AN OLDTIMER SUGGESTS SOME ACTIVITIES FOR IMPROVING ROADSIDE SAFETY

Roger Stoughton
CALTRANS

THE YEARNING FOR A SAFE LIFE

Safety in America! That is the desire of every one of our more than 200,000,000 US citizens. We want streets safe against crime and terrorists, safe water, safe schools, safe sex, safe toys, safe toasters and safe worksites to name a few. We believe it is our birthright to have life, liberty and the pursuit of happiness, all of which imply a safe environment where we work, live and play at all times. There are probably millions of our citizens who play some role in keeping our country safe in one of a thousand ways.

Our small community assembled here has carved out a special niche for our careers - the pursuit of better roadside safety. Our network has been formed over a period of 40+ years, ever since John Beaton at Caltrans ran cars over bridge curbs to see if they would serve as bridge barriers to keep the cars on the bridge. They didn't work very well, and so we were off on a 40 year adventure to design bridge rails, then median barriers and guardrails and finally all the other roadside safety furniture needed to create the "Forgiving Highway," which is our ideal.

Along the way we have collected crash test researchers at universities, state and federal agencies and in the private sector, AASHTO committees, safety hardware manufacturers and vendors, TRB committees and workshops, NCHRP research projects, computer simulation experts, accident data investigators, consultants and others in our roadside safety community. We have a fine web that stretches across the US and extends even to Europe, Canada, Japan and Australia.

We have toiled assiduously at our own specialized tasks and compared notes once or twice a year at our TRB committee meetings and elsewhere. Every few years we write and rank research problem statements. Now some wise people have suggested it is the right time to raise our heads from our work, look back where we have been, assess where we are now and how we are doing, and then to look into the future and try to see a vision for roadside safety and try to develop a strategic plan so that our work has greater direction, meaning and purpose and so that we are all pulling together in a common direction, if possible.

This white paper will be my personal assessment of where we are and where we might travel. It should be noted that this is my personal assessment and that my comments do not necessarily reflect the current or proposed policy of the management of Caltrans. I will not spend much time on where we have been because that was covered so well in several papers in our last TR Circular. I will begin with some accident data, summarize some trends that are under way with emphasis on ones we should promote, describe at least a partial vision of the future and propose some activities needed to get there. The ideas presented in this paper are intended to be at least a little bit provocative. They are not claimed to be the only path into the future, but it is hoped they will inspire some discussions about where we should put our greatest efforts.

DATA ON DEATH BY ROADSIDE HAZARD: REPORT ON A GUERILLA WAR

The handiest accident data available to me was from the publication titled, "Facts, 1994 Edition" from the Insurance Institute for Highway Safety (IIHS). They state that their information is based largely on data from the US DOT's Fatal Accident Reporting System (FARS). The following tables contain information excerpted from the IIHS report.

These tables lead to the following observations:

1. The absolute number of deaths are going down - that is good news.
2. Roadside crashes have stayed at a constant percent of all vehicle crashes.
3. Overrepresented drivers are young, male, intoxicated and night travelers.
4. Rollovers and ejections are significant common factors.
5. A large majority of deaths are not on freeways or interstates - perhaps our work on freeways is paying off to some extent.
6. Curves are present in nearly half of all crashes, so road geometry is important.

TABLE 1 ROADSIDE HAZARD CRASHES IN THE UNITED STATES — OVERALL PATTERNS

Deaths in 1980	15,232
Deaths in 1993	11,300

Deaths in roadside hazard crashes as a percent of all motor vehicle deaths have stayed fairly constant at 28-30% in the years 1979-1993.

TABLE 2 SINGLE VEHICLE ROADSIDE HAZARD CRASH DEATHS BY OBJECT STRUCK/ROLLOVER

Hazard	Deaths—Percent of Total	Percent with Rollover
Tree/Shrub	28	17
Utility Pole	11	22
Embankment	10	63
Guardrail	9	50
Ditch	8	65
Curb	6	34
Culvert	5	56
Fence	4	43
Sign Support	3	39
Other Post/Pole	3	48
Bridge Pier/Abutment	2	15
Concrete/Other Barrier	2	45
Bridge Rail	2	51
Wall	1	28
Building	1	5
Light Pole	1	23
Other	8	--

TABLE 3 SUMMARY OF ROADSIDE HAZARD CRASH DEATHS BY GENERAL HAZARD CATEGORIES

Hazard Category	Deaths—Percent of Total	Percent with Rollover
Trees/Poles/Supports	46	17-48
Embankment/Ditch	18	63-65
Guardrail/Bridge Rail/ Other Barriers	13	45-51
Curb/Culvert/Fence/Pier/ Wall/Building/Boulder	20	5-67
Other	7	
Total	104*	

*Numbers are rounded; therefore, sum is more than 100%.

TABLE 4 ROADSIDE HAZARD FATAL CRASHES — DRIVER PATTERNS

Age<13–24	35%
Men under 35	48
Blood Alcohol Content over 0.10	53
9 p.m. to 9 a.m.	60

TABLE 5 ROADSIDE HAZARD FATAL CRASHES — HIGHWAY PATTERNS

Freeways/Interstates	16%
Major Streets and Highways	51
Minor Roads	33
Curves	42
Wet/Slick Roads	17

TABLE 6 ROADSIDE HAZARD FATAL CRASHES — CRASH PATTERNS

Frontal Impact	67%
Side Impact	21
Other	12
Rollover	37
Ejection	31
Single Vehicle	96

7. Most crashes involve the front or side of the vehicle.

8. Trees, poles and supports are involved in almost half of all fatal crashes.

9. Barriers and a variety of other objects are involved in one-third of all fatal crashes.

10. Embankments and ditches are the other main hazards on the roadside in fatal crashes.

Papers presented in the past year lead us to believe that fatal barrier crashes include many that are into obsolete or improperly built barriers, or involve non-tracking vehicles or include vehicles such as motorcycles and trucks for which the barriers were not designed. In other words, my understanding is that the barriers we have tested that met current standards are probably performing quite well for impacts within the envelope of crash test conditions.

