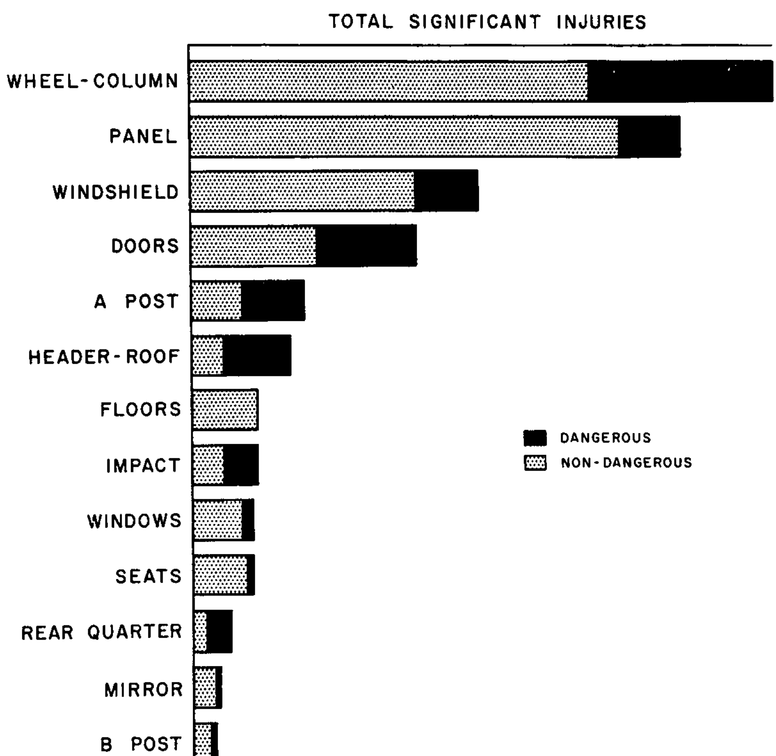

Figure 4. Causes of Injuries Studied.

The types of injuries are best illustrated by actual cases taken from our files.

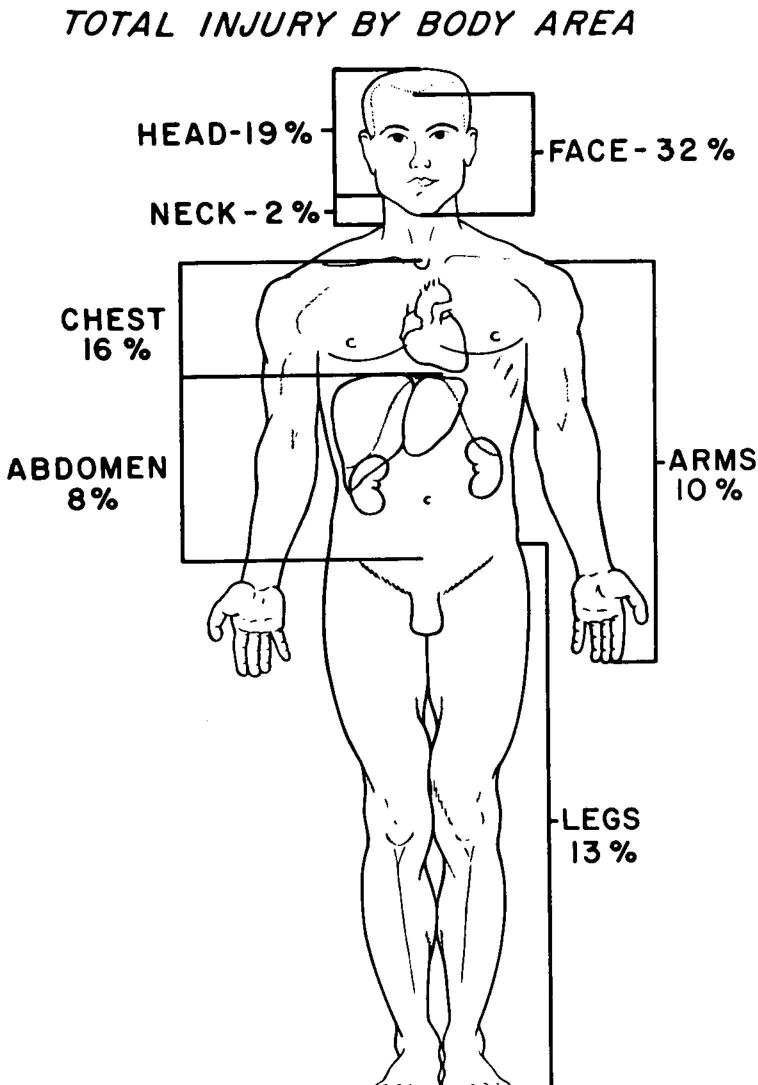

Figure 5. Body Area Distribution of Injuries.

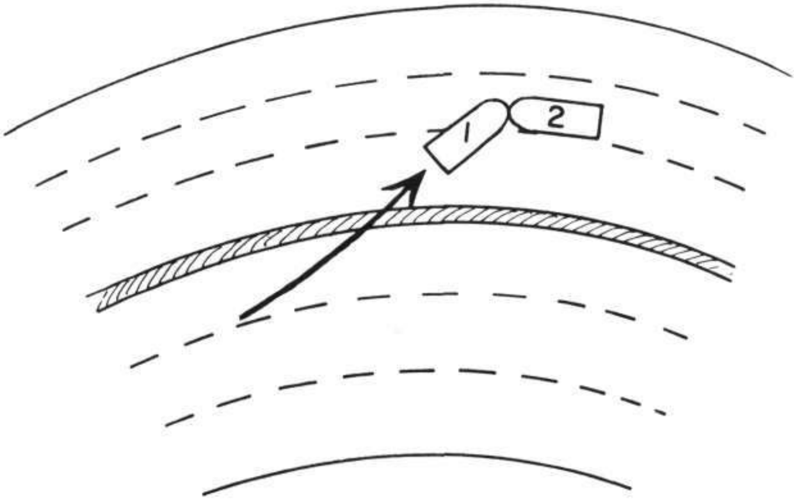

Figure 6. Collision Diagram; Case 233.

Figure 7. Vehicle 1; Case 233.

Vehicle 1, a 1960 two-door sedan weighing about 2200 pounds, carrying two front seat passengers, was proceeding down a freeway

