ROADSIDE SAFETY: AREAS OF FUTURE FOCUS

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Within the past ten years, this country and the world has undergone an unprecedented change. As Toffler described in his 1970 book *Future Shock*, life and information exchange is accelerating. We are firmly within his "third wave". Because of this rapid and accelerating change, it is proper and necessary for the TRB A2A04 Committee to attempt to visualize the nebulous future and then define a course of action. It is an honor to be asked to share my views and suggestions.

VIEW OF THE PAST

Before gazing into the crystal ball, it may be appropriate to briefly recall the relatively short history of roadside safety. Although several groups were working in the area of crash testing of bridge rails and guardrails in the early 1950s, many attribute "Day-One" to Ken Stonex when he reasoned that highway safety should be patterned after industrial safety in which workers are assumed to be non-perfect humans who may commit an unintentional error. His 30-ft wide "forgiving roadside" was recognized by AASHTO and the U.S. Congress in the late 1960s and was incorporated into the Interstate Highway System. the reduction in the rate of single vehicle ran-off-the-road fatal accidents has clearly shown the efficacy of this powerful concept. The basic concepts of the "forgiving roadside" and "clear zone" have not changed and should remain the underlying principles for roadside safety.

In 1966 the annual traffic fatality rate was 5.5 fatalities per 100 million vehicle miles traveled (100 VMT) but had declined to 2.1 per 100 VMT by 1990. If the 1990 fatality rate had been the same as the 5.5 rate in 1966, the 1990 traffic fatalities would be 118,000 rather than 44,529. This improvement has been achieved through the dedicated effort of every segment of the highway community, including the roadside design group.

As shown in Table 1*(1)*, single vehicle crashes, which are most affected by roadside design technology, are analyzed by roadway function and rural/urban setting. Roadside safety upgrading is beneficial at locations where an improvement can achieve a significant reduction in single vehicle accidents. Where the urban and rural interstate have low rates for single vehicle crashes based on 100 VMT, the rates based on highway length (i.e., 100 miles) are the highest. This table suggests that further improvement to the interstate may be needed such as premium barriers, flatter embankment slopes and increased clear zone widths.

PLAN FOR THE FUTURE

This TRB committee has achieved outstanding success in the past thirty years due to a number of factors including being in an active research area, having an active membership and producing timely and important results. This task is far from being accomplished; and it is most important to make plans for the future. As suggested by Ray, Carney and Opiela *(2)*, there are at least sixteen research issues worthy of attention. It is my recommendation that the A2A04 Committee should concentrate its effort in four primary areas.

Focus on Major Problems

In Table 2, Viner *(3)* has identified overturns, trees and utility poles as the top three most harmful events or roadside features involved in ran-off-the-road fatalities. A reduction of even a modest ten percent from the 9364 fatalities from the three events translates into a $1 billion savings in annual societal cost (using a nominal $1 million per fatality).

Effectively addressing the three events may require an approach that deviates from the committee's "hardware development/crash test" mode to a mode that involves more roadside design applications, benefit-cost analyses and development of model roadside design for various types of highways and streets. Some thoughts on the three events are discussed in the following paragraphs.

Overturns

There is a need to further define the various mechanisms that cause vehicle overturns and the biomechanics of occupants resulting in injuries and fatalities. The effects of curbs, embankment slopes, soft and/or non-uniform terrain, fixed objects and other

TABLE 1 1992 FATAL ACCIDENT REPORTING SYSTEM: SUMMARY OF SINGLE VEHICLE CRASH DATA (*1*)

ROADWAY FUNCTION	VMT (million)	MILEAGE	SINGLE VEHICLE FATAL CRASHES	SINGLE VEHICLE CRASHES/ 100m VMT	SINGLE VEHICLE CRASHES/ 100 miles
RURAL					
INTERSTATE	204,960	33,027	1,237	.60	3.75
PRIMARY ARTERIAL	196,153	94,798	1,020	.52	1.08
MINOR ARTERIAL	146,723	137,637	1,414	.96	1.03
MAJOR COLLECTOR	184,326	434,175	2,779	1.50	.64
MINOR COLLECTOR	49,945	284,706	870	1.74	.31
LOCAL	98,986	2,132,212	2,175	2.20	.10
URBAN					
INTERSTATE	302,091	12,466	699	.23	5.60
OTHER FREEWAY OR EXPRESSWAY	137,959	8,465	463	.33	5.47
PRIMARY ARTERIAL	344,195	52,165	1,004	.29	1.92
MINOR ARTERIAL	260,507	80,368	776	.30	.97
COLLECTOR	115,631	82,652	372	.32	.45
LOCAL	198,352	549,039	1,018	.51	.19
	2,239,828	3,901,715	14,019	.63	.36