TABLE 7 MAJOR AND MINOR "A" SAFETY PROJECTS ON CALIFORNIA STATE HIGHWAYS IN 1992–1993

Type of Project	Total (in Millions of Dollars)
New Median Barrier/ Upgrade Median Barrier	8.7/0.9
Curve Realignment	6.7
Spot Improvement	2.7
New Guardrail/ Upgrade Guardrail	2.1/1.5
Wet Pavement Correction	1.6
Miscellaneous Roadside Obstacles	1.1

TABLE 8 MINOR "B" SAFETY IMPROVEMENTS ON CALIFORNIA STATE HIGHWAYS IN 1992–1993

Type of Project	Total (in Thousands of Dollars)
Advance Flashing Beacon	172
Guardrail	162
Traffic Signal Modification	105
Guardrail Upgrade	104
Fencing Upgrade	95
Channelization	94
Overlay	63
21 Other Categories	752

STATE DOT PROGRAMS: THE BAND-AID/BETTER MOUSETRAP APPROACH

This is the way I describe our current approach to roadside safety. To illustrate, here is a summary of the Caltrans "Highway Safety Improvement Program for 1992/93". This report pertains to California state highways only where there were 1497 deaths and 53,934 injuries with losses of $2.2 billion. In that year 4000 accident concentration locations were investigated. A total of 61 Major and Minor "A" projects were completed at a cost of $25.6 million, 74 Minor "B" projects at a cost of $1.5 million and 23 projects on state highways funded by local agencies at a cost of $5.4 million or a grand total of about 200 projects costing $32.5 million. The following two tables show the type of

TABLE 9 CALIFORNIA STATE HIGHWAY 1989–1990 FISCAL YEAR SAFETY IMPROVEMENT PROGRAM (2 YEARS BEFORE AND 2 YEARS AFTER)

Type of Project	Benefit-Cost Ratio (Life)
Safety Lighting	36.0
Upgrade Median Barrier	19.7
Modify Traffic Signals/Channelization	16.8
New Bridges Constructed for Safety	9.2
New Median Barrier	7.6
Sidewalk Construction	5.6
Guardrails and Bridge Rails	5.0
Curve Realignment	4.6
Wet Pavement Improvement	4.1
Roadside Obstacle Removal	4.1
Others	3.7 to −15.2

projects and costs for each type of project. Note that the tables which follow do not include safety features which are built on new construction projects which would increase the grand total of safety related expenditures on California highways.

Table 9 shows the benefit-cost ratios achieved with some of these projects. Only the highest ratios are included in this abbreviated table.

It is hard to criticize a program that spends $32,000,000 on 200 projects every year, many of which have strong benefit-cost ratios. It is a comfortable program, one which could continue indefinitely, one which sprinkles safety money all over the state, one which is obviously doing good. Nevertheless, there is a disturbing feeling that this is a machine set in motion years ago that keeps moving ahead, repeating itself, beating the drum like the Energizer bunny.

Now clearly these tables cover the entire category of highway safety, not just roadside safety. Still there was nothing in the Caltrans report that indicated the program was specifically based on the kind of accident data compiled by the FARS and analyzed and reported by IIHS. There was no vision of an ideal safe highway system. Instead, we have an ongoing incremental plan where band-aids are applied at perceived trouble spots. If a new barrier design (a better mouse trap) comes along during the year - fine, we add that to our band-aid collection. And there is something profoundly disturbing when we compare yearly expenditures of $32,000,000 (which seem quite generous at first blush) to yearly losses of $2.2 billion. That means expenditures are only 1-1/2% of total losses. Further, there is no indication, at least in this report, of the ongoing efforts underway within Caltrans to collaborate with groups such as NHTSA, the auto industry, etc. to find broad solutions to reduce the accident rate.

I do know, however, that Caltrans is working with many partners, among those NHTSA and other safety interests in California as they cooperatively develop a system for the establishment of safety goals through the use of the safety management system. This is certainly a step in the right direction. Also, the accident rate has been declining over the years. Note that the preceding criticism wasn't intended to single out California. Presumably, most other states have similar programs. The information about California's program was presented because it was conveniently available. I strongly suspect that many states have much less substantial programs in place.

MIDDLE-AGED UNSAFETY HARDWARE

Over a period of forty years we have installed some roadside safety features that we now know are inadequate to meet current performance standards. Clearly, we cannot upgrade all roadside hardware every year. Much of the older hardware has a range of good performance that makes it useful; it just doesn't have the extended range of good performance that makes it useful; it just doesn't have the extended range of performance of the newest devices. Thus, careful thought and prioritizing must be carried out when deciding which hardware to upgrade.

That said, there are some blanket upgrading programs crying out for action. It was refreshing that FHWA recently leaned hard on the states to get rid of blunt end and sloping end guardrail terminals which we've known for many years to be poor performers. Caltrans has rejected the sloping end terminals for almost 30 years. Likewise, FHWA acknowledged that the "emperor has no clothes" when they stopped payment on the BCT which has a great deal of trouble handling light weight cars properly, also known for at least ten years, although, unfortunately, there have not been good replacement designs available.

Why then are there hundreds of miles of baluster type bridge rail still in place in the US that were built over 40 years ago, still there after several generations of new bridge rail designs, a slap in the face to our entire roadside safety community? Some traffic engineers may argue that they are hit so infrequently that the benefit-cost ratios don't warrant replacing them. In this case, perhaps they should at least be torn down and replaced with up to date delineation devices.