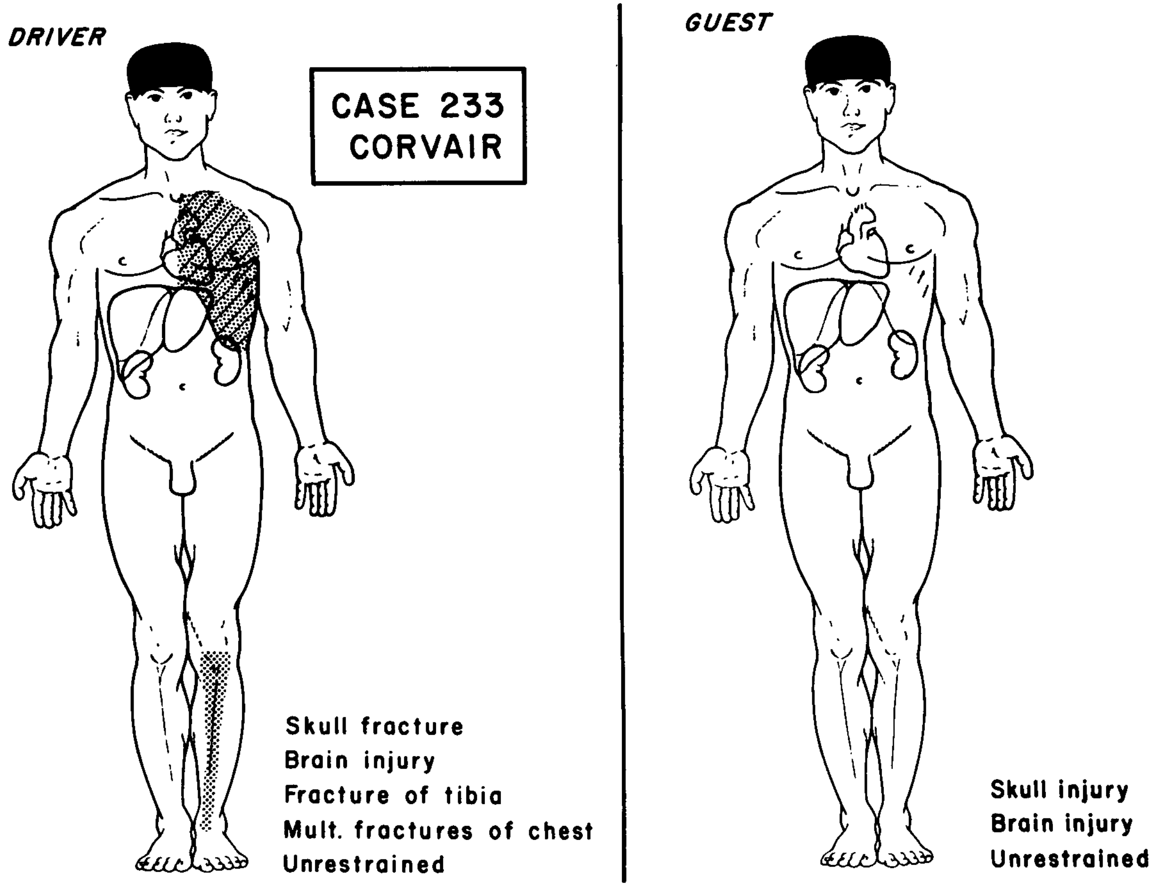

Figure 8. Motorist Injuries (Vehicle 1); Case 233.

about 60 mph. It suddenly swerved to the left, as shown in Figure 6, crossed the raised center divider and collided with an oncoming 1965 two-door sedan, vehicle 2, weighing about 2700 pounds, which was travelling at the same speed and carried only the driver. Both vehicles were almost of equal weight. Since there were no skid marks, speed estimates were derived from witnesses and the estimates of our engineers.

Vehicle 1 underwent a slightly off-center collision force crushing the right front of the vehicle as shown in Figure 7. The driver's compartment remained intact. Neither the driver nor his front seat passenger was wearing seat belts. Because of the bending forces applied to the sides of the vehicle, the right door latch was sprung and the two men were spilled out of the car and onto the pavement. As shown in Figure 8, the driver sustained multiple rib fractures and lung damage as well as several skull fractures. The guest passenger sustained severe skull fracture with brain injury. Both men were dead when the ambulance arrived.

Vehicle 2 received severe collision forces against the left front. (See Figure 9.) The driver, a 28-year-old girl, was wearing a seat belt. She moved forward and to the left, flexed forward to the

Figure 9. Vehicle 2 (Struck Car); Case 233.

left, thereby missing the steering wheel but instead striking her face against the door and A post structures. (See Figure 10.) She sustained deep lacerations and fractures of the left side of her face. (See Figures 11 and 12.)

This accident illustrates a somewhat comparable collision exposure for two opposing cars of similar weights. The case illustrates that restraining devices save lives by preventing ejection from the vehicle. However, lap belts may allow the upper torso to flex forward, permitting the face to strike dangerous areas in the passenger compartment. Therefore, an upper torso restraint is also necessary. The judicious use of energy-absorbing materials in the passenger compartment can also help to prevent injury.

Case 245

There has been much discussion about the virtues and dangers of small cars. There is no doubt that small cars are inherently unsafe for a number of reasons. Ignoring the performance problems that may affect the dynamic stability of small cars, other more important factors must be considered.

The most obvious defect is that smaller cars by virtue of their

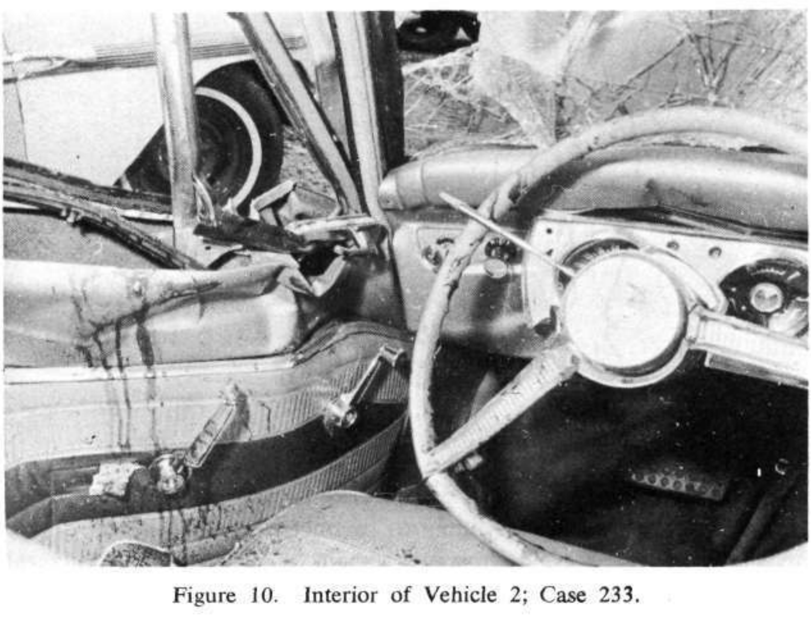

Figure 10. Interior of Vehicle 2; Case 233.

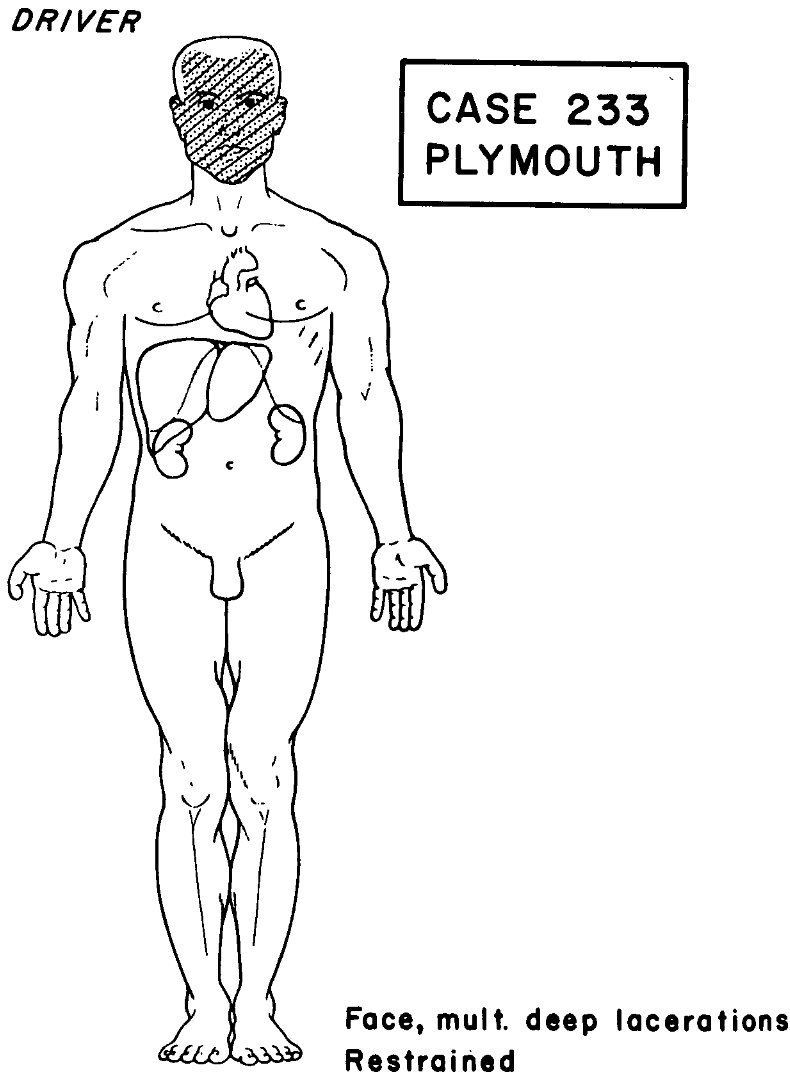

Figure 11. Motorist Injuries, Vehicle 2; Case 233.

decreased structural strength afford less protection to the average motorist against the forces likely to be encountered in severe traffic accidents. Their decreased weight means a decrease in structural integrity. In addition, the smaller passenger compartment provides

Figure 12. Facial Injuries, Driver, Vehicle 2; Case 233.

less space for motion of the passengers before striking the interior during a collision. If there were only small cars on the road, the damage resulting from striking another car would be less. However, most cars on the American highways are large. It is particularly in this type of collision between small car and big car that the small car is apt to fare poorly and fail to protect its occupants.