features should be quantified. Computer models such as HVOSM may require further enhancement to more adequately simulate tire behavior and non-ideal tire/soil interaction. Potential solutions may include recommendations for wider paved shoulders, more gentle embankment slopes, and slopes with a specified degree of smoothness and compaction. Further analyses of current accident data bases and enhancement of accident investigation programs may be warranted to refine rollover severity in terms of the number of rolls, vehicle passenger compartment deformation, speed of vehicle prior to roll, etc. For crash test assessment, there is a need to know whether a quarter roll of a vehicle after impact with a test device should be basis for failure. It is noted that the vehicle rollover event is also a concern of NHTSA and having a NHTSA staff member on the committee will be beneficial.

Trees

The roadside safety community has been timid and cowed by environmentalists into a near complete "hands-off" policy with regard to trees located within the clear zone. While an "Atilla the Hun with Chain Saw" approach is not advocated for solving the tree problem, there are many missed opportunities in which a tree or a group of trees can be and should be removed without significant adverse effect to the environment. Most importantly, a case should be made that in the future trees should not be planted in the clear zone.

Several suggestions with regard to addressing the tree problem would include the following tasks:

1. Assist in the establishment of a special task force within TRB to concentrate on trees as traffic hazards. Membership would include representatives from A2A04 and A2A05 (Landscape and Environmental Design), ITE, county engineers, urban planners, etc. Specific goals of the task force would be to develop model roadside design standards for highways and streets that consider landscape features, mailboxes, bus stop shelters/benches, signal and luminaire poles, etc. Models would be devised based on operating speed and volume of traffic. It is anticipated that the model development would follow extensively funded research

TABLE 2 HARMFUL EVENTS IN RAN-OFF-ROAD FATALITIES

Harmful Event	First Harmful Event	Most Harmful Event	Change MHE-FHE	MHE as % of FHE
Tree	2,870	3,246	376	113
Overturn	2,492	4,820	2328	193
Utility pole	1,235	1,298	63	105
Embankment	1,187	601	-586	51
Guardrail	1,101	456	-645	41
Ditch	750	302	-448	40
Other	565	613	48	108
Culvert	537	281	-256	52
Curb	506	117	-389	23
Other fixed object	461	219	-242	48
Other post	457	237	-220	52
Fence	421	156	-265	37
Sign post	295	99	-196	34
Bridge pier	211	255	44	121
Concrete traffic barrier	211	83	-128	39
Bridge rail	194	118	-76	61
Luminaire support	148	146	-2	99
Wall	143	127	-16	89
Boulder	133	76	-57	57
Bridge end	122	95	-27	78
Building	101	143	42	142
Immersion	98	354	256	361
Shrubbery	66	13	-53	20
Other noncollision	53	40	-13	75
Other traffic rail	33	16	-17	48
Fire hydrant	28	9	-19	32
Impact attenuator	7	3	-4	43
Overhead sign post	6	11	5	183
Unknown	4	272	268	6800
Fire/explosion	0	292	229	-
Totals	14,435	14,435	0	100

and study programs and ideally would be endorsed/adopted by AASHTO, ITE and others.

2. Based on benefit/cost analytical procedures, develop simplified methods that can be used by sub-professional personnel to identify trees critical to traffic safety. Recognizing that 74 percent of the nation's highways are administered by other than federal and state agencies, it should be assumed that tree decisions will be made by individuals with minimum technical skills with regard to roadside safety.

3. Develop typical standards for shielding trees that cannot be removed for political or other reasons. Such standards would reflect traffic operating speed and volume, offset distance, etc.

There are certainly other potential solutions to the tree hazard problem and these may be developed by research studies and/or brainstorming sessions within the special task force.

