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FOREWORD

The papers in this RECORD were presented in one of the Special Anniversary Sessions developed as part of the commemoration of the 50th Anniversary of the Highway Research Board at the 50th Annual Meeting. They differ in some respects from the papers normally found in RECORDS in that the authors have emphasized an overview and a broad perspective of their particular subjects. These provocative papers will stimulate thought and activity among specialists and generalists in highway safety for some time to come.

Brenner highlights safety implications in 2 major areas, at least one of which may not be widely known. Although development work on experimental safety vehicles has received some popular notice, this discussion focuses attention on the potential for major safety improvement through rapidly changing technology. There is probably little popular awareness of the significant international contributions to safety being developed in several countries through the auspices of the NATO Committee on the Challenges of Modern Society. He describes these efforts in interesting detail.

In recent years major attention has been concentrated on the roles of the highway and the vehicle in safety, but some feel that not enough attention has been directed to the driver. Hartman begins with 2 central challenges related to development of driver-education programs and to driver-licensing and driver-control programs. By examining a series of succeeding challenges, he draws conclusions regarding research needed to allow authorities to influence these important areas related to human factors.

Vanstrum and Caples describe a newly developed perception model for dealing with driver involvement in highway accidents. The conclusions regarding research and countermeasures suggested by the model are exciting in their clarity and simplicity and can be very useful in selecting relative priorities for a variety of safety improvement programs.

The sponsorship of the Road User Characteristics Committee is recognized elsewhere in this RECORD, but special recognition is due Group 3 Council member Slade F. Hulbert for his vital role in development of the program for this Special Anniversary Session.

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SOME INTERNATIONAL ASPECTS OF ROAD SAFETY INVOLVING THE NATO COMMUNITY

Robert Brenner, National Highway Traffic Safety Administration

•FOR THE past year, it has been my privilege to serve on the U. S. delegation to the NATO Committee on the Challenges of Modern Society (CCMS). Road safety is one of the challenges adopted by this organization. I welcome this opportunity to describe the program to leaders of the highway research community.

Military defense and political consultation have been the 2 primary functions of NATO since its inception. Shortly after taking office, President Nixon proposed that a third dimension be added dealing with social problems of industrial society. The reasoning was this: If 15 of the most powerful nations of the world had learned to work together effectively on mutual problems of military defenses, could they not learn to work together effectively on mutual nonmilitary problems of the environment, health, safety, and well-being of all mankind, in the President's words, "to enhance our environments rather than destroy them"?

The North Atlantic Assembly adopted the President's proposal and created the Committee on the Challenges of Modern Society to bring this third dimension of NATO into action on November 1969.

From the start, the U. S. delegation to the CCMS has been headed by Daniel P. Moynihan, who has developed and enunciated the principles and purposes of this newest subsidiary body of NATO. In his address to the North Atlantic Assembly in October 1969, he said, "Just as advancing technology has given rise to the central social vision of our age, so also has it become the central problem of the age. In massive and dominant proportion, the things that threaten modern society are the first, second, third, or whichever order effects of new technology" (1).

What are some of the degradations to the environment, health, and safety caused by technology? The examples are, unfortunately, legion and include air pollution; ocean pollution; inland water pollution; compelling issues of nutrition, such as cancer produced in animals by chemical food additives as preservatives or diet fads; indiscriminate use of space in our cities; irreversible destruction of natural resources; irreversible destruction of natural beaches, for example, in California; color TV set that floods unsuspecting children with damaging X-rays as a concomitant to their seeing Captain Kangaroo or the Rose Parade in glorious living color; 55,000 people who die every year and the millions seriously injured in vehicle crashes; and the billions of dollars lost in the equally senseless destruction of property.

All of these are the results of technology, pure and simple. People do not die in vehicle crashes in countries where there are no vehicles; children's eyes are not damaged in front of TV sets in countries without TV. These and other serious degradations to the quality of life occur only in the industrialized nations that are impacted by technology. Created by technology, these degradations will be mitigated, if not cured, only by this same technology. With the degradations emanating largely from technological activity in the industrialized nations, it will have to be these same nations—at the highest levels of government—that will have to start the corrective forces in motion.

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We now can begin to see more of the rationale for this new, third dimension of NATO. To quote Moynihan again:

> NATO is unique. For almost two decades now it has carried on, at ever-increasing levels of complexity, a massive system of technology transfer. There has been no such sustained experience in the history of the world. If technology is the issue, NATO is uniquely the forum in which to raise it. Moreover, if the issue is one of pressing urgency, which somehow does not seem to command the attention it deserves, NATO is doubly appropriate, for here is an institution which year in and year out has been able to command attention and response at the highest levels of government.

Thus NATO as an important quorum of the industrialized world, with major experience and success in intergovernment transfer of technology for mutual problems of military defense and related political consultation, is uniquely qualified to spearhead the needed intergovernment transfer of technology for mutual problems in the defense of the world environment.

The thrust of the NATO effort is to command attention and response at the highest levels of government. Toward this end, a somewhat unique approach, suggested by the CCMS Chairman, Gunnar Randers, the Assistant Secretary General of NATO, has been adopted in which a single nation or pilot country assumes the primary responsibility for a given area of activity. It conducts the effort with its own resources, stimulates cooperation with participating countries, and prepares the reports to the CCMS. This pilot-country approach provides for single-country responsibility and leadership to promote more rapid action than usually is possible through multilateral responsibility.

In some cases, 2 countries share the leadership, but there is no major CCMS secretariat in NATO because most of the operational detail and expenses are met by the pilot countries. In effect, the NATO allies have divided leadership responsibilities, and each member nation cooperates with studies led by others even while it might itself be the leader of one or more efforts. It is interesting to note the wide range of pilot studies now being led by member nations.

Study Area	Pilot Nation	Copilot Nation
Open-water pollution	Belgium	Portugal, Canada, France
Inland-water pollution	Canada	France, United States, Belgium
Environment in the strategy of regional development	France	None
Scientific knowledge and decision-making	West Germany	None
Work satisfaction in a technological era	United Kingdom	None

The studies that the United States proposed and NATO approved include air pollution, with Turkey and West Germany; disaster assistance, with Italy; and road safety, nominally alone.

U.S. PILOT STUDY ON ROAD SAFETY

I say that only nominally are we without copilot nations in the road safety study because a number of member nations have assumed leadership in specific project areas within the overall road safety study. The division of workload is as follows:

Project Area	Nation
Alcohol driving countermeasures	Canada
Advanced vehicle inspection	West Germany

Project Area	Nation
Road-hazard identification and treatment	France
Emergency medical services	Italy
Accident investigation	Netherlands

We are now negotiating with other NATO countries for possible leadership roles in pedestrain safety, safety manpower development, and passive restraints. The United States is maintaining leadership in the experimental safety vehicle program that I presently shall describe in more detail.

In illustration, our discussions with Canada on its leading the alcohol driving effort culminated in the following plan:

1. Survey present research and action programs of NATO and non-NATO countries;
2. Develop a model program on alcohol countermeasures;
3. Present model program to international conference and obtain comments from all interested countries;
4. Survey state of the art on "hardware" items and their effectiveness in controlling the problems of drunk driving; and
5. Prepare a report, based on the foregoing, for submission to CCMS and thereafter to the North Atlantic Council recommending specific governmental actions.

Another example deals with our project on road-hazard identification and correction, which is being headed by France. The U.S. liaison role has been accepted by Charles Prisk of the Federal Highway Administration.

Another major thrust of the pilot study deals with our experimental safety vehicle program, which in many ways will put to the most severe test the fundamental hypothesis of CCMS, namely, that this forum can stimulate a significant exchange of technology among a major group of industrial nations. I presently shall describe this ESV program in somewhat more detail; but, here, let me outline the overall structure of the pilot study.

The pilot study comprises a series of projects largely selected from the topics discussed in various meetings with member countries. Each project is keyed to payoff analysis of countermeasures for governmental decision-making. Several projects will be undertaken bilaterally; several multilateral efforts have also been started. The United States, as the pilot country, is leading some projects in addition to the overall study; other countries are leading other projects. Apart from project leadership per se, all NATO governments are ready to participate in varying degrees on the exchange of information called for in the various projects of the pilot study.