The problem can be illustrated by an example of a low-speed collision. A small 1964 two-door sedan weighing about 1600 pounds with a man driving and his small daughter in front was proceeding down a suburban street at about 25 mph. A 1962 sedan weighing about 3300 pounds and containing two college students was travelling in the opposite direction at about 25 mph. The heavier car crossed the double yellow center line and collided with the left side of the smaller car. (See Figure 13.) There were no skid marks.

The striking car showed moderate damage along the left front area. (See Figure 14.) The two passengers did not sustain any injuries.

The struck car received extensive damage along the entire left side; the driver's side of the passenger compartment was penetrated. (See Figure 15.) The driver moved to the left into the side of his car which was collapsing inward. He sustained multiple left-side rib fractures with lacerations of the heart and spleen. He died in the emergency room of the hospital. The occupant in the right front seat was not injured.

Small cars afford less protection for their occupants. This protection is particularly inadequate when great collision forces are generated by contact with larger cars or unyielding environmental

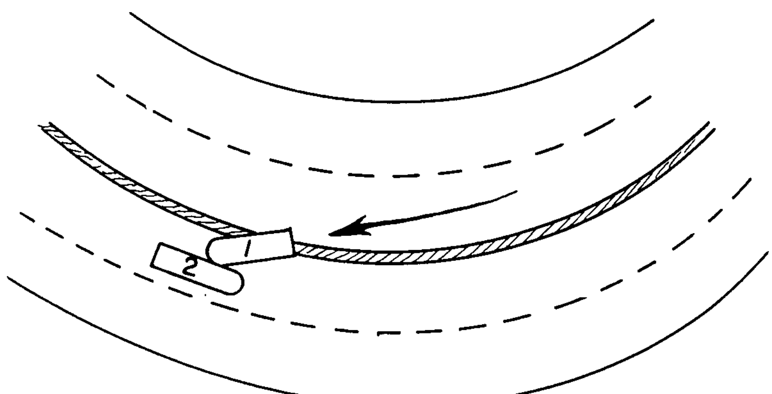

Figure 13. Collision Diagram; Case 245.

Figure 14. Vehicle 1 (Striking Car); Case 245.

Figure 15. Vehicle 2 (Struck Car); Case 245.

objects. Small cars tend to be most vulnerable in side impact collisions where the minimal structural protection permits easier penetration into the motorist cabin. The car occupants, who are propelled by collision forces toward the direction of impact, have little or no space between them and the car structure. Smaller cars must be required to adhere to the same standards of safety that are being demanded for larger vehicles. For some of them, this may be impossible to achieve.

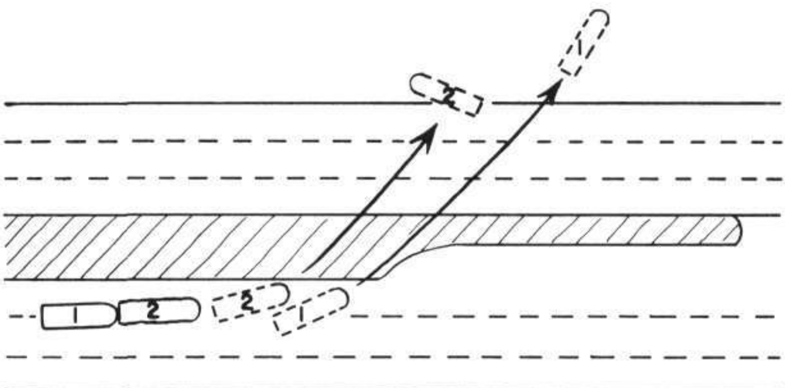

Figure 16. Collision Diagram; Case 241.

Figure 17. Vehicle 1 (Striking Car); Case 241.

CASE 241

A 1963 four-door sedan weighing about 5,000 pounds was proceeding in the left-hand lane of a suburban street at about 30 mph. A man and his wife were the front seat passengers. Without warning, they were struck from behind by a 1965 two-door sedan weighing about 2700 pounds and proceeding at about 80-90 mph. There were no brake marks prior to impact. After impact both cars continued across the raised concrete center divider and came to rest against the curb of the opposite traffic lane. (See Figure 16.)

The single driver-occupant of the striking vehicle, the smaller car, was not wearing a seat belt. His car underwent great collision forces that caused collapse of the front end and pushed the engine backward. (See Figure 17.) These same forces shoved the steering column and wheel rearward at the same time that he was moving forward. (See Figure 18.) His chest contacted the steering wheel, which caused the sternum and ribs to be crushed inward. The center hub of the steering wheel is seen lying on the seat in Figure 18. The imprint of the hub is clearly seen in the middle of the driver's chest in Figure 19. The aorta, the major blood vessel coming from the heart, was sheared by the force of the impact. (See Figure 20.) Death was almost instantaneous.

This would have been a survivable collision if the driver had not contacted the steering wheel. Adequate restraints provided by a lap belt in combination with an upper torso restraint would have helped to prevent the forceful contact with the steering wheel, and the resulting injuries. The steering wheel and column can be lethal to the driver particularly in view of its tendency to be forced back toward the driver when the vehicle receives a frontal impact at right angles to the long axis of the steering assembly. The collapsible steering wheel and column are a step in the right direction toward correcting this dangerous condition.

The occupants of the larger struck car were more fortunate, but by chance only. A rear-end collision at this speed is frequently fatal to occupants of the struck car who undergo what is described as the whiplash movement. In the rear-end collision, the struck car is suddenly accelerated forward. The car seat pushes the supported part of the body forward. However, the head, which is usually unsupported, lags behind, swinging backward in an arc on the neck. This severe movement may not only tear vital supporting ligaments, but

Figure 18. Interior of Vehicle 1; Case 241.

Figure 19. Driver of the Smaller Car; Case 241.

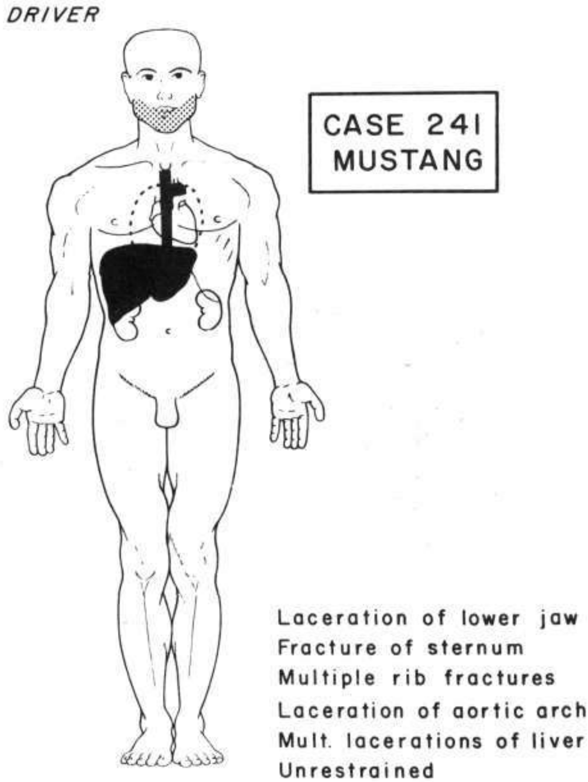

Figure 20. Driver Injuries; Case 241

Figure 21. Vehicle 2 (Struck Car); Case 241.

