SAFESTAR

European Effort To Establish Safe Road Standards

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The level of road safety is determined largely by the features and layout of the highway infrastructure. Proper road design can limit the human errors that result in accidents. Indeed, it has been estimated that improvements in roadway engineering have been a primary factor contributing to the recent reduction in highway casualties in countries of the European Union.

Scope of SAFESTAR

Standards play a vital role in highway design, yet the knowledge needed to support the development of such standards is lacking in many respects. The SAFESTAR (Safety Standards for Road Design and Redesign) research study was undertaken to fill some of these knowledge gaps.

SAFESTAR was a cooperative effort among nine institutes representing eight countries: the Czech Republic, Denmark, Finland, France, Greece, Portugal, Sweden, and the Netherlands. The study was focused on traffic safety for the trans-European roadway network that links the major European centers. Particular emphasis was on the following topics:

- Emergency lanes and shoulders along motorways
- Tunnels located on motorways
- Express roads
- Cross sections of rural roads
- Curves in rural roads
- Major junctions on roads in urban areas
- Road safety audits

Investigation of the above topics was focused on differences among current and emerging design standards of individual European countries. Of particular interest were the differences among the eight countries participating in the study. Efforts carried out under the study included integrating and analyzing knowledge gaps and developing procedures for safety audits. Recommendations for designing a new or modified road infrastructure were also formulated.

SAFESTAR Study Topics

Emergency Lanes and Shoulders Along Motorways

Many highway accidents are associated with the design and use of emergency lanes. Moreover, many injuries are attributable to the presence of obstacles on the shoulder and poor shoulder design. SAFESTAR examined the nature and degree of danger in the emergency lanes and shoulders of European motorways. The various measures currently being employed to correct these problems were then inventoried and analyzed. Finally, the study explored in depth the criteria for applying various kinds of safety provisions, such as safety barriers.

Tunnels Located on Motorways

Roadway dimensions within tunnels are often smaller than those elsewhere. Tunnels also pose limitations related to visibility and lighting conditions. Moreover, entries and exits within long tunnels can result in problems during merging in substandard conditions, as compared with entries and exits on the open road. SAFESTAR selected a tunnel design deemed optimal according to expert opinion. This design was then tested in a driving simulator.

Express Roads

Express roads perform an important function for both long-distance and local and regional traffic. Yet these kinds of roads, which remain prevalent in Europe, are known to be relatively unsafe. SAFESTAR charted the dangers of express roads and in so doing analyzed the reasons for choosing this type of road. Attention was also given to the future development of express roads—whether the problems associated with these roads will disappear with the construction of additional (semi-)motorways, or the situation will worsen with increasing traffic volume. Recommendations for safe express road design and for the circumstances under which such roads should be constructed were then formulated.

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Under the Safety Standards for Road Design and Redesign (SAFESTAR) study, the quality of various kinds of marking and signing for curves in rural roads was evaluated on the basis of trips taken by test subjects driving specially equipped vehicles.

Cross Sections of Rural Roads

The cross section of a road determines to a great extent the kinds of traffic situations, as well as the types of accidents, that can occur on that road. Frequently on a narrow road, for example, slow-moving and fast-moving vehicles hinder one another, overtaking occurs, and it is difficult for road users to get out of each other's way. SAFESTAR evaluated differences among cross sections in light of the characteristics of the accidents with which they are associated. One promising corrective measure (physical segregation of directions) was selected, and its effects were studied among test subjects driving vehicles equipped with special recording devices.

Curves in Rural Roads

Opinions differ widely with respect to the effect of curve design on the safety of rural roads. Two methods are employed in designing curves: use of models for speed profile and accident frequency, and investigation of driving behavior immediately before and in curves when different kinds of marking and signing are used. Improved calculation models should make it possible to assess curve designs for their safety aspects before roads are constructed. SAFESTAR evaluated the quality of the various kinds of marking and signing for curves by examining trips taken by test subjects in vehicles equipped with test devices and by testing certain new design elements in practical situations.

Major Junctions on Roads in Urban Areas

The design methods used for important junctions in urban areas vary widely, as do the numbers of vehicles and kinds of road users that encounter these junctions. In designing junctions, it would be desirable to have a mathematical model for predicting accident levels expected to occur once the junction was built or placed back in use after modifications. Such predictive models already exist, but require a great deal of improvement, especially with regard to the needs of cyclists and pedestrians. The existing models are also insufficient in the detailing of the design of the junction. SAFESTAR focused on obtaining an improved predictive model that would address these limitations.