All of the projects are directed toward stimulating government action because, although much safety research is still urgently needed, much is already known that can be placed into operating practice and start saving lives immediately. For this reason, the pilot study is oriented not to research as such but rather to government decision-making and action based on a full and open exchange of technology and operational experience.

To be successful, the exchange must be two-way; and, having accepted the responsibility for the pilot safety effort, the United States is most encouraged by the number of member countries that have accepted leadership roles in the various projects that constitute the pilot study. We anticipate that much of the road safety practices of member nations will aid the United States in planning and implementing its safety programs, even as the new U.S. safety technology is helping member nations in planning and implementing their efforts.

The pilot study as such is to end with the submission of a final report by the United States to CCMS in December 1972. It is neither conceived of as being nor intended to become some form of effort continuing indefinitely into the future. The end-point concept maintains as well for individual projects constituting the study. For some, the end point will be a sustaining unilateral, bilateral, or multilateral arrangement, and, once such an arrangement is working satisfactorily, the project will be terminated as a CCMS pilot study effort. In other cases, the project end point will be limited to a report submitted to CCMS with recommendations on permanent or sustained operations, which NATO of course can adopt or reject.

THE ESV PROGRAM

Thus, the heart of this NATO third dimension is to stimulate a significant exchange of technology among a major group of industrialized nations of the world. As I stated earlier, what might prove to be the severest test of this fundamental hypothesis is the experimental safety vehicle program. I accordingly will devote the remainder of my remarks to encapsulating some of the international aspects of this activity; a more detailed treatment is presented in another paper (2).

The concept of government sponsoring the development of experimental vehicles in which safety is the overriding design goal is part of the landmark vehicle and highway safety legislation enacted by the U.S. Congress in 1966. The substance of the program to date under this statutory requirement is as follows:

1. The United States has awarded a contract to each of 3 private companies—Fairchild-Hiller, AMF, and General Motors—for the design and construction of a prototype vehicle to meet or exceed levels of safety performance specified by the U.S. Government. For example, one of the specifications calls for full survivability of the vehicle occupants without serious injury in a 50-mph barrier impact or 70-mph rollover. Details of the design are left to the contractors who are to deliver to the Secretary of Transportation a prototype and backup vehicle that meets the safety specifications.
2. Upon receipt of the 2 complete vehicles from each contractor, the Secretary of Transportation will initiate a program of testing the safety performance of each design. A destructive test under high-speed impact of one vehicle of each design is part of the test program.
3. Based on the results of the comparative tests between the Fairchild-Hiller and AMF products, the Secretary will select one design and contract for the construction of 12 more vehicles of this design. These vehicles will then be used in an extensive test and evaluation program. Their performance will be compared with that of the GM product that is to be delivered to the Secretary 10 months after the products of the other contractors.
4. The results of the tests and evaluations of the safety prototype vehicles will then constitute the technical foundation for issuing new federal safety standards for all vehicles sold in the United States.

The basic goal of the ESV program is to stimulate through safety design of the vehicle as a complete system a quantum jump in vehicle safety performance over the incremental improvements that industry has always made in varying degrees in production vehicles from one model change to the next. Such progress by industry in introducing new safety features must be described as largely evolutionary, with successive improvements introduced only at rates compatible with factors such as sunk cost in tooling and the competitive position in the marketplace. The introduction into the market by industry of a vehicle that is completely new from the safety point is, in fact, comparatively rare. It is precisely to circumvent the constraints inherent in the marketplace and similar considerations, which largely preclude a quantum jump in vehicle safety design by industry, that government sponsorship of ESV's becomes important.

In addition to producing the quantum jump in safety performance, the ESV program has other major purposes. For example, it can mean a reduction in the price the consumer pays for cars having higher levels of safety performance. We strongly believe that the combined effect of a group of safety improvements on the price the consumer pays for the final product will be substantially lower if most of the improvements are designed into the vehicle as a total integrated system from the start rather than as a sequence of add-ons to a basically unchanged vehicle design.

In ESV developments, automotive designers have unique opportunities to develop innovative, low-cost solutions that incorporate all safety requirements into the vehicle at once and yield high levels of safety performance in the end product as a total system. They can optimize and suboptimize the performance and cost of various subsystems of the vehicle that they deem appropriate to meet or exceed the performance requirements of the complete end product. They can establish priorities among all candidate safety improvements, priorities that might not be the same for classes of vehicles either large or small. In short, within the disciplinary constraint of having to design and construct a complete vehicle, designers are afforded the opportunity, in fact, are forced, to make the trade-off analyses among safety improvements.

Still another underlying objective of the ESV program is to examine how a comparatively large number of safety requirements for vehicle subsystems can be consolidated into a smaller number of standards dealing more with the vehicle as an integrated system. For some time we have been concerned about the increasing number of individual standards that collectively will define the safety performance of the total car. We now have in effect some 31 vehicle safety standards, and approximately 170 new standards, changes, or additions to existing standards now under development. Increasing the number of standards is not a good approach from either the engineering standpoint or the effect on vehicle price. We much prefer to move over the next several years in the opposite direction, that is, toward a fewer number of standards that treat safety performance of the total vehicle as a complete system.

Consolidation of safety requirements into a fewer number of standards dealing with the safety performance of the vehicle as a total system is an almost axiomatic concept, but one that as yet has not been tested as a viable approach to government regulation of production vehicles sold to the general public. The ESV program provides an important first step toward validating this principle. One of the key questions that we will be carefully appraising in the ESV program is, How well does the performance of the prototype vehicles overtake the safety standards that are in effect or under development for production vehicles?

Another potentially important benefit from the ESV program also has recently emerged. During the course of our negotiations with various foreign governments on the ESV bilateral agreement, the issue of whether the consent decree in the government's antitrust action in California on manufacturers' cooperating with each other in research in exhaust emission control also applied to safety in the ESV program. We now have a legal ruling to the effect that, in the course of participating in an ESV program with the U.S. Government, the company-to-company exchange and cooperation in research is permissible provided that the government is represented or aware of all transactions. We are particularly interested in developing this new mode of communication between industry and government on the technical issues.

It can be seen that the various reasons for the ESV approach apply to all classes of vehicles. However, the initial U.S. effort has been limited to the 4,000-lb family sedan for several reasons: this class of vehicle predominates on U.S. roads; the incorporation of new safety improvements, especially in the protection that the vehicle affords its occupants in crashes, is less difficult in larger cars than in smaller cars; and ESV programs are inherently expensive from all standpoints—dollars, engineering manpower, and time.

The United States is nevertheless most interested in the development of prototype safety vehicles in the smaller size and weight classes. Although the nearly 5 million vehicles in the under-2,000-lb class represent 6 percent of the total vehicle population in the United States, they are involved in slightly more than 10 percent of all crashes producing serious or fatal injuries. Furthermore, a very strong association has now been firmly established between the weight of the car and the percentage of accidents in which there was a fatality or serious injury in that type of car. For vehicles in the 4,800-lb class, this figure is 3.1 percent and rises to 4.0 percent for 3,700-lb vehicles and 9.6 percent for 1,900-lb vehicles. Thus, the vehicles in the 1,900-lb class have a morbidity-mortality crash incidence more than 3 times that of the 4,800-lb cars.

In addition to safety considerations, our interest in small-sized ESV's bears heavily on the economics of providing safe, personal transportation for low-income groups. One analysis shows that the cost of small-sized cars now priced around $1,800 in the United States will increase by more than 40 percent in 1975 from 1969 levels because of U.S. safety and antipollution standards. This would mean that an $1,800 (Renault, VW, Gremlin, or Pinto) car would cost $2,400. This 40 percent estimate probably does not reflect all of the rule-making actions (new standards and amendments) that we now are developing. It is unmistakably clear that, if these cost data are correct, we might be on a course that will ultimately drive the low-cost, economical car out of the U.S. market. This is an end result that our government considers undesirable from every standpoint—transportation cost, fuel consumption, highway capacity, parking space, air pollution, and provision of personal transportation for low-income groups.