Decision makers and the public need to be persuaded that a purging of our roadside of obsolete barriers (plus other hazards) would yield great safety benefits, modernize our highways, create jobs, and yes, get lots of money to contractors. Other than the selling job, the toughest facet of this activity is devising a plan as to what types of safety devices should replace the old ones now and in the future. More on that as we continue.

TRENDS OBSERVED/ACTIVITIES SUGGESTED TO IMPROVE ROADSIDE SAFETY

The Roadside Safety Community Has Done Good (Mostly)

Here I give our roadside safety community high grades. We have labored diligently for forty years. We have been through several generations of design for most types of hardware. There has been much clever innovation in the past and it continues. Many of our designs appear to be very effective. Most, if not all of the tools we need are in place, or soon will be to design barriers that will handle any impact conditions we impose.

We have assembled NCHRP 350, a comprehensive set of recommendations for crash test procedures and evaluations. It covers all vehicle speeds and vehicle sizes in up to six different test levels. It will require fine tuning periodically, but I recommend that we not begin from scratch as we have in previous iterations in 1974, 1981 and 1993. Instead, at about five year intervals, I recommend that we only make needed changes to NCHRP 350 so that we have as much continuity as possible in the future after each review. Others here will describe the next changes we may wish to make.

THE MULTIFACETED APPROACH/STRATEGIC PLAN

In our roadside safety community we have taken many roads to improve safety. Many have paid off. No doubt this trend will continue in the future. The lower the accident rate goes, the tougher it may be to make further gains. Thus, we will need to continue our multifaceted approach; we may need to spend more time on targeted groups. For example, in recent years some researchers have been looking for ways to help older drivers with larger letters on signs, wider edge stripes, etc. Young male drivers would be another group that should continue to be targeted. Our roadside safety community may be targeting utility poles and trees. Also, as mentioned in the earlier section on safe vehicle design, the auto industry still has areas that can be targeted for significant gains in safety.

With this in mind, it seems to me one of our most important activities in the future will be to improve communication and coordination between organizations and disciplines so that we can give an extra push to the most cost effective activities, and so we are all headed in approximately the same direction. I'm hoping our NCHRP project to develop a strategic plan will be one good step forward in that direction. It will need to address the many possible approaches to improving roadside safety.

STATE DOTs: CAN THEY GRAPPLE WITH HIGHWAY SAFETY MANAGEMENT SYSTEMS?

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 requires the development and implementation of a Highway Safety Management System (HSMS) similar to pavement and bridge management systems that have been in place for several years. Obviously, roadside safety must be an integral part of an HSMS. Our summer workshop in 1992 centered on this topic, and the proceedings were collected in Transportation Research Circular No. 416.

It is noted in the Introduction to the circular that a good management system should include

- Information systems;
- Analysis techniques;
- Countermeasure installations;
- Countermeasure evaluations;
- Maintenance of safety system components;
- Policy development;
- Education; and
- Enforcement.

The Introduction adds that "because of limited resources, institutional constraints, and political realities, an organized and well managed highway safety system has been difficult to achieve". It is my opinion that a good HSMS is one of the keys to improving roadside safety. No matter how much brilliant research we do in the roadside safety community, it all goes for naught if it is not implemented. State DOT's are the major channel for implementing the research which we complete. We must ask ourselves why we still have roadside safety hardware on our state highways that has been obsolete since our first five years of crash testing almost forty years ago.

If we had a good HSMS, each state would have a complete detailed inventory of roadside hardware, with its location on the highway network. We would also have complete accident data with a similar location scheme that could be tied back to the hardware location. Analysis of these data would permit formulation of a plan to replace obsolete hardware with a ranking system based on probability of accident exposure. The inventory could also be analyzed to devise a regular routine maintenance program. The inventory could be made available to maintenance forces to reduce the burden of ordering replacement elements and to insure that current safety standards were recognized when replacements were made. The inventory and accident data could be analyzed to plan a replacement parts inventory that was ample but not excessive at each maintenance station. Accident and inventory records could be analyzed to prioritize the worst safety problems, for example impacts with utility poles and trees. Using this information and related information, each state DOT could develop its own strategic plan for attacking safety problems in that state. Once problem areas were isolated, the state could do literature searches and tap technology transfer centers to find solutions. If they found no satisfactory solutions, they could draw up a performance specification and/or request for proposals in search of innovators. Oftentimes, if a problem is clearly defined and publicized, a good solution will be forthcoming. In a good HSMS there would be a quality control unit that made spot checks of roadside safety hardware to insure it was installed, maintained and repaired properly. Recurring problems that were discovered might lead to a training program and/or training video. New safety hardware designs, after careful evaluation and testing, could be installed in large enough quantities to get some accident history. Analysis of this subset of accident data would lead to either full approval of the hardware, re-design and modification where needed, or complete and immediate removal if the hardware proved unsatisfactory. Further, all safety hardware should be evaluated periodically using the inventory and accident data to verify it is still effective and to plan replacement with improved designs when warranted.

The above thoughts probably sound simplistic. Most, if not all, of the above activities are done in bits and pieces by the states but not with a well organized system approach. The pieces of the HSMS may be scattered through several offices. Many activities may rely on the engineering judgment of seasoned employees. Many of the above activities are probably done incompletely because of lack of personnel and funds, with only one person trying to coordinate the work of several offices. The overall programs in most state DOT's probably do not have a rigorous plan to collect complete data, analyze the data, develop policies, take action, evaluate the actions, evaluate the system periodically, educate all members of the HSMS team, and enforce established standards.

What many states do have is a reactive system rather than the more proactive one described above. In a reactive system, a state DOT would locate high accident locations, prioritize them and dole out the funds available for corrective measures. This process would be repeated year after year without any long term planning or vision for improving highway safety. In a proactive program, improvement of high accident locations might still be an important segment, but it would be in the context of a much better analyzed, long term plan.