Road Safety Audits

The aim of a safety audit is to assess the safety level of road infrastructure design. A design can be assessed at various stages: when a project is defined, during the design stage, during the detailing of the design (development of specifications), during construction, and immediately before the infrastructure is placed into use. Teams of experts not directly involved in a project perform the safety audit. Some European countries already have procedures for carrying out safety audits. As part of SAFESTAR, these procedures were studied with the aim of exploring their introduction in other European countries.

Recommendations

As noted above, SAFESTAR led to the formulation of recommendations aimed at facilitating the application of safety standards to road design and redesign. These recommendations included the following:

◆ The European Commission should pilot a road safety audit scheme and develop a protocol for conducting these audits, devise a code of practice for European road design, disseminate information on the safety aspects of road design, and stimulate cooperative research to support policy and design standards across Europe.

◆ National governments should set targets for improved road safety, provide the resources needed to facilitate achievement of these targets, and develop procedures and methods for road safety audits.

◆ Road authorities and those responsible for road design manuals and guidelines should adhere to three basic design principles (classification of

SAFESTAR study included examining major urban junctions such as this one in Voorburg, the Netherlands, with objective of creating improved mathematical model for predicting expected accident levels at such locations.

road systems into types with different design standards; designing to avoid simultaneous differences in speed, mass, and direction; and designing to facilitate the predictability of behavior in traffic situations); integrate the principles and practice of road safety audits into the design and construction processes; and incorporate new safety standards emerging from the SAFESTAR research (see box below).

◆ Research institutes should evaluate road safety audits, improve involvement in cross-national and pan-European research, and address in their research programs the requirements set forth in SAFESTAR reports.

Areas for Further Research

Motorways

Within the SAFESTAR project, some of the design characteristics of long tunnels were investigated, including the width of the hard shoulder (emergency lane), patterns on the walls and ceiling, and exits and entries within the tunnel. Other important characteristics remain to be investigated, including lighting conditions, lane widths, curves, slopes, restriction of sight distances, and variations in traffic volume.

In addition, accident risk on the hard shoulder can be established only with reference to data about

Safety Standards Emerging from SAFESTAR

Motorways

- The design of motorways should incorporate an obstacle-free zone at least 9 m wide on each side of the carriageway.
- Any inclines within this obstacle-free zone should be no steeper than 1 in 5 (20 percent) for slopes with a total height of more than 5 m. Where the total height is 2 m or less, the slope should not be steeper than 1 in 6 (17 percent).
- The median strip should have a width of at least 20 m, except where an appropriate safety barrier is used.
- Where sections of hard shoulder (emergency lane) are identified as having a greater than normal risk of accidents, they should be improved through an increase in width, the application of a rumble strip, or enhanced lighting.
- The road layout within a tunnel should not have a great effect on the road user's choice of speed. For example, the sudden disappearance of the hard shoulder (emergency lane) has a substantial influence on speed choice.
- At entries and exits situated within a tunnel, the road user should always have a clear view forward of at least 100 m.

Express Roads

- Use of express roads should be restricted to high-speed motorized traffic.
- The frequency of access and exit for such roads should be restricted.
- Vertical alignment over the brow (crest) of a hill (convex curve) should be such that the forward view is never less than the distance required to stop safely.
- Vertical alignment through a dip (concave curve) should have a minimum radius of 3,000 m.
- The lane width on both single and dual carriageways should be 3.5 m.
- The cross section of the carriageway should include a continuation of the paved area beyond the edge of the traffic lanes.
- The median strip should have a width of at least 20 m, except where an appropriate safety barrier is used.
- Where a safety barrier is used in a median strip, a recovery zone should be employed between the barrier and the traffic lanes. This zone should be wide enough to allow the recovery of vehicles to take place.
- The median strip should be free of slopes and obstacles.
- Where a single-carriageway road climbs a significant incline, a crawler lane (climbing lane) should be included on the uphill side of the road.
- Cuttings and embankments alongside the carriageway should not be steeper than 1 in 5 (20 percent).