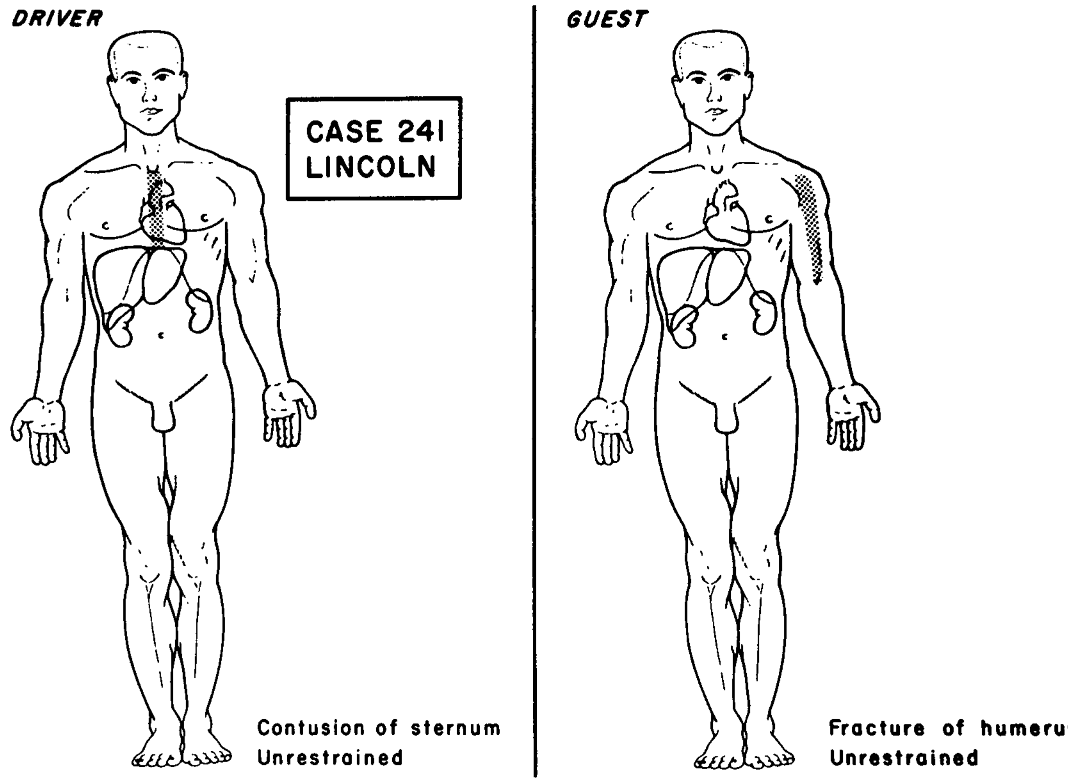

Figure 22. Motorist Injuries, Vehicle 2; Case 241.

can compress the vulnerable spinal cord, resulting in paralysis and even death. In the accident described here, the rear end of the car was crushed, forcing it into the rear seat area. (See Figure 21.)

In this instance, the man and wife sustained only minor bruises. (See Figure 22.) At first glance this appeared to be a miracle, but examination of the vehicle revealed the answer. The force of the impact broke the seat attachments and both passengers fell backward, thus avoiding the backward whiplash movement of the head and neck. (See Figure 23.) Fortunately, the seat metal broke instead of the passengers' necks.

Head rests are essential to prevent whiplash and injury to the neck. The fortuitous occurrence illustrated should not delude motorists into believing that this can be counted on to happen.

Case 163

A 1964 two-door sedan weighing about 3,000 pounds with two young men in the front seat was travelling down the freeway at an estimated speed of 80 mph. The driver lost control of the car in the gutter of the right hand lane and hit a solid concrete bridge abutment. (See Figure 24.) The collision forces demolished the front

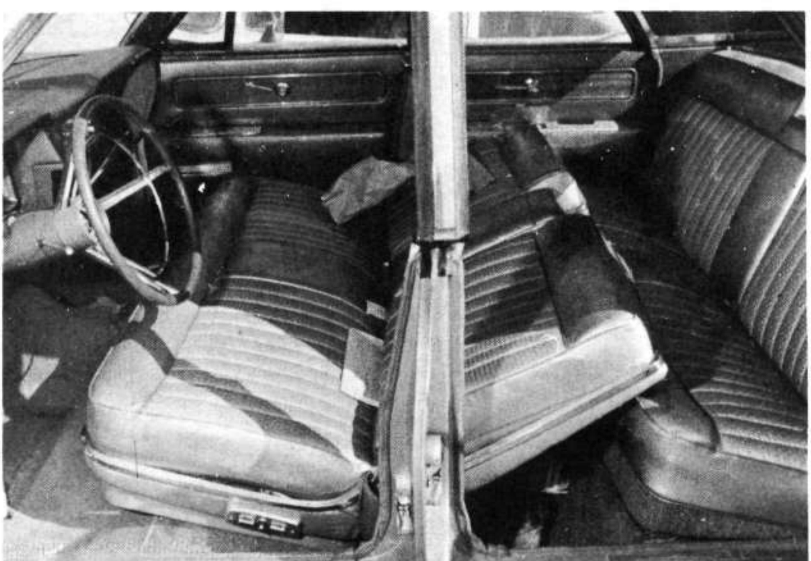

Figure 23. Interior, Vehicle 2; Case 241.

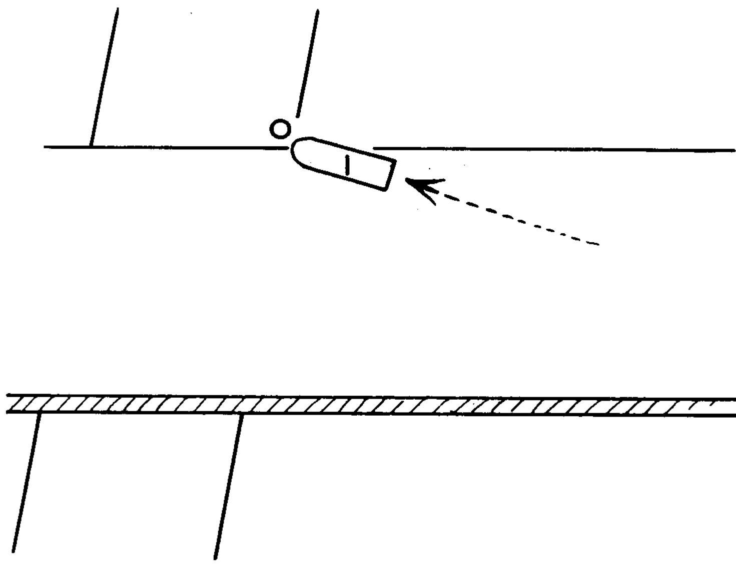

Figure 24. Collision Diagram; Case 163.

Figure 25. Accident Scene; Case 163.
(Courtesy *Los Angeles Times*)

Figure 26. Interior of Vehicle; Case 163.

end of the vehicle and separated it from the motorist compartment. Parts of the drive train were found 100 feet from the point of impact. The car bounced off the bridge and onto the freeway. (See Figure 25.)

Both of the occupants were wearing seat belts. Both men flexed forward and struck their faces against sharp objects in the compartment. The driver struck against the wheel and the guest passenger against the instrument panel. (See Figure 26.) Both sustained multiple facial lacerations.

However, because the passenger cabin remained intact and because the passengers were wearing seat belts, they were able to survive what ordinarily would well have been fatal collision forces. Inside the car is the safest place to be during a collision, provided the inside has been made safe. An upper torso restraint in this case would have prevented the facial injuries.

The research study underway at the UCLA School of Medicine has revealed some interesting facts about seat belts. (See Table 1.)

RESTRAINT USAGE	
MOTORISTS INJURED	242
MOTORISTS WITH RESTRAINTS AVAILABLE	72 (30%)
MOTORISTS USING RESTRAINTS AVAILABLE	19 (26%)

Table 1. Statistics of Restraint Usage.

In the accidents studied, 242 motorists were severely injured. Thirty percent of them had seat belts available but of this 30 percent, only 26 percent had been wearing the belt at the time of the accident. In other words, only 8 percent of the injured had been concerned enough to protect themselves. The possible value of restraints is indicated by Table 2, which shows that 90 percent of the severe injuries tabulated could have been prevented or at least decreased

VALUE OF RESTRAINTS	
TOTAL SIGNIFICANT INJURIES	496
INJURIES PREVENTED (OR DECREASED TO MINOR) BY USING RESTRAINTS	447
PROTECTION POSSIBLE	90% Of Injuries

Table 2. Potential Protection of Restraints.

to a minor category if the motorists had been using proper restraining devices.