It should be noted, however, that these estimates result from adding the cost of each improvement to the price of the car incrementally. The need for an ESV approach to small-car safety is apparent, particularly in the difficult areas of cost-safety trade-off analysis. Let me offer this hypothetical example: Consider that 2 safety improvements have been perfected. The first is a high-performance braking system with computer-controlled sensitivity to impending skids or crash impacts, and the second is a structural configuration that would enable occupants to walk away unharmed from a 70-mph crash. Either improvement is feasible within the size, weight, and price constraints of a 2,000-lb vehicle, but both are not. The choice, therefore, is either improvement but not both. In this type of trade-off situation, I would choose the structural improvement for the lightweight car because the braking performance of at least some small cars is already quite good while structural crashworthiness is not. On the other hand, I might choose the braking improvement for heavier cars because the reverse is true.

As difficult as such choices might be in an ESV development program, they are much more difficult, but nonetheless inexorable, later in designing for production vehicles. The ESV program thus might be the forerunner to different safety requirements for different classes of vehicles. Moreover, with such decisions being made in parallel small- and large-car ESV development, we might be laying the foundation for a new approach to vehicle safety regulation, namely, one in which priority safety requirements might vary between different classes of vehicles—for example, between large and small vehicles.

Thus, while we have had to limit our ESV program for the reasons cited to the 4,000-lb ESV development, similar programs in the 3,000; 2,000; and even 1,500-lb family sedan classes are also of major importance to us. The need for broadening the base of ESV development is patently clear. In this regard, in February 1971 at the first technical meeting of the U.S. Pilot Study on Road Safety for the NATO Committee on the Challenges of Modern Society, we proposed that our 4,000-lb ESV developments become the foundation of a broad program of international cooperation among nations, each of which would be sponsoring ESV developments in parallel with the U.S. effort. Since then, it has been my privilege to discuss this program separately with government and industry officials of every NATO country having a major automotive industry. I have also had similar discussions with representatives of Sweden and Japan and their industries.

On November 5, 1970, the U.S. Secretary of Transportation and the Minister of Transport of the Federal Republic of Germany signed a bilateral agreement under which the German Government supported by its industry will develop a 2,000-lb ESV and exchange information and technology with the U.S. Government in our current 4,000-lb ESV program. On November 18, 1970, the U.S. Secretary of Transportation and the Minister of International Trade and Industry and the Minister of Transport of Japan signed a similar agreement.

Intensive discussions are now in progress on similar bilateral agreements between the United States and France, the United States and the United Kingdom, and the United States and Italy. A meeting to exchange viewpoints on the specifications for this class of vehicles will be held in Paris under the sponsorship of the French Government in conjunction with the Renault and Peugeot companies. Although the thrust of the meeting centers on U.S.-Germany-Japan exchanges, the other nations and their industry representatives will participate fully in anticipation of bilateral agreements being completed soon with the United States.

I will not detail fully all aspects of the cooperative international program, but let me briefly list some of the general activities that we plan to pursue:

1. Transmitting all engineering and technical data that the U. S. Department of Transportation has developed during the past 3 years with regard to the program definition phase of the ESV procurement;
2. Meeting with foreign automotive engineers so that they and U. S. Department of Transportation engineers can exchange information on the ESV program;
3. Making available to the participating governments and their automotive firms selected to design the ESV all engineering and technical data developed in the U. S. ESV program;
4. Arranging for the interchange of data among all countries involved in the development of the ESV; and
5. Providing for such other technical assistance to the participants as may be required.

One of the many issues to be resolved in order to have an international effort of this nature work relates to preexisting patents as well as new patentable ideas that may evolve. We have communicated U. S. patent policy in this regard to every government that we have invited to participate in this effort. We recognize, however, that patent laws vary among countries. For this and several other reasons, our approach has been to reach a separate bilateral agreement with each country that is prepared to sponsor an ESV program in cooperation with the United States. Significantly, our agreements with both Germany and Japan call for strong cooperation with other governments that later choose to sponsor ESV developments.

To digress, the question arises as to the participation of Japan, which is not a NATO member, in this program. Recall that the United States is the pilot country of the study and is solely responsible for its report to CCMS. Under the CCMS arrangements, the pilot country is largely left to its own devices as to how it obtains the relevant operational experience and otherwise collects the information that it finally includes in its report on technology transfer in this problem area. The agreement is between Japan and the United States, not between Japan and CCMS. However, the United States on its own initiative can extract from the results of its cooperative efforts with the Japanese whatever lessons (or problems) are appropriate for inclusion in its report to CCMS. The pilot study is examining the process of technology transfer even while the substance of technology transfer is occurring in the separate bilateral arrangements.

In initiating these agreements with the German and Japanese and, it is hoped, with the Italian, British, and French Governments, we are most cognizant of formidable obstacles that can prevent as free a flow as we would hope to achieve of new automotive technology across all boundaries of the industrial world. These obstacles include the proprietary rights of private manufacturers who discover new technology of vehicle safety performance or the favorable trade balance sought by all countries. We recognize the stimulus to discovery provided as a consequence of protecting legitimate self-interests.

We also recognize the urgency of the need to pool our technology in vehicle safety and to find effective ways to accomplish this transfer. If, as miraculous as it would be, an absolute cure for cancer were discovered somewhere in the world, I am sure that it would move most rapidly across corporate and international boundaries. Our challenge is to find ways to stimulate a similarly rapid flow of the automotive safety breakthroughs across corporate and international boundaries.

CONCLUSION

I would emphasize that the technology of road safety, especially in vehicle design for safety, is changing very rapidly. In fact, it is changing so rapidly that some of us are now cautiously speculating that, spearheaded by the ESV program, a generation of vehicles might be at hand in which the chances of a vehicle occupant being killed or seriously injured in a 50- to 60-mph crash will be almost nil. This technology might be producing what for a substantial part of the traffic death and serious injury problem would be the analog of what the Salk vaccine was to the polio problem. I might add that the vehicle crash—as the No. 1 killer of our youth—has been producing more than 20 times the death tolls that polio ever produced in the worst epidemic years. This brings to mind that it was not many years ago that no solution was in sight for polio.

We know that we are on the verge of breakthroughs that can eliminate the traffic crash as the No. 1 public health problem of our young people in the United States. With these solutions in sight, what we are striving to accomplish in effect is what medical profession and health scientists have been doing for years. This is to expedite the flow of effective countermeasures to public health problems across international boundaries.

We are confident that, with NATO bringing the collective strength of this important quorum of industrialized nations of the world to bear on traffic and other challenges of modern society, this transfer of responsible technology will occur more rapidly. As a result, the day will come much sooner when all mankind looks back on traffic deaths as memories of irresponsible technology in uncivilized societies of the past.

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RESEARCH CHALLENGES IN DRIVER EDUCATION AND DRIVER LICENSING

Charles H. Hartman, National Highway Traffic Safety Administration

•WE ARE all aware of the reality and the enormity of the problem that we face in highway safety today. I need not review the statistics that illustrate the magnitude and the seriousness of the highway safety problem in terms of the losses in lives and property sustained each year across this country. The national 2 percent down-turn in lives lost through highway crashes in 1970—about 1,100 fewer deaths in 1970 than in 1969—is heartening but scarcely provides an opportunity to relax our research and program efforts.

Some will argue that driver education, driver licensing, and other aspects of the precrash phase of a total loss-reduction plan hold little potential. Indeed considerable attention and emphasis must be given to the crash and post-crash phases in order to reduce the frequency and severity of injuries sustained in crashes that do occur; this was not widely accepted until recent years.

The precrash phase deserves research and program attention as well. All crashes averted in the first instance represent a gain for the entire loss-reduction program. Driver education and driver licensing represent potential payoff areas of considerable magnitude provided that appropriate research and program challenges are identified and met. I hope to identify some of these challenges in this presentation.

As a base I suggest two central challenges: (a) to develop through research driver-education programs that will enable the states to prepare safe, effective drivers and (b) to develop through research driver-licensing and driver-control programs that will enable states to identify and control drivers who, for whatever reason, are a hazard to themselves or others on the nation's roads.

Our orientation and our efforts should be responsive to these central challenges. Our research must be directed to provide the scientific and technical basis that will enable the states to meet these challenges. One thing is clear: The highway safety problem is a "here-and-now" problem, and the programs in education and licensing are programs that are in operation now. This leads to other challenges that are discussed in the remainder of this paper.

CHALLENGE 1

The challenge is to make certain that research efforts in these areas provide useful answers to the programs with which they are concerned.