What are some of the reasons the states don't have a good HSMS - a system that sounds almost self-evident to a conscientious engineer? And what can be done to overcome these problems?

Problem No. 1: Lack of personnel and funds. We seem to be in an era of downsizing government. It is politically expedient for elected officials to blame government bureaucracies for problems, and to charge ineptness and corruption. It is politically expedient for elected officials to promote tax cuts no matter what the needs of the society or its financial health. The electorate, perhaps swayed by antigovernment political slogans, perhaps less willing to share their earnings in our materialistic and acquisitive culture, and perhaps unclear what resources it takes to provide the government services they would like to have - support tax cuts.

The upper level managers appointed by elected officials take these views as a mandate to downsize their agencies. They are more likely to order across the board cuts in personnel than to do a rigorous analysis of the importance of different units in the agency. For example, they may require a ten percent cut in personnel positions. Hence, the traffic engineers who have the potential to save lives are whittled away as much as the unit which is picking up litter (a not unimportant job - just lower priority in my mind). After a few years and a succession of managers who succumb to the mindless fix of 5% and 10% cuts, the traffic safety unit may be lucky to have a skeleton crew and a very thin layer of expertise centered on one or two old-timers. In this situation even the best intentioned and hardest working state employees cannot carry out a full fledged HSMS.

This downward spiral is demoralizing and frustrating. There do not appear to be any quick fixes. It takes a long time to change the cultural and political climate. We must compete for limited resources. The only possible solution I can dream up goes something like this:

1. The roadside safety (and highway safety) community develops a well thought out and detailed strategic plan.

2. Resources are sought to influence federal and state lawmakers. These resources are used on carefully crafted videos, white papers, and presentations. These papers and presentations describe the current roadside safety problem and its horrendous magnitude and malign influence on our society and economy, some past successes, and some specific plans for the future. High quality public relations consultants should be hired to help prepare these battle plans. Roadside safety organizations in the private sector may be the most appropriate ones to carry out this part of the campaign with input from the public sector.

3. Part of the pitch would be to get legislation passed at federal and state levels that would create tough organizational modules. It would be determined how many persons were needed as a minimum to run a good HSMS in that state. Funds would be dedicated to these modules and there would be a guarantee of at least, say ten years, before sunset of funds and personnel with some kind of inflationary factor included. There would be heavy penalties for assigning other work to these people or diverting their funds. Brief but useful reports would be required yearly. It would be required to present them to the president and the governors of each state and on the Internet. This would allow the states to have a program that was thorough and continuous. Unless the states assigned their worst slackers to these units, surely we could see some lives saved and injuries lessened in severity in future vehicle accidents.

Problem No. 2: Lack of good management practices. Again one would think that good managers would almost automatically develop good HSMS's. The few murmurings I hear are to the effect that not many states are jumping on the bandwagon immediately to implement vigorous fleshed out HSMS programs. They are doing the minimum paper work and reporting to FHWA. Clearly, if they lack resources, they have one big excuse. Nevertheless, they could be using good management techniques to optimize the resources they have.

Again, I must confess to being frustrated and a little cynical about the possibility of ideal managers in the state bureaucracy. (So perhaps the politicians' complaints are not completely without merit.) Viewed from my lower level in the "pyramid", managers often seem caught up in their own world, putting out fires, shuffling what resources they have, fighting turf battles, trying not to make waves etc. When has a manager ever gathered the working engineers down near my level and asked, "What are your problems and how can I help you get the job done?" And yet that is the essence of being a good manager — smoothing the way ahead so workers can be efficient and productive. Not only have they not asked these simple questions, they have barely communicated, if at all, what their expectations, long range goals, philosophies etc. were. The list could go on.

Managers need intensive training with frequent tune-up sessions in team building, communication skills, communication plans, conflict resolution, motivational skills etc. This training should come from well qualified professionals in the field of organizations and management. Managers should have key meetings involving strategic plans and policy setting, team building, brainstorming etc. facilitated by full time professionals. As a general rule engineers have not had this type of training, do not have these skills, and many probably don't even realize there are professionals who do this kind of work. Some managers with strong personalities and large egos will not understand the value of using professionals of this type. Unfortunately, a manager must accept the above ideas and want to pursue them; he or she cannot be forced to use them.

Improvement in this picture might come two ways. First, publicity and education are needed to entice managers to modernize and improve their management techniques. This would require assistance from professional organizations that specialize in management, organization theory, facilitation of meetings, etc. Perhaps they could be persuaded to tailor their promotional materials to the needs of state DOT managers. Second, federal legislation could include rewards for state DOT's that document high levels of management training and usage of modern management techniques documented by management professionals.

Problem No. 3: Personnel regulations in a bureaucracy. Civil service rules often bog down any half-way creative idea in state government and strangle it to death. For example, job classifications may be quite general. Thus, vacancies in the traffic engineering division may be filled with engineers with no expertise in the area at all. Furthermore, their main interest may be in having a secure job or getting a promotion for higher pay - not any special zeal for saving lives or improving roadside safety in general or improving their strategic plan. Also, civil service procedures usually require that all engineers and other disciplines start work at the entry level. There is no way of rewarding professionals who earn advanced degrees by hiring them at higher levels when they enter state service, or even of rewarding them if they earn advanced degrees after being in state service. Thus, a manager who suddenly had the resources to assemble a full fledged HSMS could be completely hamstrung by these rules. The manager could not search out the best traffic engineers, data analysts, computer specialists, etc. and hire them directly.