Research studies on human volunteers have shown that the human body can withstand large collision forces if it is restrained by proper devices. (See Figure 27.) The problem is to convince the

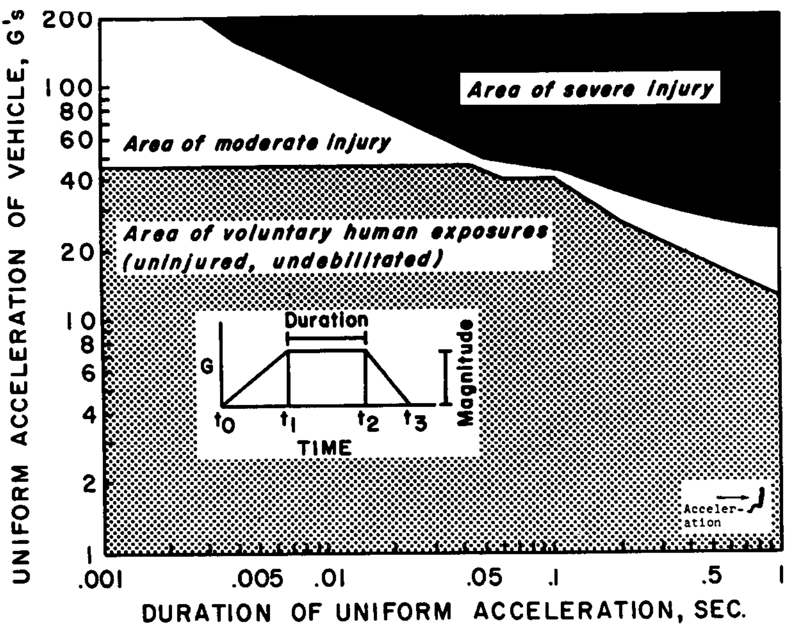

Figure 27. Human Tolerance to Deceleration Force. (After Eibend)

motoring public of the value of these restraints. The same marketing methods that are employed to sell potentially harmful products such as cigarettes must be utilized to sell traffic safety measures as well.

We have failed to curb the toll of deaths and injuries resulting from traffic accidents. The problem is complicated and many solutions have been offered. The confusion comes in part from the power struggle between the various vested interests. In confusing the public by emphasizing the complexities of the traffic accident, the various interests have diverted attention from the fact that the prevention of deaths and injuries need not wait for further data, further research, but can be achieved now. More than half of the present number of deaths and injuries could be prevented by (1) the use by the motorist of proper restraining devices, and (2) the modification of vehicle design by the manufacturers. The modification would primarily be the strengthening of the protective shell of the motorist compartment, and the altering of lethal structures such as steering wheel and column, instrument panel, and other surfaces within striking range of the involuntary acrobatics forced upon motorists by collision forces.

Those who confuse the issue or who have it within their power to make design changes and have not done so must bear the responsibility for the continuing deaths and injuries to trusting and innocent motorists.

DISCUSSION

Moderator, RAYMOND L. BISPLINGHOFF

MR. VERSACE: With regard to the relative penetration of the steering column into the driver's compartment, I think the situation can be over-simplified. What might apply for the steering column of today may not be the case for a completely different future design. Actually, relative steering column penetration toward the car occupant is not necessarily bad per se. What is bad is the rigidity of the wheel and column in some present designs; when a driver strikes it during a collision, there is little compliance. On the other hand, if during the collision the steering assembly could be made to move all the way back to the driver before he slides forward, and then begin to collapse, there would be considerably more distance available for gradual energy absorption as the collapsing took place. As a result, the steering wheel and column would become what is essentially an effective upper torso restraint feature of the car. Thus, while the idea of designing a column that does not "spear" the driver is a very appealing idea, it does not necessarily follow that relative penetration rearward by the steering assembly is in itself bad. It depends only on whether wheel and column will collapse when struck by the driver. I wanted to make this clear so no one would become so completely conditioned to the idea of the badness of the steering column's relative movement into the compartment that he would be blind to a possibly excellent energy-absorbing design if one does come along.

DR. NAHUM: There is no doubt about the fact that the steering wheel and assembly can be modified so that they actually afford protection to the driver. Mr. Versace is saying that it is possible to convert it to a collapsible structure and obtain some benefit from it. There is no doubt that it can be done, and it is likely that steps are being taken in this direction at the present time.

MR. MC INTYRE: I have served nine years as a member of the McLean, Virginia, Rescue Squad and I have seen much the same types of accidents as those shown in your illustrations. Do you have any comments about the attitude of newspapers and others against showing pictures of accidents, publishing photographs or what might be called documentary evidence of motorists who have been injured? Those having such an attitude seem to feel that the public should not be made aware of the disastrous results of accidents. I know this is typical of the press. They never like to show a picture of an accident.

DR. NAHUM: There is one extremely important consideration in regard to showing brutally realistic pictures. According to psychologists, some individuals can be frightened to the point that will deny the existence of the problem rather than receive the message intended for them. An illustration of this is the Cuban missile crisis. During the time it was going on, the man-in-the-street was asked what he thought about the situation, and some individuals, rather than consider the problem, denied it. It was pointed out that fear made them do this.

I think that showing a very gory film such as "Signal 30" might frighten some viewers and cause them to stop thinking about traffic safety altogether. The object is not to convince a person that riding in a car is unsafe, but to convince him that certain precautions and equipment can increase his safety. If he is merely frightened, he will stop thinking about the total problem; he might even start tearing out the seat belts and throwing them away because to wear a seat belt implies to him that the whole situation is dangerous and he will be killed.

We also know that the average person rejects the idea that the tragic events he sees in pictures could happen to him. He believes he is invulnerable and that nothing can happen to him; therefore, he reasons, he doesn't need to worry about safety devices. I am implying about the marketing of safety that instead of showing pictures of victims of a bloody death on the highway, it might be more effective to show an open green field with a beautiful blonde, symbols of the good and happy life to be associated with safety measures.

TREATMENT OF THE INJURED

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Treatment of patients with multiple injuries is often complex and difficult. It is most satisfactorily accomplished in specially equipped facilities by physicians with special skill and interest in dealing with trauma. However, persons who are seriously injured in traffic accidents often need immediate, life-saving attention at the roadside, and always they need knowledgeable handling as they are moved from the accident scene to a hospital.

There is a great need for more education among members of the general public in simple, effective roadside first aid. Probably some of the injured motorists who die at the scene of an accident would have lived had someone on the spot taken simple measures to relieve breathing difficulties and to control external hemorrhaging. Much suffering can be relieved by laymen who have been instructed in the most elementary first aid treatment for fractured bones.

It could be said that while early, careful removal of the injured to a hospital emergency room is mandatory, it is equally mandatory that good roadside management prevent imminent death if possible, and minimize further damage to body tissues.

The following principles are generally accepted as guide lines for good management. The first task for the on-the-spot team, whether lay or medical is to take what measures it can to ensure the patient's optimal breathing. The second task is to control obvious external hemorrhage. After these two priority tasks are accomplished, open wounds should be covered with sterile or clean dressings, if available, and fractures should be splinted. The injured person should lie flat as long as this position can be tolerated, although sometimes with chest injury, breathing is easier if the chest is somewhat elevated. In general, it is important not to flex the body either at the neck level or lower down the vertebral column. If there is a vertebral column fracture present, flexion may cause the spine to dislocate and damage the spinal cord, often irreversibly.

In moving first to ensure the free flow of air in and out of the lungs, the roadside first aid administrant should bear in mind some of the main ways that breathing can be obstructed.

Drivers and front seat passengers are more apt to sustain facial, head, and chest injuries. Facial and head injuries often result in the flow of large amounts of blood and mucus into the mouth and throat. There may be associated unconsciousness and, depending on the depth of the unconsciousness, there may be loss of the normal protective mechanism that normally prevents inspiration of mucus, blood, vomitus, or other fluids into the lungs. There is a great danger that these secretions will enter the larynx and descend to the lungs. If immediate death by drowning does not occur, there is severe and often irreversible lung inflammation from which death results later. Even if these materials do not enter the lungs, their accumulation in the back of the throat rapidly obstructs air flow. Also, in the unconscious state, the tongue may fall backwards into the throat, thus obstructing the airway; if there is a fracture of the jaw, this may occur more easily.

The most satisfactory way to clear secretions from mouth and throat is by suction, but since a suction machine will not be immediately available at the roadside, the first aid administrant must rely on gravity. If secretions are accumulating in the patient's throat, he should be turned on his side, the back kept straight. This position allows secretions to drain out of the mouth by gravity. If the chest wall is injured on one side, turn the patient to that side.

If the tongue tends to fall backwards, turning the patient on his side may also take care of that problem. If not, the tongue must be grasped with the fingers and pulled forward. I have been told that one way of holding the tongue forward is to put a safety pin through the tip and then to apply traction. It seems a rather painful way. It would be preferable to use a simple mouth airway and to hold the lower jaw pushed forward. Unfortunately, the passerby would not be apt to have an airway although airway tubes should be a standard part of first aid kits.

If there is continuing breathing difficulty, the chest wall should be rapidly inspected. There are two obvious chest wall injuries that prevent the back-and-forth exchange of air. The first is the large open wound of the chest wall, which allows air to enter the chest cavity through the wound hole each time the chest expands; air thereby fails to go down the windpipe into the lungs. Air exchange rapidly becomes inadequate and the patient is in serious trouble. The treatment is to close the open wound in the chest wall by applying a large dressing over the hole, thus preventing air entry.