For many understandable reasons, it is easy for researchers to get sidetracked onto questions that, however interesting they may be or however far they may advance the frontiers of science, produce no useful output for the programs that they are intended to support. This is not to say that we should not pursue research that has long-term payoff. Clearly, such research is needed in a balanced program. The challenge is to keep an appropriate portion of our research effort relevant and useful. Our response to this challenge must be a continual soul-searching and frank self-evaluation in answer to the question: Does this research have payoff potential in terms of solving real problems in existing or contemplated programs in driver education or licensing?

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CHALLENGE 2

The challenge is to build the required base to determine the payoffs of driver education and driver licensing and, at the same time, to provide vital, near-term products to improve ongoing programs in these areas.

The establishment of a base on which to build and demonstrate the highway safety benefits of driver education and licensing is not something that can be done on an overnight basis. I shall presently describe research to analyze the driving task and to identify its elements; this project is an essential building block in our program. It is also fundamental to note that effective data systems are necessary to give us essential information. Tools and techniques must also be developed that will enable operational personnel in education and licensing to render objective, valid measurements of driving proficiency, in terms of both driving safety and driving effectiveness. Clearly, all of these are needed before we can really measure the effectiveness of driver education or licensing with any precision.

Nevertheless, we cannot duck the issue that driver-education programs and driver-licensing activities are operating in every state today. Thus, while we conduct the complex and detailed research necessary for scientifically valid advances, we must also provide key personnel with the information they require to plan and upgrade their current programs.

Our answer to this challenge is straightforward. Initially, we must use what we have. We must consolidate the existing knowledge, which is sometimes based on no more than "expert opinion." Such opinion may ultimately be proved sound through research. Until that time, however, it can only be regarded as our best guess.

With this consolidation as background, we can perform analyses that will enable us to specify (and pass on to the state program personnel) the first step forward in an iterative process that will eventually allow us to increase significantly the cost-effectiveness of education and licensing activities. Let me given an example.

The analysis of the driving task that I will describe in greater detail later is extremely valuable to researchers; it also has substantial value for program people, who will now have an inventory list with which to work. This will enable them to ask questions such as, What fraction of the total driving task is being taught by my state's driving-education program? It will also enable license examiners to have a better picture of how much of the driving task is tapped by the written and road tests.

Obviously, each research project cannot be molded so that it can yield products that will be immediately useful to state program operations. Nevertheless, if in the planning stages of all research we consciously seek to maximize the useful output to ongoing programs, major benefits will be realized on the near-term basis; and the programs will, themselves, evolve more gracefully and easily toward their ultimate form.

It should also be obvious that, if current programs need near-term answers, we should be able to support all the research that can provide such answers.

CHALLENGE 3

The challenge is to convince legislators that adequate financing is needed and is justified to fund research that will upgrade ongoing programs in driver education and driver licensing.

This country spends more than $0.25 billion each year on its driver-education and driver-licensing programs. Yet in 1971, the federal research budget was such that the National Highway Traffic Safety Administration could allocate $600,000 for research to support these program areas. Even if the total amounts spent by the states for research were added, I would suggest to you that this amount of money is simply not adequate to upgrade ongoing major national programs. Aggressive research in these areas not only is needed but also has, ultimately, high payoff potential for all involved. We know, for example, that the U.S. Coast Guard loses many more man-days to the highways than it does to the high seas. Similar problems face industry. Insurance companies surely would like to minimize the amounts they pay out to hospitalize and heal and even to bury casualties of traffic accidents. Funds needed for research and development of these programs should be increased as an investment in program improvement.

CHALLENGE 4

The challenge is to determine the effect of driver education on subsequent driver performance and, at the same time, to upgrade the cost-effectiveness of these programs.

In large part, the impetus and the direction of the Administration's research programs in driver education (and also driver licensing) have been influenced by the Moynihan Report. Indeed, the challenge that I cited is a paraphrasing of a criticism offered by the Moynihan Report: There is no scientifically sound evidence that shows that driver education provides significant benefits that in any way justify its cost. Clearly, we cannot take refuge in the companion statement of the Moynihan Report, which stated that there is no sound evidence to show that driver education does not do any good. In the National Highway Traffic Safety Administration, we have taken what we feel is a constructive, positive orientation in answering this challenge. We simply cannot afford to take the risks of curtailing all driver-education programs until they can be thoroughly researched. We are, therefore, moving to develop the data base, the controlled conditions, and the measurement techniques that will enable us accurately to depict the effects of driver-education programs. At the same time, we cannot in good conscience fail to explore and implement promising new teaching techniques, technology, and various devices and facilities proposed to improve training effectiveness. Admittedly, it is more difficult to show the effects of driver education if driver-education techniques are continually being modified. Nevertheless, we can and we are establishing controlled exposures to various driver-education techniques under the circumstances where we can also obtain fairly complete data during a number of years to ascertain the effectiveness of these techniques.

CHALLENGE 5

The challenge is to establish controlled field research projects in education and licensing and to develop a system to gather and retrieve criterion data.

Obviously, we must have some means at our disposal for testing the effectiveness of different methods of teaching and of different devices, such as simulators, for use as teaching aids. To make such comparative evaluations, we must have at our disposal some means for controlling exactly what is taught and what devices are used for teaching. We also must have some means to obtain valid records of the subsequent driving performance of individuals educated by the use of various techniques. Until this is possible, we are left in the same morass that the Moynihan Report noted when it indicated that there was no good evidence to show the effectiveness of driver education in the United States. Similarly, the same controlled exposures in the same follow-up of road records must be available to assess the effectiveness of various improvements in modifications to licensing process. The National Highway Traffic Safety Administration is trying to answer this challenge in 2 programs, one in driver education and one in actual record collection.

In the first of these, we have a joint program with the U.S. Coast Guard at its Cape May Training Center. Here we are using a specialized research team that is teaching selected driver-improvement techniques to coast guardsmen entering the Cape May facility. Most of the recruits will receive this training, but a randomly selected group will not. In this way, we will have a comparable control group, against which we can compare the effectiveness of the techniques used. Special provisions have been established to acquire accident and violation reports during the recruits' entire enlistments. Clearly, with this real-world laboratory, we can assess the benefits of this training exposure as well as compare the relative effectiveness of different techniques.

When we know what types of data should be collected and when we have resolved the question of control groups, we will be able to approach the various states and solicit their cooperation in a joint program where the results of this program would be extended to a high school setting.

We are working on means to upgrade the quality of accident investigation and to increase the reliability of reporting, retaining, and retrieving data. This is essential if we are to evaluate the effectiveness of any of our safety countermeasures. One glaring lack in the data that are collected currently is the identification of the at-fault driver. Ideally, for those accidents that are caused by driver error, we would like to know and be able to retrieve exactly what the driver error was. Obviously, this kind of information has great significance in pointing our education and licensing programs in more effective directions.

CHALLENGE 6

The challenge is to achieve a consensus on the makeup of the driving task.

We cannot make definitive statements concerning exactly what to teach in driver education or what to examine in assessing student performance or what to measure in driver licensing until the driving task has been clearly and completely described and all of its elements are identified.

The lack of this consensus was very pointedly brought home to us by initial studies, which the Administration supported, to define the status of driver education and licensing. As a result, we undertook a program in early 1969 to analyze the driving task and to develop a taxonomy of its elements.

The task analysis was built on a consolidation of past work combined with the detailed systems analysis of the driving task. This product was subsequently reviewed and refined by a multidisciplinary team, including specialists in driver education, driver licensing, and human factors. The task analysis is extremely valuable to researchers. It also has substantial value for program people, who will now have an inventory list of critical tasks with which to work. These can be used to determine (a) which driving task elements are taught in the state's driving-education program; (b) what driving tasks are tapped by the written and the examination road tests in licensing; and (c) which driving-task elements can be presented in simulators or ranges.

As these examples indicate, we plan that this taxonomy of driving-task elements can be used, in its present form, as a basis for evaluation and improvement of driver-education courses, of the licensing process, and of devices and facilities used in these programs. As additional data are made available as a result of its use and its evaluation, the task analysis will be validated and updated further, improving its usefulness to the states and their program development.

Within the past year or two there has been new direction shown in the area of driver-education curriculum development. The Automotive Safety Foundation's Driver Education Curriculum Study and Development Project, the several state curriculum guides (e.g., Illinois, Maryland, Massachusetts, and Colorado) that have spun-off from the ASF project, and other similar ventures have brought a new rationale and system to driver-education curricula. When combined with a scientifically derived driving task analysis, the day should be close at hand when instructional programs will be based on more relevant content and presented in ways permitting a higher order of measurement and evaluation.