Again, we have another quagmire that seems almost hopeless to traverse. What could a stout-hearted crusader do to surmount this obstacle? First, federal legislation could include a model system for filling positions in an HSMS and reward states that quickly amend their civil service systems accordingly. The model system would have to include all the fairness concepts typical of a civil service system, but would allow special job classifications needed in a HSMS, would provide for hiring professionals with advanced degrees and/or other specialized experience, would have graduated pay level based on education and experience, would include demonstrated zeal for the HSMS program as one hiring factor, and would include accelerated dismissal procedures for employees who turned out to be poor team members. These special rules would be justified because of the high priority importance of improving roadside safety by establishing good HSMS's, and making the case for that high priority classification would be part of the plan to obtain legislation of this type.

Problem No. 4: Lack of communication. If the state Dot's had the proper resources to develop an HSMS, each system would probably turn out different from the others. Some programs might be much better than others. Ideally, the HSMS staffs should be able to meet occasionally to share ideas. Unfortunately, many states treat out-of-state travel like the plague. Here again, federal legislation could include funds for a national meeting once every two years for, say, up to ten HSMS staff members from each state DOT. This would allow the major disciplines in each HSMS all to be represented. It would allow sharing of ideas that worked and plans for the future. It would greatly enhance networking contacts so that staff members from one state DOT would feel more comfortable about contacting their counterparts in other state DOT's. And as everyone knows who attends a good convention, it would pump up the "zeal" factor. Further, a little publicity would demonstrate to citizens that government was really serious about attacking one of our society's most serious problems.

THE ROADSIDE SAFETY COMMUNITY: SHOULD IT TURN SOME CORNERS?

Low Maintenance Hardware

In Caltrans the last few years we have increasingly heard the plea for maintenance free hardware. This has led to a shift from metal mesh glare screen to concrete glare screens in some locations, a shift from metal beam guardrail to concrete roadside barrier on urban freeways, and to disapproval of some new crash cushions that are repair work intensive, for example. This trend will probably intensify as our highway system is built out and carries heavier and heavier loads of traffic. Under these conditions we do not want to close lanes of traffic for repairs because of increased congestion and potential safety degradation and we do not want to expose our employees to the hazards of traffic anymore than necessary. A few Caltrans workers are killed every year when they are run down on the highway.

Non-Tracking Vehicle Crash Tests

FHWA led the way in conducting side impact tests into lighting standards a few years ago. Virtually all previous crash testing in this country was done with tracking vehicles. The FHWA tests had the vehicles oriented 90 degrees to the direction of travel. These tests showed the great hazard of light poles and the weak side structure of vehicles in their broadside impact tests.

Recently Caltrans conducted a side impact test where the vehicle was yawed with respect to the direction of travel, but not a full 90 degrees as in the FHWA tests. Now Caltrans is working with UC Davis to design and build a sturdier side impact carriage that will allow the vehicle to be towed at any yaw angle. It also has the potential to impart a yaw velocity to the vehicle before it is released from the carriage and travels into a test article.

We know that side impacts represent a significant number of all roadside impacts and they can be quite severe, even at lower speeds. Therefore, it appears it will be fruitful to develop side impact test procedures, evaluation guidelines and test equipment to try to design roadside safety hardware that is forgiving in side impacts. This activity provides further reason to work with the auto industry on vehicle/barrier compatibility, and to make use of computer simulation programs to find good design solutions.

Computer Program Simulations of Vehicle/Barrier Impacts

These have been covered extensively elsewhere. I concur wholeheartedly that these programs have the potential to optimize our roadside safety hardware design and to determine their limits of performance. This quest should be pursued vigorously.

New Materials

We should stay alert for new materials that become available. Composites that have special properties such as superior strength and durability may be good replacements for timber and metal roadside hardware. Recycled plastic and rubber elements may be useful in some roadside safety hardware in addition to being environmentally benign.

THE AUTO INDUSTRY: IS A PERFECTLY SAFE VEHICLE ITS HOLY GRAIL?

We know with our present highway system that some drivers will get in trouble, their vehicles will leave the roadway for whatever reason and they will strike an object on the roadside and/or rollover. Ideally all vehicles would be designed in such a way that the passenger compartment was never damaged in an accident. In addition, seat belts, air bags and other restraints would cushion passengers in an impact so that they could survive high levels of deceleration with little or no injuries.

Although we have not reached this ideal state, great strides have been made over the years to improve vehicle safety. Besides the many safety components such as safe windshields, collapsible steering columns, crushable dashes, seat belts etc., that have been standard for over 25 years, there have been more recent improvements in side strength, rollover strength, energy management in frontal crashes, air bags etc. Some more gains may be possible. A recent issue of the Status Report newsletter from the Insurance Institute for Highway Safety claims that new NHTSA rules on anti-lock brakes for trucks and car occupant head impact protection might save 1400 lives per year. Simply using padded sun visors, like those required in Australia, could save many lives and the visors are not necessarily more expensive.

As vehicle safety improves, roadside safety devices do not have to be designed for such delicate vehicles. For example, whereas barriers that deflected during impacts have been preferred in the past, (cable and metal beam barriers), now more rigid barriers may be as good a choice. If rigid concrete barriers can be used more widely, they have several advantages. They take less space because they don't deflect, they require less repair and maintenance - hence lowering life cycle costs and reducing exposure of workers to traffic hazards, and they can more easily handle a wider range of vehicle geometry and weights which includes being less susceptible to changes in vehicle design that would make them obsolete.

In the past highway people have had almost no contact with the auto industry. Roadside safety people have tried to design barriers and other hardware to last over twenty years while the auto industry was changing designs every year.

A much needed future trend would be for increased dialogue between the highway agencies and the vehicle industry people to make roadside safety devices and vehicles more compatible. For example, if all barriers were eventually concrete, then the vehicle industry could design bumpers accordingly and could insure that air bags and other restraints could handle most impacts with concrete barrier. Similarly, bumpers and side structures of vehicles could be designed to resist impacts with trees and pole type structures.

The roadside safety community needs to initiate more communication with NHTSA and the auto industry for our own good. It could make our design process much easier. FHWA has made a good start by working with NHTSA in some of its side impact testing and its work on computer simulation programs. Let us hope that the quest for a perfectly safe vehicle becomes the quest of the auto industry.