The second type of chest wall injury that prevents air exchange is the multiple rib fracture. This injury allows the chest wall to flap back and forth as the patient tries to breathe. The flapping action prevents the creation of a negative pressure in the chest cavity during inspiration, which means that the lungs cannot expand. The treatment is to stabilize the chest wall where flail motion is occurring, by hand pressure, sandbags, or adhesive strapping.

Sometimes in breathing difficulty, especially with laryngeal obstruction, a tracheotomy is required. This consists of making a hole in the trachea or windpipe for entrance and exit of air. Tracheotomy, although at times life-saving, is often a difficult operation even with good conditions of lighting, help, and proper instruments. There is almost no place for this operation at the roadside and certainly it should not be done by unskilled laymen or physicians.

External bleeding, the problem to be attended as soon as good breathing is established, can usually be controlled by direct compression to the bleeding area. A sterile or clean cloth is placed on the wound and hand pressure is applied. I have seldom applied a tourniquet to control bleeding. Surprisingly, if large extremity arteries are completely severed, the ends sometimes contract and arrest bleeding for a time. Venous bleeding always responds to pressure unless clotting mechanisms are deficient, which is not apt to be the case in automobile injury. Once bleeding is controlled, the dressings should not be disturbed until the patient reaches the hospital because a secondary hemorrhage may be fatal.

Nothing should be done at the roadside except bandaging to prevent further bacterial or foreign contamination. If dressings or clean cloth bandages are available, apply these, without using any medications locally.

A broken bone is very painful and any motion, no matter how slight, accentuates the pain. Movement causes spasm of muscles surrounding the break, which causes shortening and distortion of bony alignment. Furthermore, a blow severe enough to break bone also tears adjacent muscle, blood vessels, and sometimes skin. Unrestricted movement of the broken ends of bone further damages soft tissue and increases internal or external hemorrhage. Therefore, it is important to apply splints at the roadside before transportation. Gentle steady firm traction on the limb beyond the site of break or distortion serves to overcome muscle spasm and permits the restoration of gross anatomical normalcy. If such correction of deformity can be accomplished and there is material suitable for a splint, the splint should be applied, maintaining traction. The inflatable splints that many ambulances carry are very good for this purpose and hold the broken bones and muscles firmly. The Thomas splint, which most ambulance attendants know how to apply, still serves well for major fractures of thigh or hip.

The patient, now breathing well, his external bleeding under control, and his broken bones in traction, needs transporting to a hospital.

Safe, gentle transportation is what is needed. It must be a rare case indeed where excessive speed is a requirement if the simple roadside measures I have described have been carried out.

For the next stage of treatment, a well-equipped hospital emergency room with an adjacent x-ray facility is a must.

At the hospital, it is important that one doctor coordinate management of the patient's injuries. Serious injury often cuts across areas of surgical specialty and it would be most confusing and undesirable to have each surgical specialist manage his area of interest without someone's considering the whole problem. Usually an experienced general surgeon makes the best coordinator. Among the first things he should do is remove the patient's clothes and rapidly examine the body, noting bruises, laceration, chest wall activity, and evidence of deformity suggesting fracture.

He should immediately assess the air-way problem. Secretions from the throat should be removed by suction and the chest wall stabilized if necessary. If it is apparent that there is upper airway obstruction, a tracheotomy should be performed.

The presence of pneumothorax must be looked for, a condition that most often is the result of a laceration of the lung, which allows an internal air leak. Sometimes this leak of air into the pleural cavity builds up so much pressure in the closed space of the chest that the lung cannot expand and the heart is pushed to one side, which prevents optimal return of blood to the heart. This condition, known as tension pneumothorax, endangers the patient's life and must be relieved immediately by removing the trapped air and arranging for its continued escape from the chest cavity so long as the lung air-leak persists.

It is important to ensure the control of external hemorrhage, and if this has been done at the roadside the compression dressings should not be removed until all is in readiness to resuscitate the patient if there should be further hemorrhage.

The blood pressure and pulse are immediately and continually monitored; a large needle is placed in a vein and blood is taken for type and cross-match; a saline drip is started in order to have a vein available for rapid transfusion.

Shock is a clinical syndrome frequently present in serious injury. The patient in shock is cold, sweaty, ashen grey in color, has a low blood pressure and a fast weak pulse. The presence of shock means that the tissues are not being adequately perfused with blood even though the heart is pumping faster than normal. Traumatic shock is always a manifestation of blood loss, which may be external and obvious, internal and hidden, or both. The body responds to the loss of blood by trying to maintain the flow of the diminishing blood volume to vital areas such as the brain, heart muscle, liver; to do this the small muscle-lined arteries in the gut area, kidney, extremities, and skin clamp down, thus attempting to let blood by-pass the open vascular bed of these less vital areas.

For a time a precarious balance exists and as long as the patient is not disturbed, the blood pressure holds up and vital organs continue to get sufficient blood. If in this precarious state something is done to promote further bleeding, such as permitting motion in unsplinted fractures or removing compression dressings, sudden collapse may result. Similarly, a precariously stabilized patient may collapse if he or she is suddenly or roughly moved. Apparently the small contracted arteries open up, thus suddenly increasing the size of the vascular bed for which there is now insufficient blood, and a fatal drop in blood pressure may result. Hence the need for gentle transportation and handling. If the injury is obviously serious, a blood transfusion must be started as soon as blood type and cross-match work is done; if shock is present, some blood substitute such as dextran must be given while awaiting the blood.

Nothing further can be done for the patient until the blood pressure is stabilized. This may take from two to five liters of blood.

During this time, nasal oxygen may be desirable, especially if there is any type of respiratory problem. Blood transfusion alone cannot resuscitate a patient if there is persistent uncontrolled blood loss. Hence, it is important to examine the patient for continuing internal hemorrhage; if such bleeding is considered likely, surgical operation to find and control the bleeding must be attempted as part of the resuscitation. Operating on patients in shock who have no recordable blood pressure is extremely hazardous but may be the only alternative at times.

Pain is not usually a major factor early after injury except for motion of unsplinted fractures. Patients in shock rarely complain of pain because the sensorium is usually dulled. If medication is required for pain, it should be given in small amounts (especially if there is associated head injury) and it should be given by the intravenous route. By all other routes, absorption is uncertain until resuscitation from shock is complete and normal blood perfusion of tissues is once again established. Seriously injured patients are not usually restless unless they are having breathing difficulty or are bleeding. It is more important to correct these conditions than to medicate for restlessness, but at times the administration of a barbiturate is helpful. All injured patients should receive tetanus prophylaxis as part of the admitting routine although care must be taken regarding possible sensitivity if passive immunization is used.

I believe also that all seriously injured patients should be given an antibiotic to discourage bacterial growth in contaminated areas during the time that tissue perfusion by blood is inadequate.

Death or survival from injury depends on so many factors that generalizations are not too helpful. However, there are two factors of special importance. The first is time lag. Usually a prolonged time lag between the occurrence of a serious injury and the start of medical care is associated with an increasing mortality rate. A certain number of seriously injured will die regardless of medical help; most of them die within the first six hours. For example, of 61 deaths studied by Gissane, 34 were instantaneous, 14 occurred within six hours, 3 others from six to 12 hours, and 10 after 12 hours. Probably most persons who were not killed instantaneously but died within a few hours were beyond medical help. The marginal cases who might survive with maximal medical care have a better chance to pull through if the time lag between the moment of injury to the onset of treatment is minimal.

The second major factor determining death or survival is the type of organs injured or number of injuries sustained. Most seriously injured patients who survive sustain from three to five separate injuries; statistical evidence suggests that fatality rate increases as the number of injuries increase. Obviously, a single injury to a vital organ such as the heart may be more lethal than several injuries to less vital areas.

Not all severely injured patients are in shock when they are first seen by the physician. Sometimes, as in the case of a ruptured spleen or brain blood vessel, there is no early evidence of impending trouble. For that reason, it is important to obtain for all patients, even the apparently well ones, a history of the mode of injury; a careful physical examination including baseline neurological observations should be made as soon as possible. If the history of the mode of injury shows that the patient may have sustained a forceful acceleration or deceleration, a blow, or blows, then he should be kept at the hospital under observation for perhaps 24 to 48 hours. During this time, if pulse, blood pressure, and blood count remain normal and no significant symptoms or signs appear to suggest internal injury, the patient may be released.