CHALLENGE 7

The challenge is to develop objective criteria for safety and for flow.

The basic challenge in establishing criteria for safety and flow is not in defining what they are but in obtaining useful measures that relate to an individual driver and that can be used to support the basic program objectives already discussed. Clearly, crashes, particularly those involving fatalities and bodily injuries, are easy to establish as an ultimate criterion regarding unsafe drivers. Traffic volume as related to highway capacity is also a reasonably clear criterion of flow. However, because of the infrequency of accidents and the unreliability of the all-too-few data that are reported in the event of an accident, most accident records are currently unsatisfactory for use in judging the effectiveness of an individual's education or licensing. Even with good accident records, we would still need some index of driving safety that we can use without having to wait the months and years necessary to obtain a reliable accident index on an individual. In addition, we simply have no generally accepted, valid measures to assess how effective a driver is in terms of his contributions to the flow of traffic.

In terms of the first area, we have been trying to improve the accident investigation and records system. Multidisciplinary teams have been established throughout the country to conduct in-depth studies of highway crashes. State driver-licensing files are being updated and automated, and this should help in the analysis and retrieval of accident-related information. Indeed, the automation of driver-licensing files has accounted for about 20 percent of all 402 funds expended to date. Utilization of the combined effects of these systems and research efforts should improve our understanding of accidents and help refine the measurement of the accident criteria by relating it to causative factors.

If we are to use accident data as an ultimate criterion for determining program effectiveness, we must improve the reporting of these accidents. Many studies have shown that there are definite biases in accident records. One recent study indicates that females, middle-aged individuals, professionals, and semiprofessionals report only one-third of reportable accidents compared with other groups that report two-thirds. There is, therefore, a need to consider ways of improving the reporting of accidents if we are to use the data to measure effectiveness.

However, because an accident may never occur during the life of some drivers, intermediate criteria of driving proficiency must be developed and be predictive of such potential occurrences. The infrequency of accidents, their low correlation with traffic citations, and the absence of such measures during assessment of an individual's performance in driver education and licensing dictate the need for intermediate criteria. Obviously, to be valid, these measures must relate to the ultimate criteria of traffic accidents or flow data or both.

Intermediate criteria are needed and are being developed for on-the-road performance as well as for performance in the classroom, in simulators, and on ranges. A comprehensive study of on-the-road driver performance is currently being performed by Michigan State University. The focus of the study is the identification of behavior that is indicative of safe and unsafe drivers. Clearly, the real test of the validity of such intermediate criteria will be the extent to which they predict (or are indicative of) subsequent real-world, on-the-road driver performance. Once these intermediate criteria have been developed, we must have or develop practicable means for operational personnel to measure driving performance reliably and validly.

CHALLENGE 8

The challenge is to develop useful, objective, valid measuring techniques and tools to assess driving proficiency.

A critical step toward improving driving proficiency is the placement of cost-effective means of measurement in the hands of education and licensing specialists. Such means may be provided by new or refined techniques or by new or refined tools. For example, we may find that observing the behavior of a driver at an intersection is a good intermediate criterion of safety performance. However, unless we can also develop a technique (or tools) that will enable a reliable measure of this behavior, the technique will not be useful or valid. The word "reliable," in this case, simply means the extent to which 2 independent observers will rate a particular segment of driver behavior in the same way. A number of techniques can be used to increase the reliability of such measures. These include simplifying the measures, making them more objective, using special instruments to sense and display the values measured, or developing automatic devices that sense, display, and record the values of interest.

Of course, the most difficult task for both the educator and the license examiner is to determine, by observing an individual driver's performance, when he is competent to enter the traffic system or whether he requires additional practice or training at skills in which he is deficient. If either of them is to do this, he must have valid and reliable techniques and tools at his disposal. The program at Michigan State University is intended to provide just such techniques for making these assessments.

Parallel activities are concerned with developing and using instrumented vehicles to obtain the kinds of objective, reliable measures of driver performance to which I referred earlier. Of course, the variables we measure must also be shown to be valid. The capability of an instrumentation package that can record in a vehicle a variety of variables has vast potential for education, for licensing, and for research. For education, it can be used to provide both the student and the instructor with unbiased, objective, accurate feedback about the student's performance, and we know this will accelerate learning. For licensing, it will provide an unbiased, objective recording of performance to assist the examiner in his determination of whether he is willing to allow a driver to be licensed. For research, it provides objective, accurate data in a form that can easily be analyzed with EDP equipment and thus free the researcher from a very time-consuming and noncreative element of his work.

CHALLENGE 9

The challenge is to identify the most appropriate roles for various devices and facilities in the education and licensing process.

At the present time, a wide variety of simulators, ranges, instrumented vehicles, skid pans, and other specialized facilities and devices are being used in research, education, and licensing activities. Further, the state and the federal governments are continually being solicited by manufacturers who feel that their new devices and ideas offer additional advantages not contained in the present generation of facilities and devices. Many of these devices are very expensive and, as such, could represent extremely significant commitment of funds for most programs to purchase, operate, and support them over the years.

The Administration is meeting this challenge by undertaking a program to assess, first on an analytical basis and then on an empirical basis, the utility of many of these devices as training aids. We are carefully examining the potential utility of simulators, ranges, instrumented vehicles, and other devices as teaching aids. The extent to which the skills learned on these devices are transferred by the student into the real-world driving situation will be the ultimate measure that will be employed to determine their effectiveness. At the same time, our joint program with the U.S. Coast Guard will provide a unique opportunity to determine, in a carefully controlled field research situation, the utility of various driving range configurations, and even the utility of any range exposure at all, when measured against long-term driving performance records.

In the field of driver licensing, several state programs are designed to determine the utility of simulators in the license-examining process. For example, Project METER in the state of Washington was an evaluation of the usefulness of computer-based "simulators" for driver-knowledge and driver-performance testing. Project DRIVER conducted in Oklahoma represents another program concerned with evaluating automated devices in the license-examination process. The current studies in North Carolina on the application of instrumented vehicles represents another approach to measuring driver proficiency in the licensing process. Based on these programs, and others like them, the role of various devices will become more clearly delineated, and suggested guidelines will be prepared for their incorporation into the licensing procedure.

CHALLENGE 10

The challenge is to define the relevant data set that must be gathered in the licensing process.

In their current licensing activities, all states collect a variety of data that describe their driving populations. In addition to serving the screening function, these are frequently used as the basis from which predictions are made concerning an individual's anticipated driving performance. Clearly, if this process is to be effective, we must assure ourselves that we collect the relevant data, that we make provisions for adequately storing and updating the data, and that we have an effective means for assessing or retrieving the information when required.

With these goals, the National Highway Traffic Safety Administration undertook a program in 1969 to define what biographic, demographic, and medical data should be collected during the licensing process, to determine the most valid sources of these data, and to recommend appropriate storage and retrieval systems. This program has been completed and guidelines have been made available to the states. We must, of course, realize that this set of guidelines is the first product of an iterative process. It reflects expert opinions combined with the latest research data available. As we improve our accident data stores, we will be able to refine our specifications of licensing data to be stored, so that the stored information will be of greater value, both in diagnosing and in predicting, to license program personnel.

Another project we are funding seeks to define the requirements for visual tests during the licensing process and to recommend a standardized technique for their administration. We are also supporting an effort to develop an improved standardized driver-knowledge test. This is being undertaken by the University of Michigan to form a national data bank of knowledge items. The intent is to develop effective knowledge-testing procedures for screening, diagnosing, and educating applicants. A key element in this study is the application of knowledge requirements identified by the driving-task analysis. Early findings of the study indicate that questions about many critical driving tasks are not in current licensing examinations.

Objective measures of road performance are being obtained by using instrumented vehicles in work by Campbell in North Carolina. These studies will systematically determine the correlation between objectively measured performance of both young and old drivers and their subsequent driving records.

All of these classes of information will be validated against appropriate measures of driver performance and records. The California research program, in which knowledge tests were administered only to a portion of the renewal applicants, should help to determine what contribution, if any, is made by "knowledge tests" to predicting driver performance.