THE PUBLIC: IS IT POSSIBLE TO DEVELOP A HIGHWAY SAFETY CONSTITUENCY?

In the present political climate, laws are passed and resources allocated for those citizens who have organized powerful lobbies with large treasuries. It is a case of the "squeaky wheel" *AND* the "well greased wheel" getting the attention. These lobbies and support organizations spend large sums of money to "educate" the public and to sway legislators. Recent examples include all the anti-tobacco legislation which has passed. The only way that the powerful tobacco lobby could be challenged was through similar efforts by the American Lung Association, American Heart Association, American Cancer Society, ASH etc. They raised the public consciousness enough to get legislation passed that furthered their cause. Until that time, over 465,000 persons a year were dying from tobacco related causes and there was no organized effort to analyze and solve the problem. This is a simplistic analysis of that situation intended to show that concerted efforts by a few special interest groups can mobilize public opinion and influence legislators to begin solving a serious public health problem.

We know that about 40,000 Americans die in vehicle accidents every year, many more have incapacitating injuries and the economic loss is horrendous - billions and billions of dollars. Many less persons die each year from drugs, AIDS and some other highly publicized problems. The nation grieved for weeks after less than 70 people died in the Loma Prieta earthquake, less than 200 died in the Oklahoma City bombing, and less than 200 died in a recent major airline crash.

Tragic as these events were, they pale in comparison to our highway death toll where an average of about 110 people die every day of the year and several times that many are grievously injured. Why is there no public outcry? Perhaps it is because those 110 fatalities are scattered all over the country, and we only read about one vehicle in our own city every few days. Only a few family and friends grieve, and the rest of the community continues to worry more about crime and drugs etc. In effect, we have the equivalent of a guerrilla war taking place in our country where a sniper picks off one or two victims in isolated places at random times.

No constituency or lobby develops for highway safety because there is no economic payoff. We have small non-profit groups like MADD and the Center for Auto Safety which exert a little influence in narrow fields of interest, but no broad based group promoting highway safety. Such a group could be a great boon to those in roadside safety. It could educate the public about the death and injury toll and the economic loss so that an aroused citizenry might finally push for increased support for highway safety programs as being a high priority, high payoff program best coordinated by government agencies, but fully involving the private sector as well. The group could be called the American Highway Safety Association (AHSA). The roadside safety community can't collectively form such an organization, I assume, but we can encourage any who would do so and work with them, once formed, to make sure they have accurate information to dispense. For example, if we can develop a well thought out and detailed strategic plan for improving roadside safety that is updated regularly, that could be a very useful roadmap for an organization like AHSA and ensure its efforts had maximum payoffs.

THE FUTURISTS: IS THE AUTOMATED HIGHWAY SYSTEM PIE IN THE SKY?

Surely most persons involved in highway safety have agonized many times about ways to improve safety and have resigned themselves to limited gains. This is because the key factor in the majority of accidents is the driver - our tragic black sheep cousins who drink, take drugs, lack sleep, lose control of emotions, speed, don't maintain their vehicles, and have no concept of the physics of auto collisions. They lack "driving intelligence." It is virtually impossible to change the attitudes, personalities, health and skills of most of these people. If this type of person survives that long, finally 20 or 30 years of adult living and several close calls may give them the driving and life experiences to temper their unfortunate highway behavior. Roadside safety engineers know that some of these folks will run into their barriers at 90 mph or 90 degree angles. Much as we'd like to save their lives for better days when they may "sober up" permanently, there is little we can do to protect them in such extreme impact conditions.

We understand that our highway system has three components - the highway, vehicle and driver - but it is not designed as a system. The vehicle and highway cannot compensate for the erratic behavior of some drivers. The only possible total solution is to take control away from the driver. That, of course, is what is done by the AHS. It uses electronics and mechanical systems to keep the vehicle moving safely on the highways with little or no input from the driver. It substitutes reliable artificial intelligence for the flawed "driver intelligence" in the present system.

Assume for the moment that AHS will work. If the components can be made almost perfectly reliable (no small task), then we could see a one or two order or magnitude improvement in safety. Vehicles would never leave the roadway; hence, roadside safety would be a moot issue. Embankments, rivers, trees, poles, barriers, ditches, curbs etc. would no longer be potential hazards. Roadside safety engineers could have a glorious and satisfying retirement.

Is AHS a pie-in-the-sky scheme that will never work? We know that such a complicated system will take many twists and turns, but (barring economic collapse in this country) the press of new technology will surely carry the AHS to some kind of national system on many, if not all, of our highways, and perhaps even down to the local level of streets and roads. Only the time table is uncertain.

If we assume that an AHS is inevitable, then roadside safety engineers need to keep one eye on the future, on the long term, so that we can integrate our short term and long term goals. What is the time table envisioned now? I spoke with an engineer at Caltrans who is working on AHS issues. He said that in 1997 Caltrans plans a demonstration on I-15 with 20 vehicles having lateral and longitudinal control capability. That means the vehicles will have collision avoidance systems and lateral guidance systems to keep the vehicles on the roadway. Concurrently, Caltrans is included in efforts to select the best concept proposal for an intelligent highway system. Sixteen proposals must be narrowed down to one, and a prototype of this system would be built in the year 2002.

Beyond that, it becomes increasingly hard to predict when such a system would be widely implemented. If a freeway lane is dedicated to AHS, then 20 to 25% of the vehicles must be equipped with AHS systems. That means a large number of car owners must be willing to pay the premium for these cars, but they may be reluctant until there are an ample number of roadways equipped with AHS systems. In other words, there is a "chicken and egg" dilemma here.