Single-Carriageway Rural Roads

- Single-carriageway rural roads should have a lane width of 3.5 m.
- Shoulders on each side of the traffic lanes should have a width of 1.3 to 1.5 m, with a total carriageway width of approximately 10 m.
- Cuttings and embankments alongside the carriageway should not be steeper than 1 in 5 (20 percent).
- Obstacle-free zones should extend for at least 3 m on each side of the carriageway.
- The horizontal alignment of the road should remain consistent.
- Road marking and signing within curves should be based on the strategy tested under SAFESTAR.
- Poor perception of a curve during both approach and negotiation should be prevented by improved marking and signing, and by cutting back of vegetation that might obscure the view.
- The speed at which a curve is entered should be constrained by various devices.
- Situations in which a vehicle leaves the road should be prevented or ameliorated by the use of hard shoulders, safety barriers, and high-friction surfacing.
- Head-on collisions should be reduced by the use of ghost islands and hard shoulders.

Major Urban Junctions

- The design of major urban junctions should incorporate a clear view for an adequate distance for all road users, regardless of weather or lighting conditions.
- The layout used should ensure that crossing will occur only at low speeds.
- Junction type should be chosen according to the model and approach developed under SAFESTAR.
- Traffic streams should be arranged so as to avoid to the extent possible compromising both visibility and prediction of the behavior of road users.

Roadway tunnels pose unique safety challenges, such as narrowing of roadway dimensions and limitations related to visibility and light.

the number of accidents and the level of exposure to risk. There is a need for collection of these data.

More work is needed as well on the comparative cost-effectiveness of the different types of safety barriers. Barrier testing should also be carried out with regard to impacts by heavy vehicles, particularly those with a higher-than-average center of gravity.

Express Roads

If express roads continue to exist as a separate class within the road network, more work will be required on the comparative safety of motorways, express roads, and other interurban roads. There is also a need to identify which safety measures can improve safety on express roads without generating false expectations of adherence to motorway standards. Research is needed to determine what long-term strategy and level of standards will produce an acceptable level of cost-effectiveness for governments and authorities dealing with express roads.

Single-Carriageway Rural Roads

The design of these roads can currently be supported by the use of speed and accident models, but these models are in need of considerable improvement. The existing data require augmentation and refinement, and the variables modeled and the range of applications need to be extended and better defined. Another area needing further work is the effectiveness and availability of alternative methods for separating opposing traffic streams and avoiding accidents in which vehicles leave the road.

Major Urban Junctions

Although a great deal of experience has improved the current design of major urban junctions, there is a need for more investigative work with regard to cyclists and pedestrians, especially in terms of behavior, conflicts, and accidents. The design of junctions can be supported by accident models. However, these models still need a great deal of improvement with regard to the data (numbers and types of junctions, numbers and types of accidents), the model structure (types of variables), and the specifications for the range of applications (which design elements, which stage of the design, which type of junction, which country).

U.S. Efforts To Enhance Safety in Highway Design

Research is under way in the United States to encourage more explicit consideration of safety in highway design. The Federal Highway Administration is developing a computer-based Interactive Highway Safety Design Model (IHSDM) that can be used by state departments of transportation and their consultants to evaluate the safety of alternative highway designs. Typically, "safe" design has meant satisfying a set of minimum design criteria. Using the IHSDM, designers will be able to directly compare the safety of various alternative designs or to optimize the safety of a particular design as an integral part of the design process. The goal is to incorporate the IHSDM directly into the computer-assisted design packages currently used by highway designers.

Several National Cooperative Highway Research Program projects are also addressing ways to improve the consistency of highway design. NCHRP Project 15-16A, Superelevation Distribution Methods and Transition Designs, will develop recommendations for more consistent methods of designing the superelevation rate of a curve and the transition from a crowned to a supereleveated cross section. NCHRP Project 15-17, Geometric Design Consistency on Higher-Speed, Non-Urban, Two-Lane Roads, will develop guidelines designers can use to improve the geometric design consistency of roadway features on higher-speed, nonurban, two-lane roads. Inconsistent design of geometric features, such as alignment, intersections, and lane drops, can confound driver expectations and increase crash risk. Federally sponsored work is also under way to improve design consistency on low-speed urban streets where the roads are shared with vulnerable pedestrians and bicyclists.

Two recent NCHRP reports address issues related to safety in highway design: NCHRP Report 375 *Median Intersection Design* summarizes research conducted on appropriate median widths at rural and suburban divided-highway intersections; NCHRP Report 383 *Intersection Sight Distance* reviews research on driver needs for sight distance on approaches to at-grade intersections and provides recommended revisions to current policies on intersection sight distance design.

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