Once we have designed techniques to assess acceptable driving performance, we must then develop techniques to identify problem drivers and techniques to improve their performance on the highway.

CHALLENGE 11

The challenge is to make license enforcement activities more effective.

The ultimate control that any state can exercise over its drivers is that the state can, and will, revoke a driver's license if the driver demonstrates a driving record that indicates he represents an unreasonable threat to his own safety or the safety of others. Although accurate data are nearly impossible to obtain, it is suspected that a significant percentage—some estimates are as high as 60 percent—of the drivers who have had their licenses revoked or suspended operated a motor vehicle on public roads during the period of their license suspension. Clearly, if we cannot enforce the requirement that all drivers must possess a valid, current operator's license, the effectiveness of the threat of suspension is largely negated.

Under our present licensing system, it is highly improbable that a "well-behaved" driver will be checked to verify that he has a license. This occurs for many reasons, not the least of which is the understandable reluctance of police officials to detain the traveler, disrupt the flow of traffic, or otherwise interfere with drivers who are apparently exercising good driving practices. This is particularly true in most states today where, because of limited communication and data retrieval systems, the time required to check a license is excessive and the probability of a "hit" is small. A broad attack on this problem has been initiated in California through the introduction of digital communication systems and high-speed data retrieval. Using this system, an officer can check out a license in a few seconds rather than the much longer time periods that it takes by using most other systems.

There is still what I consider to be a serious limitation in that the officer must stop a motorist before he can check his license. If the officer were able to make knowledgeable preliminary screening of drivers and then stop only the select few whom he had good reason to suspect of being in violation, we would have a significantly improved system. We recently sponsored a research project where many alternative solutions were examined that included broad policy changes at the management level of communities and police departments and new detection and surveillance techniques. To follow through on these findings, we intend to pursue the research and demonstrations necessary to establish those systems and procedures that would enable and upgrade enforcement action without unduly bothering the vast majority of validly licensed drivers.

CONCLUSION

I have mentioned only a few of many research challenges in driver education and driver licensing. To the extent that these and other challenges are met, there can be important contributions realized. I would like to conclude by issuing a final challenge, one with an organization-management flavor. That challenge is to develop and improve a coordinated program of research and exchange of research information to serve operational needs at all appropriate levels of government.

Because of limited resources—money, people, and time—traffic crashes will be reduced only if we cooperate in a continuing program of research, evaluation, and implementation. The useful tools, techniques, and procedures that are under development at the state or federal level should be shared with other states and regions at the earliest possible time. There is a definite need for communication of research and development activities within and between states.

In the National Highway Traffic Safety Administration we feel we have a responsibility to uncover and disseminate the status of research, development, test, and evaluation; we are currently studying plans that will help us to meet that responsibility more fully. We would welcome any suggestions. Our intent is simply to help ensure that data developed in one state or community is made available to others who could profit from it through program improvement to better serve highway safety needs. We seek to close the gap between researchers and practitioners. We also seek to lessen the time lag from generation of research findings to the adaptation of those findings to ongoing operational programs.

As qualified professionals concerned with highway safety devote their energies and talents to meeting challenges such as these, we can look with optimism toward further reductions in the nation's highway crash losses.

ACKNOWLEDGMENT

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PERCEPTION MODEL FOR DESCRIBING AND DEALING WITH DRIVER INVOLVEMENT IN HIGHWAY ACCIDENTS

Robert C. Vanstrum and George B. Caples, 3M Company

•THIS paper explores a theory or model that relates driver perception and action to hazards on the road and discusses what research and countermeasures are suggested by the model.

One useful overview of highway safety is the 9-cell matrix that was developed by Haddon and Brenner several years ago (1) and that is being used today by the National Highway Traffic Safety Administration's multidisciplinary accident teams in characterizing accidents or crashes (2). The matrix is shown in Figure 1. It has been often stated that, in order to describe the operation of highway transportation, we must consider that all 3 factors on the left side simultaneously operate as a total system. All of the interactions of the system must be taken into account. However, in carrying out research aimed at trying to find out how the system works, we usually single out just one component or a subcomponent for attention. It is much too complex to try to deal with the system as a whole. From the results of research on just one part of the system, ways to improve the entire system including accident countermeasures are suggested and, in certain cases, implemented.

Traditionally, the factor getting most of the attention on the highway system is the human. He is regarded as being the chief instigator of highway accidents, as being his own worst enemy. However, a long history of scolding, pleading, cajoling, fining, jailing, and generally trying to influence and modify man's driving behavior does not appear to produce any conclusive, clear-cut results toward greater safety. Consequently, safety men in the past few years have more and more centered their attention on the other 2 factors of the highway system—the vehicle and the environment, the latter including the roadway.

Another reason why attention seems to have switched to these latter 2 elements is that they are inanimate. Thus, they are easier to research. The physical sciences can be employed. Actual crash tests where energy levels comparable to actual highway crashes can be designed. The human, on the other hand, is much harder to research scientifically. It is certainly inhumane and out of the question to subject humans to actual, dangerous road conditions to determine just what psychological and physiological factors lead to crashes. Yet, this is precisely what is needed in order to obtain the scientific background leading to solutions of the problem.

The human part of the puzzle is hard to understand. Normal human behavior is to drive safely and to avoid accidents. In highway accidents, we are dealing with relatively rare events that are not normal and that require an untangling of the roles that man plays. This is no easy thing to do by research or by other means. Certainly controlled laboratory experiments and realistic driving simulators, to name 2 tools used for understanding the human factor, are effective to a degree, but they always leave some measure of doubt as to their relationship with actual conditions. From a research standpoint, it would be nice to eliminate man completely as a control element from the highway system. Then all problems become inanimate ones and, thus, much easier to research and much easier to change and control. However, the fully automated system with man removed completely from control is years away from adoption on primary roads, and probably will never be universally adopted on all roadways. It

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appears that man with all of his capriciousness, complexity, and cussedness will remain one of the 3 factors in the highway system for some time to come.

How about the top of the matrix? We believe that most drivers would prefer to have accident countermeasures begin with the precrash. If given a choice between (a) driving into a barrier at high speed a test vehicle completely equipped with cushioning and restraining devices that had been proved to be 100 percent effective or (b) driving a vehicle and stopping short or steering around that barrier, we believe that it would not take a driver long to make up his mind that he would much rather avoid the barrier completely.

	PRE CRASH	CRASH	POST CRASH
Human	1	2	3
Vehicle	4	5	6
Environment	7	8	9
Results	Accidents	Trauma Injury	Mortality Morbidity

Figure 1. Highway system crash matrix.

However, again from the research standpoint leading to countermeasures to be employed, it is easier to deal with the specifics of the crash and the post-crash. The sequence of events preceding the crash become more and more complicated the farther back in time one goes, and they become lost in haze of uncertainty not very many minutes back. The many factors having cause-and-effect relationships produce an extraordinarily complex picture as one investigates the precrash phase. Then, too, the interplay of the matrix starts to interpose, and there is a suspicion, intuitive and otherwise, that man plays a dominant role in the precrash phase. Because of this, it appears more attractive and effective to research the crash phase and the post-crash phase.

This brings us back to the complete matrix. Are all cells equal to each other? Based on the foregoing discussion, it would appear that it is easier to obtain scientific facts, and hence develop effective countermeasures, by concentrating on (a) the inanimate part of the matrix and (b) on the crash and post-crash phases. The cell that does not fit either definition is the first one, the human-precrash cell. This would appear to be the hardest part of the matrix to research successfully and to develop scientific facts about leading to effective countermeasures.

Are human-precrash factors important, or is this importance just a holdover myth from an earlier, less scientific day? The preliminary findings of an in-depth accident investigation team of the National Highway Traffic Safety Administration show that human-precrash factors are the most frequently cited factors contributing to a crash (2). In 271 accidents investigated, cell 1 contained 444 contributing factors. The next cell was cell 5 with 190 contributing factors. Significantly, the drunken driver represents a human-precrash factor. Even the seat belt, present in the vehicle but not used, is in reality a human-precrash factor.

Perception, too, is a human-precrash factor. Because it involves man and because it is entwined in the complex factors preceding a crash, it is hard to uncover scientific facts concerning it and its role in highway safety. As an alternative to direct research in this area, a theory or model can be formulated that deals with perception. The theory, of course, must fit observable facts as they are known, be able to predict certain other events that would be subject to verification by research, and be able to suggest useful countermeasures. Theories are not only useful but indispensable. Theories are needed especially when research is hard to perform or there are too many variations to explore.