Changes in the vehicles will probably be incremental, the first being an advanced cruise control with a collision avoidance system. Only a younger generation who grow up with AHS may be completely accepting of such a system, according to the AHS engineer. Hence, widespread use of the AHS may take 40-50 years. That sounds like a long time into the future. Nevertheless, many incremental changes will be occurring well before that milestone. If experimental sections of highway are built in 10-15 years, it is not too soon to begin thinking how our roadside safety concerns will coincide with the AHS.

In preparation for this paper I skimmed through a dozen or so reports from the PATH program. According to the report, "The California PATH is a joint venture of the University of California, the California Department of Transportation and private industry to develop more efficient transit and highway systems. The goal of PATH is to increase the capacity of the most frequented highways and to decrease traffic congestion, air pollution, accident rates and fuel consumption. PATH is part of the Institutes of Transportation Studies at the University of California at Berkeley, Davis and Irvine, in collaboration with California Polytechnic State University at San Luis Obsipo, and the University of Southern California." PATH is deeply involved in AHS research. Most of the reports which I reviewed were written by a consultant to PATH, Anthony Hitchcock, who was employed to analyze the safety problems of an AHS. Following is a brief description of an AHS and some miscellaneous ideas related to its safety. This particular scheme has not been adopted and is not necessarily the final concept of choice. It was considered better than some other schemes and was used in order to have a specific basis for a safety analysis.

The following is a description of an AHS taken from a draft report titled, "Layout, Design and Operation of a Safe Automated Highway System," by Anthony Hitchcock, dated March 1994.

> We must first define terms. Operation in platoons means that vehicles follow one another very closely (our nominal close intraplatoon spacing is 1 m), in groups of between 2 and about 20. Between platoons there is a gap of 60-80 m or more, which is such that vehicles in a following platoon can brake to rest if a leading one stops as quickly as it can. Dividers are physical barriers between lanes. They contain gates, gaps in the dividers (no moving parts!) through which vehicles can change lanes. We permit two kinds of dividers. The first is a high divider, probably 0.7 - 1.2 m high, (Figure 2) which will resist cars approaching perpendicularly. The second is a low divider, (Figure 3) which will permit

a car door to be opened over it, and is ankle-high. Dividers must be designed not to present a danger if struck end on at a gate.

In the preferred design, automated vehicles operate, in platoons, on one or more automated lanes (AL), from which manual vehicles are excluded. Entry and exit are from a transition lane (TL), which is separated from the ALs by a divider. Entering vehicles join at the immediate rear of an existing platoon: If more than one has to join the same platoon, they do so as a preplatoon which has been formed, at low speed, on the TL . . . acceleration of the preplatoon occurs on a stretch of the TL called the entry maneuvering length (EML) of which part at least is separated from the manual lanes by a high divider, while between EML and AL there is a low divider (permitting communication and sensing). The EML is probably of AL width, narrower than the parts of the TL open to manual vehicles.

Platoons are considered to be the safest way of moving vehicles. If a vehicle in a platoon has a failure, the following vehicles in the platoon may have low relative impact speeds that cause minimal injuries to occupants, but following platoons will have enough space to be slowed or stopped. The divider would prevent a crippled platoon from straying into other lanes. The author says the accident rate should be less than 10% of the current freeway accident rate, but it is impossible to prevent all accidents. The few accidents that do occur will probably be multi-vehicular, hence, more spectacular in a news sense. Other miscellaneous information from the report:

- Automated lane widths could be about eight feet wide.
- The safety analysis assumed only cars and light trucks in the automated lanes. Trucks and buses might need to be in their own automated lanes.
- A previous analysis, assuming an automated lane was added to the Santa Monica freeway, which now has about 8 fatal accidents per year, would add 0.4 of a fatal accident if dividers were used with the automated lane, but 4-5 fatal accidents per year (ten times as many) if dividers were not used.
- As usual there will be trade-offs between cost and performance (includes capacity and safety).
- Estimate 6000 vehicles/lane/day with an automated lane versus 2000 vehicles/lane/day maximum with a conventional lane.
- Fence (divider) materials and height might be controlled in part by requirements for electronic communication between highway and vehicles.
- As new vehicle safety components are developed (building blocks in the AHS), they can be evaluated for safety by determining what types and how many injuries they would prevent. In depth accident data, not now available in quantity according to the author, would be needed for this type of analysis.
- Gates (gaps) in the dividers are about 80 m long.
- The AHS is designed so no single fault will cause an accident, only multiple faults occurring simultaneously will do that. Faults are not uncommon and two or more may interact.
- In the AHS, driver errors are replaced by designer errors. The AHS must be designed by "complete verification" and the design must be verified as safe using a fault tree analysis. Separate teams must perform these two critical tasks.
- The author claims 90% of road accidents are now caused by human error.

One of the key features of AHS is that vehicles will be able to receive information from receptacles along the highway. These information stations may also be gathering traffic information from counters, TV cameras etc. to be fed into traffic operations centers. This could require many posts, poles, blocks or other fixed objects to mount the electronic devices that are needed. Already, we have seen a "forest" of call boxes erected which may be used later to support other information systems also. In the near future we expect to see numerous closed circuit TV towers erected on the roadside. Perhaps some of these devices will be mounted on the dividers mentioned above.

This has been a long detour to sketch a possible AHS scheme. It seemed relevant to me because I just became aware that barriers (or "dividers") may be critical elements in an AHS. The author spent almost no words describing the barriers he needs, and his concept sketches appeared relatively naive. Thus, it seems clear to me we need to make some strong links with the AHS community, work with them on suitable barrier designs and draw on our 40 years of experience with barrier analysis and testing.

