be the sole cost factor to be considered in selecting one of several candidate designs or systems. For example, a well-designed cable-type median barrier may be less costly to install than a concrete barrier. However, if installed in the median of a relatively heavily traveled urban freeway, it will be frequently hit unless the median is quite wide. Each hit would result in costly repair to 25-100 ft. of barrier whereas the concrete barrier would be relatively maintenance free. Thus, repair costs become a significant part of the total cost of a cable barrier over its service life. In addition, maintenance and repair effort in the median of an urban freeway is a hazard to maintenance personnel as well as to the traveling public, which can result in additional loss of life.

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

HARDWARE PERFORMANCE AS AFFECTED BY SITE CONDITIONS

Maurice E. Bronstad, Southwest Research Institute

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

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

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

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

DESIGN REQUIREMENTS--DATA NEEDS

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

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

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

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

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

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

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

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

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

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

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

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

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

COMPUTER SIMULATIONS--LIMITATIONS AND DATA NEEDS

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

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

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

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

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

Table 2: Limitations of Computer Simulations of Appurtenance Collisions

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