Nearly everyone who approaches the problem of structuring the driving task, in fact, develops his own individualistic theory or model. These models can vary from relatively simple, broad, overview types of models to those that attempt to define everything a driver may do. Many good models have been described but, in the absence of a standard or accepted model, we developed the following in order to help us understand the driving task and accident avoidance.

The driving task is basically getting from the start of the trip to the finish and avoiding hazards along the way. Getting from start to finish involves trip planning, directional information, maps, and area and route designation, but these will not be discussed at this time. We will concern ourselves only with avoiding hazards along the way.

Figure 2 shows a drawing of the perception model. What appears to be a crude musical instrument or weapon on the left is in reality a vehicle moving down a roadway with a zone of committed motion projected ahead (3, 4). This zone is composed of 4 segments or bands. Band 1 represents distance traveled during minimum perception time; band 2, distance traveled during minimum decision time; band 3, distance traveled during minimum reaction time; and band 4, the minimum committed motion area of the vehicle after activation has been made to turn or stop. Zone 4 out to arc S represents the minimum stopping distance for the vehicle based on vehicle speed and weight, brake efficiency, coefficient of friction between tire and road should the driver choose to brake, and other factors. All of the bands go into making up the minimum zone of committed motion extending in front of the car to arc S. It could be larger, of course, due to any perception, decision, or reaction delay.

On the right, box X indicates a hazard of some sort. This could be many things—a stalled vehicle, a pedestrian, debris on the road, or an oncoming car. As a special case, it can also be considered a potential hazard such as an intersection, a curve, a car ahead just starting to slow down, a railroad crossing, or even the edge of the road.

Point T is the true point, the last point at which action can be initiated to avoid the hazard. It is a point of no return and is determined by the zone of committed motion and the laws of physics. Action initiated after point T may help for injury reduction but will not be effective in avoiding the accident completely. Point M is the mental point and is the driver's perception of the true point T. It is where the driver believes the point of no return is. Point A is the action point or where the driver decides he actually will take action. The action involves slowing, stopping, steering, or accelerating. Points M and A are shown as points on the roadway for the sake of simplicity; they are probably perceived by the driver more as areas. Also, the model represents just one moment in time; in the dynamic situation, the various points, the committed zone of motion, and the driver's perception of the relationships are changing from second to second.

Before going further, we should define perception. The unabridged dictionary gives many choices, but perhaps one that applies here might be "awareness of the elements of the environment through physical sensation" and another version "physical sensation as interpreted in the light of experience." At least 2 elements are involved in perception: (a) a physical sensation such as vision, hearing, or touch and (b) an awareness or recognition of what that physical sensation means compared with other physical sensations received by the driver. In the case of vision, it is not just an image on the retina but a recognition and interpretation of that image that go to make up perception.

In driving, the chief physical sensation received by the driver is a visual one. Other senses play minor roles although, in some cases, important ones. In the case of the model presented here, we will consider that the driver gets his information and perceives the hazard and the various points ahead visually. He perceives his speed in relationship to other objects visually by the changing roadway perspective and visually by referring to his speedometer. From the perception of speed and based on "experience," he has some perception of his committed zone of motion. He makes judgments of the speed and distance of other objects visually. From these visual judgments, he he sets up points A and M continually ahead as he drives. The process is a perceptual one. Sometimes the driver is highly conscious of his search for perceptual cues; at other times, awareness is almost at the subconscious level.

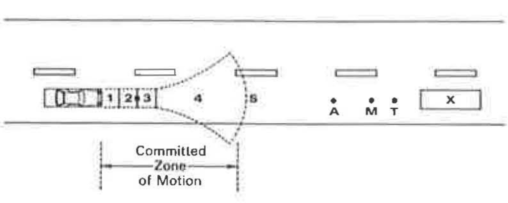

Figure 2. Perception model.

The distance between points T and M is termed perceptual error (Fig. 3). The driver's mental point M can be ahead or behind the true point T and, if no perceptual error is involved, it coincides with

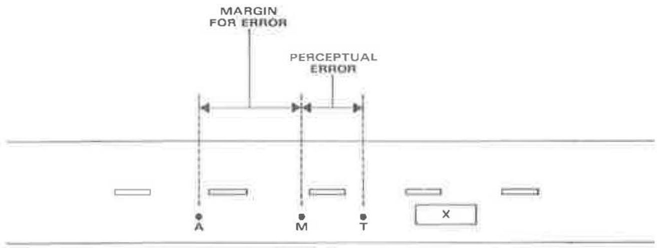

Figure 3. Margin for error and perceptual error.

point T and the distance between points T and M is zero. But generally, this distance is a plus or minus quantity; point M can be on either side of point T.

The distance between points M and A, or the difference between the mental point M and the action point A, is the driver's margin for error (Fig. 3). This quantity is usually plus from point M to point A, if the direction from the hazard back to the driver is taken as the positive direction. It is only minus when a driver deliberately tries to ram into something. A driver consciously trying to commit suicide would have a negative quantity. For most drivers, however, the distance is positive. In other words, the driver places his action point A ahead of his mental point M, the point of no return. He allows some margin for error.

The interaction between points T and M, perceptual error, and points M and A, margin for error, determines whether an accident results. It determines whether point A is toward the driver from point T where no accident results or whether point A is on the other side of point T away from the driver in which case an accident does occur.

Figure 4 shows, in the upper left, that both points T and M, perceptual error, and points M and A, margin for error, are positive producing a safe situation. In the upper right, a larger margin for error (points M and A) compensates for a negative perceptual error (points T and M) producing a safe situation where point A comes before point T. The unsafe situations are shown in the middle of the figure. In the middle left, the margin for error (points M and A) does not compensate for a larger perceptual error (points T and M), and an accident results. (An accident can be defined as an unwanted event and need not always result in a collision. Driving off the roadway, for example, results from perceptual error, but a collision may or may not occur depending on the nature of the adjacent environment.)

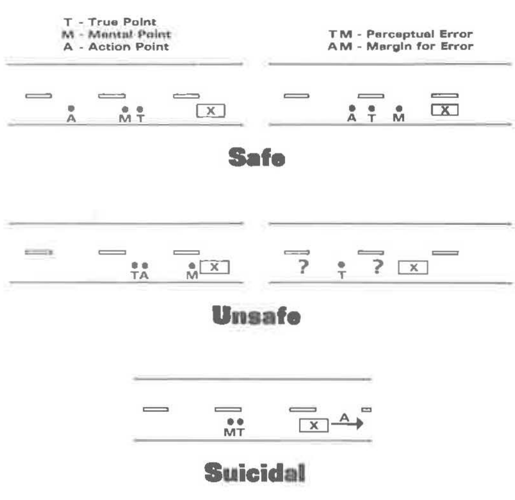

Figure 4. Safe, unsafe, or suicidal situations.

There are many special cases for the unsafe condition. The middle right part of Figure 4 shows failure to set up points M and A entirely, or until after point T is reached and a perceptual error occurs. Failure to treat potential hazards as real hazards, resulting in failure to set up potential points A and M, is a perceptual error that results in an accident that may be benign only if the driver is fortunate. Speeding through an intersection or passing on a curve or hill is indeed an accident waiting to turn into a collision. Figure 4 also shows the deliberate or suicidal situation where point M is established but no action to avoid the hazard is taken. Here the distance between points M and A is negative.

Many conditions and factors contribute to producing this perceptual error. Alcohol has been identified as a significant human-precrash factor and affects the magnitude of perceptual error by degrading vision and producing lack of attention. This produces a potentially greater perceptual error. It also degrades defensive factors such as margin for error and adequate reaction time. Figure 5 shows that the intoxicated driver has a larger zone of committed motion for any given speed because of increased reaction time that alters the true point T, moving it farther back from the hazard. This is not usually perceived adequately by the intoxicated driver, and he continues to set his mental point M as if he were sober. This is coupled with a reduced distance between points M and A (or margin for error) as the intoxicated driver takes greater risks. Figure 5 shows the intoxicated driver setting up the unsafe situation with point A on the wrong side of point T. Similar analysis could be made for other factors such as fatigue and inattention. All lead to that point in time where the driver sets up points A and M and either avoids the hazard or has an accident.