THE OLDTIMER STICKS HIS NECK OUT WITH THE FLUME CONCEPT

Having mulled over the foregoing ideas, I have tried to speculate on some possible future barrier designs. Again, I should emphasize that the ideas which follow are intended to provoke discussion, and, if there is interest, would lead in the future to some rigorous studies with input from many sources to work on an "ideal" future freeway cross section. This search for the ideal roadside hardware system may be part of our strategic plan. Following is a proposal for busy urban highways that could be called a "flume freeway" design. It is intended to channel traffic just as a flume channels water, even when the flow is turbulent. This design is all concrete for strength, durability, appearance and flexibility to handle a range of vehicle sizes. It is a continuous barrier with no gaps and placed on the outer edge of the shoulder. it assumes more impact resistant vehicles. It attempts to capture vehicles rather than rebounding them. It prevents vehicle rollovers. It shields all roadside obstacles behind the barriers from possible impact. It can be slipformed and is easy and inexpensive to construct. It lends itself to separation of traffic by vehicle size as noted in the figure. Whereas placing guardrail and bridge rail here and there is a "gambler's approach" and a "band-aid approach" (trying to guess the locations where accidents will occur), the proposed design is a complete continuous solution. It can easily be adapted to contain AHS information equipment. It may be an appropriate transition into the AHS era highway. It may be desirable to provide separate roadways for trucks over 20,000 lbs. or to down size trucks into 20,000 lb. modules that are three or four modules long. This would help keep the standard concrete barrier down to a reasonable size. The continuous concrete barrier could house or support any AHS equipment as needed. The curb/wheel trap trough probably wouldn't work as shown. It is included to represent the desire for 1) a method of trapping vehicles, rather than reflecting them back into traffic and 2) minimizing the chance of rollovers.

High traffic volumes and limited access on urban highways may make the flume freeway design a reasonable approach. On rural highways there may be many locations where a flat, wide, clear roadside completely free of obstacles is the ideal to shoot for. Some rural highways, however, may warrant the flume approach because there is no other completely safe solution. This might be true on narrow mountain highways that can barely have room for a shoulder, let alone a clear roadside. Once even the most safely designed vehicle goes over a steep embankment, there is little chance of saving the passengers other than by pure luck (vegetation on the slope that slows the plunge). A continuous concrete barrier that did not deflect when struck would prevent all embankment accidents.

If it was placed on the other side of the highway also, it might serve to trap rockfalls as well as contain errant vehicles. We have not placed continuous barriers on mountain highways in the past. Perhaps we have not placed a high enough value on saving lives and preventing injuries, and a good barrier system should be on every design checklist, just as environmental concerns have been added to design checklists in recent years.

Many rural highways and urban streets do not fall into the clear cut design categories above. At these locations we must still use a combination of strategies including the clearing of roadside obstacles to the maximum distance possible (including on city streets), adding roadside safety hardware where necessary and setting speed limits that relate to current vehicle safety design. And perhaps we should lobby for AHS facilities to reach these areas as soon as possible. Where continuous barriers were impractical, speed limits could be set based on vehicle impact survivability speeds, assuming there continue to be more improvements in vehicle safety. Not much attention has been given to the needs of local agencies in our roadside safety community. This is fertile ground to do research on safety solutions specifically for local areas.

The Whole Enchilada: The Power of Positive Thinking. Within our own roadside safety community I observe much cooperation, information sharing and consensus building. I would urge we continue this kind of positive approach as we begin dealing with the broader highway safety community. Again, let us employ expert consultants, as needed, to help us with"win win" conflict resolution of critical issues. Where we are proposing or supporting legislation or new rules, let us promote the use of rewards instead of penalties to provide motivation to make changes in an organization or program. Let us reach decisions by consensus rather than by vote whenever possible. Let us be open minded about promoting the best ideas whether they came from our agency or somewhere else. This suggestion may have a Pollyanna sheen, but I am convinced there is much power in positive thinking and acting.

SUMMARY: SECOND CHANCE FOR THOSE WHO DOZED IN THE MIDDLE

Following are some future trends that are either under way or should be soon:

1. Establish high-quality HSMSs in every state DOT.
   a. Pass legislation to ensure they have adequate funds and personnel for a continuous ten year period.
   b. Promote good management practices in state HSMSs and hire well-qualified professionals in the

fields of organization and management to assist with some parts of the program.

c. Pass federal legislation with model civil service rules and reward state DOT's which adopt these or similar rules in order to staff the HSMS's with well trained and zealous persons.

d. Pass federal legislation requiring bi-yearly national meets of state HSMS personnel with funding for travel and meeting expenses to enhance communication of good ideas.

e. Use the HSMS to help initiate robust programs to quickly remove the most obsolete roadside safety hardware.

2. Coordinate long-term roadside safety goals and research with the Automated Highway System community.

3. Communicate and coordinate efforts between the highway safety community and the auto industry to improve vehicle/highway compatibility, thus lessening the severity of accidents.

4. Encourage highway safety constituency organizations that could educate the public and lobby legislators on behalf of the highway safety community.

5. Continue a multifaceted approach to solving roadside safety problems.

6. Brainstorm roadside safety barrier schemes that reflect current trends, will work short term and long term and that limit the number of schemes used by states to a small collection of simple and cost effective designs. This exercise might help state DOTs get a vision of their long-term goals in roadside safety.

7. Continue work on computer programs that simulate vehicle/barrier/roadside geometry impacts.

8. Continue development of side impact test procedures, evaluation guidelines and test equipment, and coordinate with the auto industry.

9. Participate in a rigorous process to formulate a strategic plan for improving roadside safety that defines specific tasks and time goals; establish a communication network, if possible, by newsletter or computer; make plans for regular gatherings of the broad highway safety community to report results of the assigned tasks and to review and update the strategic plan.

10. Give higher priority to preventing roadside accidents than softening them, while continuing to improve ways to lessen the severity of roadside accidents that still occur.

11. Use positive methods of conflict resolution, motivational rewards and consensus building to reach safety goals when dealing with all members of the highway safety community.