Utility Poles

Utility poles are unique items in the right-of-way (ROW) as they are usually owned by other than the transportation agency and are allowed to be placed in the ROW by agreement or franchise. In many cases, the pole owners have wide latitude where the poles are placed and have little incentive to relocate an existing

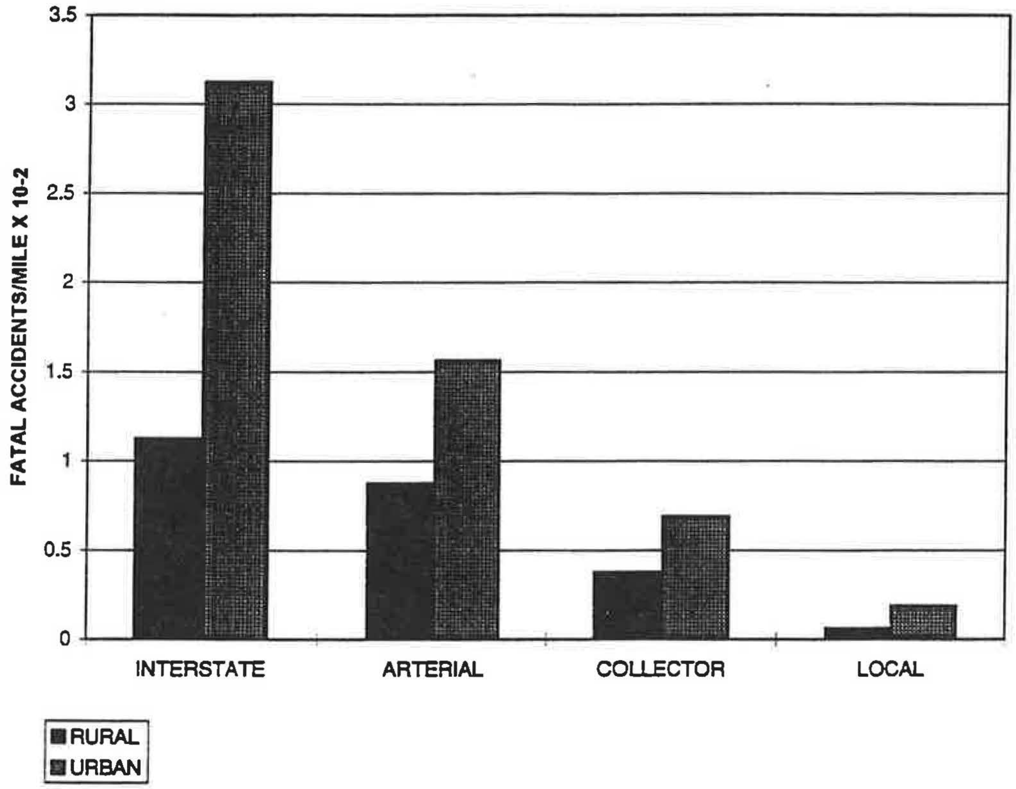

FIGURE 1 Comparison of rural and urban single vehicle ran-off-road fatal accident rates (*4*).

pole. Current National Electric Code considers a utility pole located as near as 18 inches from a curb face as acceptable, regardless of traffic characteristics. Evidently the utility industry considers the non-forgiving, cluttered roadside solely a highway agency concern.

Since 1975, FHWA has funded extensive research to develop methods to convert timber utility poles into fail-safe, breakaway devices with some success. However, it is evident that the breakaway design will not be a total solution; it will be necessary for the highway and utility agencies to employ complementary techniques such as burying service lines and/or relocating poles further away from the traveled way.

To focus on the utility pole problem, the A2A04 committee should push for the formation of a special task force with representation from TRB Committee A2A04 and A2A07, from AASHTO, FHWA, ITE, and National Electric Code committee. Examples of goals for the task force would include:

1. Development of pole placement procedures as related to highway geometrics, cross section and traffic characteristics.
2. Development of model roadside design cross-sections for various classification of highways and streets.
3. Development of model franchise/easement agreements that will insure preferred placement of new poles.
4. Investigate pole/foundation design that minimizes need for guys and stub poles.

Admittedly the three problems of vehicle overturns, trees and utility poles may presently be outside the main stream of the committee's technology and interest, but nevertheless the three problems should be addressed vigorously. Otherwise the roadside safety community will be like the befuddled drunk who searches for his keys under the street light even though he knows he dropped them somewhere else. Vehicle overturn, trees and utility pole problems are presently in the dark.

Focus on Urban Highways and Streets

To date most roadside applications have been directed to rural highways with high-speed, high-volume traffic with less attention given to urban highways and streets. Yet a significant number of single vehicle ran-off-the-road fatal accidents occur in urban areas as shown in Figure 1 *(4)*. The urban highway roadside has probably been avoided because it poses a more difficult set of problems, namely more clutter, more environmentally sensitive features and a more constricted right-of-way. It is time that the urban roadside problem is tackled.