The professional race-car driver and the skilled, youthful driver probably have certain things in common. Both have good perception, fast reactions, and low margins for error. As shown in the bottom of Figure 5, the distances between the perceived points are small, and there is very little leeway for any departure from perfection. The effect of just a small amount of alcohol would be and is disastrous in this latter situation. The professional racer certainly does not drink a six-pack just before driving, but what about the young male driver?

What does this exercise in modeling the driver's action suggest? I believe the following points can be made:

1. Perceptual error is the proximate cause for most preventable accidents. It is the factor common to most accidents out of the myriad of factors possible in the chain of cause and effect. It is a human-precrash factor. On the other hand, margin for error is not an accident cause but a defensive, ameliorating action that does prevent many accidents. There are, of course, sudden cataclysmic failures, such as a heart attack or a blowout, that cause loss of control. Perception, as we are considering it, does not play a major role there. For the great preponderance of accidents, however, perceptual error is the proximate cause and the common factor present.

2. The perception model presented here indicates that accidents can be prevented by increasing the margin for error, making the perceptual error always positive, and making the perceptual error as small as possible. Increasing the margin for error is the predominant method that has been tried in the past. Admonitions to "drive safely" and "slow down—speed kills" and numerous safety articles have emphasized that drivers should develop larger margins for error. In our model, this means increasing the distance between the mental point M and the action point A. Although this is well-meaning and would be effective if drivers really could be influenced to increase this margin for error, actual experience indicates that this approach has not been too effective. It is too restrictive for many to drive ultra-cautiously all the time. Each driver has a built-in risk level that is part of his personality. Remote admonitions that seem unreal have little effect to change it. One good method of producing an increased margin for error would be to arrange for a hair-raising close call for everyone, but this is obviously not practical. Increasing the margin for error of a large number of drivers does not appear promising. It theoretically might be possible to make the perceptual error (points T and M) positive by optical illusions, road

Figure 5. Perceptual errors of drinking drivers and professional racers.

propaganda, and the like. However, experience indicates the driver soon adjusts and compensates for situations that appear unrealistic. For example, an advisory speed sign reading 15 mph on a curve that appears can be driven at 40 mph is usually disregarded. This does not appear to be a promising approach. Making the perceptual error as small as possible perhaps offers the best chance for preventing accidents. To explore this fully would be much too time-consuming here.

1. INANIMATE

A. Generation of the visual signal
B. Transmission of the visual signal

2. ANIMATE

A. Reception of the visual signal
B. Perception of the visual signal

Figure 6. Countermeasures to perceptual error.

The following areas for further research leading to countermeasures will be discussed briefly. The list of countermeasures to perceptual error, by no means meant to be all-inclusive, is shown in Figure 6.

1. Generation of the visual signal relates to the highway environment, to vehicles, and to available illumination and contrast. In daylight, illumination levels are high, and a large variety of natural, visual information exists. Nevertheless, perceptual error can be introduced wherever there is lack of contrast, glare, and visual clutter. At night when this natural information becomes much less visible, the accident rate increases. The essential details visible in the day should be preserved for night driving. Illumination is one answer for selected portions of the roadway if this illumination is bright and does not introduce glare. A more universal solution, applicable to all roadways, is to develop much more efficient headlights and vehicle rear lights. Motor Vehicle Safety Standard 108 is concerned with this area. For many reasons, progress in adopting better headlight systems and more efficient vehicle rear signal systems is slow. Perhaps the reasons are well founded, but, if reducing perceptual error is basic to preventing accidents, the research and its implementation should be accelerated. In general, greater use of distinctive colors and patterns on vehicles, on the roadway surface, and on warning devices and signs should be a considerable aid to hazard recognition either day or night and should lead to the reduction of perceptual error.

2. Transmission of the visual signal relates to the highway environment—fog, rain, snow, and obstructions—and also to the vehicle. At present, little can be done to alter inclement weather. On the other hand, who has owned a vehicle and has not had difficulties in keeping the windows clear of fog, frost, or rain streaks even when the system is operating at peak capacity? Have we done all we can do in this area? Motor Vehicle Safety Standards 103 (windshield defrosting) and 104 (windshield wiping) pertain to this area. Much work has been done on the front windshield in regard to controlled breakage with dramatic reduction of injury. Because of road geometry and vehicle vectors, much of the perceptual information enters through the front windshield. Manufacturers should design the front windshield with minimum optical distortion and obstruction and with maximum transmission. Where tinted windshields are desired, why not use one that fades at night to produce a higher transmission coefficient? Development of this technology should be accelerated. Considering angles to the side and rear, why cannot a truly effective rear mirror system be incorporated rapidly? It is hoped that the safety car research programs and Motor Vehicle Safety Standard 111 will accelerate this.

3. Reception of the visual signal relates to the human—his acuity, his field of vision, and the way his eye gathers the light and brings it into focus on the retina. It might be overly optimistic to hope for large gains in improving the vision of drivers. There should be control, of course, to prevent those with gross visual deficiencies from endangering their lives and others. Most drivers with vision corrected to at least 20/40 and experienced in compensating for other vision problems are probably fairly well equipped to deal with road hazards provided that other visual countermeasures are employed. Problems in vision can be partially overcome by making the light signals reaching the eye larger, brighter, more colorful, and higher in contrast and distinctive pattern.

4. Perception of the visual signal is the final link in the perceptual chain where recognition takes place. Perception, as we noted earlier, is not only the physical sensation, or the image on the retina, but it is an interpretation of that image in the light of experience. It has been demonstrated by Brody (5), Smith (6), and others that man can be taught to perceive better. Good results have been obtained in small groups. However, to our knowledge, improvement of perception has not been attempted on a large scale. In contrast to increased margin for error, which involves fear, restriction, and discipline, improvement of perception decreases fear and increases freedom—and, like the acqusition of any skill, it can be fun.

Reduction of perceptual error lies in being able to perceive the committed zone of motion of the vehicle in relation to perceived hazards or potential hazards on the roadway and to make point M coincide with point T as much as possible. Judgment of distance and velocity, attention to subtle environmental cues, compensation for vision deficiencies, and ability to see many items at a glance, recognize hazards, and distinguish patterns are all involved.

Perhaps, driver-education courses in the high schools can be adapted to emphasize visual and perceptual skills more than they do today (7). High school driver education reaches only a small portion of drivers (albeit when they need it most), and its effect might be transitory. To reach all drivers, a course in perception might be made mandatory before a driver's license is renewed. The course could be in a programmed self-instructional format and be aimed primarily at imparting information and improving skills, not at penalizing at the outset with loss of license. The motivation to complete the course to obtain a license and keep driving would compel most drivers to devote considerable interest to the material. This could be done every 4 years under Highway Safety Standard 4.

In the meantime, could not greater use of the mass media be made to refresh perceptual skills of the public from time to time? Most of the mass media suffer from being remote from the driving scene, but communications can be employed directly on the roadway. Ideally, some form of periodic education and reminder as to perceptual skills should be brought right to the roadway itself where relevancy, reinforcement, and realism are high. Very little attempt has been made to teach safety measures to the public on the roadway itself, although there is powerful logic in favor of it.

In summary, the human in the road equation is truly complex, hard to research, and hard to understand. Nevertheless, we cannot refrain from attempting countermeasures aimed at human-precrash factors on the excuse that the task is difficult.

Perhaps the proximate cause of preventable traffic accidents, which we hypothesize is perceptual error, can be best attacked by concentrating on inanimate countermeasures that have a history of producing quicker and more positive results than animate countermeasures. There is a possibility, however, to try once again to reach the drivers not by using emotionalism and psychological pronouncements but by using a different tactic—teaching them the skill of perception. Mass instruction could be implemented at the time of the driver-licensing procedure. It would not work with everyone, but nowhere in traffic safety can one deal with absolutes. A substantial percentage of lives saved and injuries prevented would make it all worthwhile.

In the conducting of research and in the development of countermeasures, there is a danger that resources may be spread to thinly. There is a need to isolate a few meaningful factors that have a major effect on safety. We believe perceptual error to be one of these meaningful factors in road safety. We need to attack this problem of the precrash phase by making the visual environment as hospitable as possible for good human perception and by training and conditioning man's perceptual process.

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