X-ray photographs of the patient must be taken following injury. Obvious fractures are, of course, confirmed and detailed by x-ray, but other sites where less obvious fracture might have occurred should also be examined. These areas include the skull, vertebral column, and pelvis. X-ray is important, too, in the evaluation of chest and abdominal injury.

In assessing possible brain damage, the history of the patient's state of consciousness, beginning with his condition immediately after the time of injury, is most important. Inquiry should be made on this point, and the patient's state of consciousness should be observed carefully thereafter. A baseline neurological examination is equally important; it should be documented and any subsequent changes should be recorded. It is the progressive changes in the state of consciousness and the changing neurological signs that often suggest the need for decompressive brain surgery.

Time does not permit a discussion of specific therapy for the many specific types of injuries. However, for the types of injury apt to be most frequently encountered by the surgeon, I would like to suggest the order of treatment priorities.

(1) The establishment of an adequate airway and the control of hemorrhage, both of which I have already discussed.

(2) The closure of perforations of the gastro-intestinal tract from esophagus to rectum. A continuing leak from the gastro-intestinal tract always leads to severe sepsis, which is often fatal. Therefore, these leaks must be looked for, sometimes by exploratory operation, and repaired when found. Likewise, lacerations in the gall bladder, biliary tract, and pancreas must be remedied early.

(3) The elevation of fractured skull depressions that may be compressing the brain. This has a high priority, but other types of head injury are less urgent.

(4) The repair of significant laceration of organs such as liver and spleen. Such wounds usually cause internal hemorrhage.

(5) The repair of kidneys, ureter, and bladder, if they require surgery.

(6) The repair or replacement by grafting of major tears in extremity arteries. This must often be done in order to save the arm or leg. In the treatment priority list, this item comes late since life must be saved before it is worthwhile to try to save the limb.

(7) The surgical treatment of large muscles with massive injury, and the sealing of open fractures. Debridement, or cutting away all crushed and devitalized tissue and foreign matter, is necessary if serious infection is to be minimized. The grossly contaminated wound is converted to a slightly contaminated wound that body antibacterial defenses can handle. Exposed bone must be covered by skin if serious bone infection is to be avoided.

(8) The closure of soft tissues lacerations, and the setting of closed fractures.

I would like to emphasize that treatment for the unconscious patient with brain injury can still follow the order of priority I have given. The brain injury can be ignored for a time. If death does not result early from massive brain injury, then the outlook is often good. Excluding depressed fractures and compound fractures of the skull, head injuries can wait until the other more urgent repairs have been made.

It must be remembered that even under the best conditions, with the surgical team doing everything it can, some patients cannot be saved from death. To succeed in salvaging a life and restoring a severely injured body to normal condition is often very difficult and may require weeks or months of healing time. If there should be a large rate of increase in the number of accidents, and a corresponding increase in the number of injured, the facilities of some of our hospitals will be taxed. Reducing the number and severity of motorists' injuries would release hospital space, ease the strain on emergency rooms, blood banks, nursing and medical staff, and para-medical personnel.

Reducing the number of injured persons who die needlessly because passersby have not been taught first aid and have no first aid supplies in their cars is a responsibility we must begin to face and begin to meet. I think the medical profession as a whole must participate in a program to educate laymen in giving effective emergency first aid at the scene of the automobile accident. Whether the medical profession has the prime responsibility to initiate such a program, I am not so sure. Perhaps a government agency should do the initiating and organizing.

DISCUSSION

Moderator, RAYMOND L. BISPLINGHOFF

C. T. VAN VECHTEN: Is the time lag between the occurrence of the accident and the arrival of the police officer or ambulance attendant significant enough, particularly in rural areas, to warrant doing something about it?

DR. BALCH: I do not have figures on the range of time lags or the average length of time lag between the accident and the appearance of the first persons able to give first aid. The lag probably varies a great deal; a significant delay would be detrimental to the injured person, especially in regard to the problems of breathing and bleeding. If persons able to administer effective help arrive within a very few minutes, and emergency measures such as I have described can be satisfactorily taken at the roadside, then there is no need for racing ambulances to take the injured to a hospital. What is needed is safe, gentle transportation to a hospital within a reasonable time and at a reasonable speed.

DR. HADDON: A documented study recently done by the California State Health Department shows that patients with exactly the same injuries have four times the probability of dying if those injuries occur in automobile accidents in a rural area instead of an urban area. The proportion of persons dying at the scene of the accident ranges from 90 percent in the rural situation to a very, very much lower percentage in the urban situation. Furthermore, most Americans injured in motor vehicle accidents in this country are not injured within close distance of a major medical center or medical school, according to the study. These are the realities of our traffic accident problem, and little is being done to improve the situation.

DR. BALCH: I am not surprised at these findings. They point up the need for more widespread education in simple, effective roadside first aid. Many persons who die at the roadside have suffered massive non-salvageable injury, but many others die as a result of airway problems or of uncontrolled hemorrhage. Airway difficulties and external hemorrhage can often be controlled at the roadside by a layman with a little training. Once those two vital problems have been attended to, the time lag before professional medical attention is available, although very important, is not vital for most injuries.

As for the high percentage of deaths from accidents in rural areas, I think another important reason may be the reduced likelihood of having available an excellent hospital emergency room staffed by people skilled in handling serious injuries. For certain types of injuries, good hospital facilities can determine whether a patient dies or survives. Significant internal hemorrhage, for example, requires early surgery and even then the salvage is not great.

DR. HADDON: Of course hospital facilities are important, but the study indicates that the primary problem is the treatment before rather than after arrival in the emergency facility.

MR. HAEUSLER: I am a first aid teacher as well as an automotive engineer. I am painfully aware of the fact that most people have no training at all in emergency treatment for the injured. I am also painfully aware of the fact that most ambulance drivers are really not well prepared to do an adequate first aid job at the roadside. Consequently, the steps that should be taken to save or relieve the injured person all too often are not taken. In view of the lack of effective help actually available to the motorist today, is there not a strong case for getting the injured person to the hospital with all reasonable haste?

DR. BALCH: Yes — all reasonable haste so long as it is reasonable. There must be very few who are salvaged as a result of excessive speed by ambulances. The emphasis should be on better roadside management.

CARL CLARK: How many medical schools are concerned with special training for medical personnel in the handling of the injured?

DR. BALCH: I cannot answer that. Can anyone here?

DR. HADDON: The answer I can give is by no means a definitive answer. I would suggest, however, that there is almost no adequate academically based program in this field. I mean a program covering the breadth of the field, not just the emergency care. There is no such program in any school of public health or in any medical school. Perhaps I have overlooked one in my haste, but offhand I don't think this has yet really entered the mainstream of either medicine or of public health.

MR. VAN VECHTEN: If the time gap between accident and the arrival of the first person who can administer first aid has a significant effect on survival rate of the injured, perhaps there is some use in doing a cost-effectiveness study on the various emergency call systems. The "help" system using citizen-band car radios is one system, but it requires a conscientious person to use it. If this shows promise of being very effective, I believe it is worth studying.

DR. BALCH: I would agree with that. It is desirable to mobilize medical assistance quickly after an accident. It is amazing how long one can sit at the scene of an accident waiting for an ambulance to transport patients to the hospital. For example, I not long ago attended an injured girl screaming in pain at the roadside. A crowd had assembled and four police cars were present. The accident was within 12 miles of a main hospital facility. I saw immediately, as any layman could have seen, that the left arm was grossly distorted and obviously fractured. Simple traction on the arm below the distorted area allowed me to twist the arm back into position. This relieved the excruciating pain instantaneously. However, it was a half-hour before the ambulance arrived with a suitable splint, and during that time I had to hold the arm in position by pulling on it. The mobilization of suitable transportation may take more than a radio call, which had been done early in the incident.

I would like to emphasize again that the roadside emergency measure I took was simple and could have been done by anyone with proper first aid training.

DR. HADDON: Can vehicle designers and manufacturers foresee the day when there will be means, automatic or otherwise, for sending out a call-for-help signal from the car as it becomes involved in an accident? In other words, a built-in signal that would call for the ambulance and police.