A strategy that the committee could employ would be based on a long term solution. As a first step, a series of roadside design models should be developed for inclusion in AASHTO and ITE documents that would provide guidance for new construction. Second, a new array of crash-safe features peculiar to the urban area should be developed; items that come to mind include fire hydrants, newspaper boxes, signal poles, mail boxes, and luminaire supports. Attention should be given to curb design including driveway and wheelchair access. And finally, safety upgrading should be applied to existing streets where it is cost-beneficial. Certainly when streets are rehabilitated, techniques to select roadside features to be upgraded should be available.

Refined Benefit-Cost Analysis

Safety upgrading of roadsides has been limited to finite allocated funds. Only in recent years with development of benefit-cost analysis models has the potential of roadside safety expenditures been more clearly defined. Unfortunately, effectiveness of roadside safety has been a well kept secret to the detriment of both research and implementation funding. Based on crude measures of accident reduction and sometimes understated benefits, roadside safety upgrading has been shown to be a very attractive investment for highway agencies. As shown in Table 3 benefit-cost ratios for highway safety improvements for period 1974-1991 range from 1.5 to 12.1*(5)*. These numbers are impressive and should be broadcast to the public.

It is recommended that such B/C models as FHWA Roadside 5 be further developed and refined, in particular accident prediction modules and severity indices. With improved and more extensively validated B/C models and with similar injury and fatal costs used by other organizations, it will facilitate the comparison of returns on investment in roadside safety with say air traffic safety or environmental cleanup. Importantly, the committee must be less timid in publicizing to the general public and funding agencies the attractive returns from roadside safety upgrading investment.

A second area of use of improved B/C models will be to develop/revise guardrail and median barrier warrant curves. Standard guardrail layouts should be examined including typical offset and flare rates. Longitudinal traffic barriers are performing much better than previously thought, although layout and sloping terrain are not always addressed satisfactorily*(6)*.

Innovative techniques to further refine and validate the B/C models should be examined, in particular the encroachment prediction module. For instance, breakaway luminaire supports located within the clear zone of a high traffic volume highway can be monitored for knockdowns. Generally, the breakaway pole is knocked down in every impact, so every impact is known and there is little likelihood for error in estimating non-reported accidents. In San Antonio, poles are routinely struck on a section of Interstate 410, and data such as these should be useful in validating the assumed vehicle encroachment rates. Also, frequency of vehicles running down and being trapped at the bottom of selected steep embankments could be another source of comparative data. There are probably a number of other useful techniques that should be explored.

Improved Roadside Feature Application

For the past ten years, several members of the committee have had the opportunity to critically examine safety features involved in vehicle collisions. It has been disappointing to find that all too often the safety features were not properly laid out and/or installed; on many occasions it has been concluded that these deviations led to performance failures and unnecessary injury and fatal accidents. The most glaring deficiency has been longitudinal barrier systems that did not adequately shield the identified hazard, mostly being too short. Another example is the approach guardrail to a bridge that while doing its job in shielding the bridge rail end failed to shield the embankment length of need hazard. Breakaway cable terminals (BCTs) have been improperly installed without the necessary 4-ft offset and parabolic curve in W-beam; both factors were determined to be essential to performance in numerous developmental crash tests but were too quickly "adjusted" to adapt to local conditions. Even one of the more recent safety devices, the ET-2000 guardrail terminal, is being installed immediately behind a 6-in. barrier curb, certainly a condition not evaluated in crash tests. These are just a few examples. These deviations exist on the Interstate System and in most states although they are more common on other highways.

Obviously if the highway safety features are not properly installed and maintained, they will not accomplish their intended purpose. It seems rather absurd that researchers are "tweaking" advanced technology features for peak performance with complex, multi-degree of freedom simulation models while the installers are completely defeating the device with careless or uninformed methods. This is a serious problem!

TABLE 3 HIGHWAY SAFETY IMPROVEMENTS WITH THE HIGHEST BENEFIT-COST RATIOS, 1975–1991 (*5*)

Rank	Improvement Description	Benefit-Cost Ratio
1	Illumination	12.1
2	Upgrade Median Barrier	8.0
3	Traffic Signs	7.3
4	New Median Barrier	4.9
5	Upgrade Guardrail	4.6
6	Remove Obstacles	4.5
7	Upgrade Bridge Rail	4.3
8	Upgrade Traffic Signals	3.2
9	Impact Attenuators	3.2
10	Improve Sight Distance	2.8
11	Improve Minor Structure	2.7
12	Groove Pavement for Skid	2.6
13	Median for Traffic Separation	2.2
14	New Railroad Crossing Gates	2.1
15	Turning Lanes and Channelization	2.0
16	Upgrade RR Crossing Flashing Lights	2.0
17	Flatten Side Slopes	1.7
18	New RR Crossing Flashing Lights	1.6
19	New RR Crossing Lights & Gates	1.5
20	Guardrail End Treatment	1.5

Source: FHWA, Highway Evaluation Safety System

There are several areas that researchers need to address. First a better job must be done in developing simple, forgiving features that are less sensitive to installation variation and maintenance needs. For example, the concrete safety shape exhibits a wide range of dynamic performance while requiring a minimum of routine and damage repair maintenance. On the other hand, the height of the 12-in. W-beam guardrail must be maintained within a narrow range of height tolerance to prevent either vaulting or submarining of impacting vehicles. Conservatively, it should be assumed that safety features will receive minimum maintenance

TABLE 4 U.S. HIGHWAY MILEAGE CLASSIFIED BY ADMINISTRATIVE RESPONSIBILITY (FHWA 1992a, DOC 1993) (7)

Administrators	No. of Agencies	Miles (%)
Federal agency	5	182,411 (5)
State agency	51	800,589 (21)
County agency	3,043	1,726,629 (44)
Town and township	16,666	483,631 (12)
Municipal	19,296	526,232 (13)
Other local	-	182,244 (5)
Toll highway authority	-	4,692 (<1)
Total	39,061	3,901,715

and/or adjustments after installation and that the features must function under unusual but expected environmental conditions.

Second, it should be assumed that safety features will be installed by individuals who are non-engineers, who are not familiar with roadside design principles and who may deal with safety features on an infrequent basis. As shown in Table 4 *(7)*, only 26 percent of U.S. highways are administered by federal or state agencies; the remaining 74 percent are counties, towns, cities and others which may lack technical expertise in roadside safety. Accordingly the technical documents and instruction manuals must be simplified. For instance, the 1989 AASHTO Roadside Design Guide is probably too complex for most county and city transportation departments. Current TRB documentation seems to be more attuned for communication among researchers but apparently ineffective in instructing the local users on where and how to properly install the devices. FHWA has devoted considerable effort to "technology transfer"; however, judging by the number of faulty installations, one could certainly conclude that more effort by all is needed.

There are of course other worthy areas of roadside safety which need to be addressed; however, it is important that the committee's effort be concentrated on those items with greatest potential payout. The four areas presented in this paper are believed to meet this criterion.

In closing, a perspective is given on three unrelated topics. First, with regard to the IVHS program, the committee should not be dazzled by futuristic plans that could divert our attention and limited resources away from more mundane rollover, tree and pole problems. The reduction in rollover, tree and utility pole fatal accidents is where roadside safety will pay off and where our focus should be.

The committee should continue as it has in the past to keep the relative importance of various research tools in proper perspective, particularly the relative roles of full-scale vehicle crash tests versus computer simulations. Most researchers who have conducted full-scale crash tests are not satisfied with the sometimes crude tests, using old vehicles and imprecisely controlled and recorded conditions; economics is generally attributed as the limiting factor. On the other hand, with exploding computer capabilities and development of more sophisticated simulation programs, many see the more universal use of this tool as the wave of the future. Maybe. However, the efficacy of the simulation program continues to be limited by realism of the input data (i.e., garbage in, garbage out) which becomes even a more challenging task as the simulation programs become more complex.

Finally, with the growing presence of airbags in the vehicle fleet, several researchers have mentioned the possibility of relaxing the occupant risk factors that assume unrestrained occupants. This may not be a good idea for two reasons. The airbag provides little if any side protection for redirectional impacts with longitudinal barriers. Second, time duration that an airbag is effective (i.e., fully deployed) is between 40 and 120 ms. For a crash cushion or energy absorbing terminal, the airbag restraint would not provide any protection for events that generally range beyond 120 ms. Moreover, maintaining the vehicle upright after a breakaway support test may be the limiting factor and not the occupant risk factor.

One might ask if roadside safety technology development has reached or is reaching a point of diminishing returns? The answer is an emphatic *no*. With over 14,000 ROR fatalities each year, there is a great opportunity for improvement. The overriding goal should be to reduce this number.

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