MR. HAEUSLER: I don't know that we have any work going on that is quite along that line. We do have the "help" program that Mr. Van Vechten mentioned. It simply provides citizen-band radios for as many cars as there are people willing to take part in the program. The radios have a range of five miles under adverse conditions and 15 under favorable conditions; they are two-way radios, which allows the motorist to call for help, indicating what the problem is, and the person who receives the call to report back what he has done about sending help. There are about a million and a half such radios in cars now. There are a great many people using these for the ordinary practical purpose of person-to-person conversation or calls to home or office. I have had occasion to use my own equipment about a half-dozen times, and in all instances except one (I was stuck in the mud) I used it to call for help for other people.

I have never had more than about two seconds delay at the most between the time I let my finger off the microphone button and the time someone who heard my call responded to it. The person receiving the call will telephone for the ambulance or the tow truck or whatever else is needed; then he will radio back to say what he has done, to indicate where help is coming from with reference to the caller's location.

The "help" system works rather well. One radio in one car, if the individual is willing to stop when he sees someone else in trouble, can provide help for a great many people. It is not a question of having a radio in every car, of course.

MR. HUDSON: It occurred to me that the signaling device Dr. Haddon suggested could be some kind of simple radio configuration or transmitter that would be activated by an impact. Then all that the police and rescue vehicles would need to do is zero in on the signal. There is a technical question, however: Is it feasible?

CLOSING DISCUSSION

MR. CLARK: What is the ratio of persons injured to persons killed in traffic accidents? This is one of the statistics that oscillates in some magnitude in the different counts made by different study groups. Perhaps the impressions that many of us get from numbers that the National Safety Council uses are wrong impressions. What is the true ratio of injured to killed? Do the figures include those, for example, who are injured in automobile accidents and do nothing about it, just go home and heal by themselves?

DR. HADDON: I can't shed as much light as I wish all of us could. As far as I know, there are several kinds of issues involved here. First of all, it is almost certainly correct that the ratio between these two is a function of the severity of the class of accidents under discussion. I don't mean to sound as though I am giving a circular definition, but if one were to take accidents of given physical severity in terms of the crash forces involved, there would undoubtedly be a shift in the ratio toward a higher fraction of fatalities per occupant exposed as those forces went up, other things being equal. I think, however, Mr. Clark was referring to the gross ratio on a population basis, and I suppose that we have to get our data from essentially two different places to get some sort of ratio for this. I think that the only adequately scientifically based source of injury data is the National Health Survey run by the Public Health Service and the Bureau of the Census, and the present annual totals under this, using a reasonable definition, and of course one's definitions make a difference, also, is somewhere between three and four million injuries a year. If one takes the death figure, I suppose there is relatively little difference of opinion as to exactly what it is. One can take it either from vital statistics or from police derived sources, which perhaps tend to be low, or the motor vehicle department sources, which tend to be low because they don't get the late deaths, and some of the secondary deaths. This comes out at present, of course, to about 50,000. So that if you put these two together you get a ratio that is considerably higher than the one you get if you take the National Safety Council injury totals and compare them with the death totals.

I am not really sure that I think that the exact figures in any one year make much difference. The issues are certainly clear. They would make a difference if they were sufficiently specifically defined, collected and defined and analyzed, so that we could use them to establish trends, but as you perhaps know, they have not been collected with such specificity, although they are perhaps beginning to be. Hence we don't have any trend information that is at all reliable in the injury area.

I will make one final comment, and that is that a lot of the injury figures which have been widely used are derived I believe by applying a standard ratio or complex set of ratios to the death figures, and that one therefore is deceiving one's self if one uses the results to suggest that there has been some change in this particular ratio.

MR. BISPLINGHOFF: From the numbers that I heard, and using my own mental arithmetic, the answer is 40 to 80 injuries per death. Is that about right?

DR. HADDON: That is probably about right, using reasonable definitions.

MR. HAEUSLER: In looking at the traffic safety situation as a whole, I think it is apparent that we already know a great deal more than we are benefiting from. Much of this information, while available, is not getting to the consumer from a neutral source. I would like to encourage the establishing of a supplementary education program for motorists already on the highway. They need to be informed about the many actions they can take and equipment they can use for their safety on the highways. Rather than thinking of driver education as something for our teen-age sons, we should realize that we need further training, too.

It would also seem entirely appropriate that after a legislature has set up a standard or a requirement, such as the one for seat belts, the government would send an information leaflet to the drivers that the new regulation would affect. The leaflet would explain briefly in simple language why the legislation was offered and passed, and what kind of cooperation is needed from the motorist in order for him to receive the intended benefits. It would explain that the seat belt must be worn down on the pelvic bones, tightened snugly and then tightened a little further in order to derive maximum protection. It would mention that locking car doors provides additional protection. Such an explanatory leaflet can be made simple and interesting — not a preachment. I believe an increasing number of people would pay attention to it and carry out the instructions. I hope we can see in the immediate future a continuing education program for the motorists already on our highways.

I would also like to suggest that we recognize that there are contributions the individual motorists can make toward improving the safety of the automobile. Designers can get a great deal of help from the motorist in regard to improvements in car safety equipment, and if any group of us as experts pushes him away and says, "We'll expert it," then proceeds to try to solve design problems from on high, we will miss our major national resource in this field. I am referring specifically now to what can be done with the car and the car's equipment. We should take advantage of interest and initiative and build them up among citizens; the steps citizens take to contribute will provide a great force insuring that more such steps will be taken in their interest.

MR. BISPLINGHOFF: Mr. Haeuslers' remarks point up two main questions: What conclusions can we draw from this discussion? What needs to be done in the future? As an interested non-expert in the field, I was much impressed by the shocking statistics of ten million accidents a year with some 50,000 deaths and two million disabling injuries. It seemed to me from our speakers that there are two areas of consideration: one, reducing the incidence of accidents; two, reducing the human damage in a given accident.

It seems to me that many of the things we were told indicated that we don't have very good statistics. I also have the impression that a greater uniformity of legal environment is needed, and that the legal environment has an influence on safety and on the accident statistics.

I was shocked to learn that we do not have much hope of correlating performance with psychological behavior as measured by present tests — although I was a little confused when our speakers also told us that chronic alcoholics, who comprise less than five percent of our population, account for some 30 percent of the fatal accidents. It seems to me that something could be done about keeping chronic alcoholics off the road, particularly if we are able to identify them through existing testing methods.

I gathered that there are many possibilities for vehicle and highway improvements that could have a profound effect on safety. This seems to require coordinated planning.

Dr. Nahum's discussion particularly convinced me that there is a certain virtue in surrounding one's body with large amounts of steel, perhaps three or four thousand pounds worth. As a driver of a small foreign car, I am certainly going to think seriously about this.

I get the distinct feeling there is some advantage in reducing time lag between accident and treatment, a need for more first-aid education, and a need for better education in medical schools in injury treatment.

One question I am wondering about is whether more research is needed, or whether we are dealing, in the first order, with political, organizational, and policy problems. What are the most important actions that should be taken?

HUGH MISER: I think we all agree there is a need for some kind of action. We would all agree probably that this action, when we get it — and it looks as if we are going to get it — should be based on perceptive knowledge. Judging from the facts brought out in this symposium, we also probably would agree that the state of our knowledge is somewhat inadequate, in spite of what is known, and in spite of Mr. Haeusler's comment that much of what is known isn't really being applied adequately. Taking the problem as a whole from Dr. Haddon's outline, we don't know as much as we need to know about many issues, including what research it is worthwhile to spend our money on.

I think a great deal more support for research must be forthcoming, but it must be decided what kind of research to do, how to deploy research resources in order to secure the most meaningful results in the national interest over the long term as well as the short. What, then, should we do? Should we spend our research money in small driblets and increase the number of highly competent groups that are working? Should we build some large empires, as has been suggested in a number of bills before Congress sponsored by government? Or should we do both?

I do not propose to answer such questions here. That would take another conference or two. What I say is that we in the research business should pay some attention to what the national research strategy should be, with something like a 20-year horizon. After all, the things we start today are going to be with us for a long time, much longer than 20 years. We should begin to think what national research strategy in the field of traffic safety should be, so that as we have specific issues to take up in the next weeks and months, our tactics in furthering our research goals will be tailored to the overall national strategy. I am speaking of the actions we can take in government, in other parts of the society, and as individuals to reduce the traffic accident problem.

I think the challenge to the National Academy of Engineering, and I hope also to the National Academy of Sciences, is to think about these two things — what the long-term strategy should be in research, and what short-term tactics should tie in with this strategy. Long and short-time planning will allow us to move forward with as little waste of effort as possible in achieving the goals we all desire. I think that is the challenge not only to these bodies, but to each one of us.