Improved Safety Information To Support HIGHWAY DESIGN

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Providing for the safety of motorists has long been a primary objective of highway design. This objective is presumed to be reflected in the design policies and standards adopted by highway and transportation agencies. It is true that safety is intended to be a factor in most decisions involving alternative designs. Yet the uneven quality of safety data and the inadequacy of the associated data management and information systems have limited the effectiveness of past efforts to incorporate highway safety in design decisions.

There is a growing commitment to improving the safety of the nation's highways. This commitment is manifest in such measures as provisions for safety in the recent Transportation Equity Act for the 21st Century and the adoption by the American Association of State Highway and Transportation Officials of an aggressive Strategic Highway Safety Plan, designed to reduce highway deaths by more than 6,000 annually by the year 2004. (See the March–April 1999 issue of *TR News*.) The success of these and other efforts aimed at improving highway safety will depend on having higher-quality data on which to base design decisions. Similarly, the movement toward flexibility in highway design—producing designs that fit environmental, community, or other local constraints—will demand that the highway profession improve its sophistication in developing and assessing alternative designs. These requirements are compounded by the fact that, despite the recent increase in highway funding, needs continue to outstrip the available funds, so that cost-effective design decisions remain essential.

National Cooperative Highway Research Program Project 17-12, Improved Safety Information To Support Highway Design, was conducted to address these issues. The project led to important insights on the role of safety analysis in the highway design process, current barriers to effective use of highway safety data, and strategies that can be used to overcome these barriers.

Safety and Highway Design

Safety-related activities that commonly occur within a transportation or highway agency occur at three levels—system planning, project design, and system management. At each level, safety information is needed for two basic purposes:

◆ To identify the existence and nature of safety problems at a particular location or systemwide

◆ To predict the safety impact of a particular design decision

An important aspect of the use of safety information is the nature and intent of the analysis to be performed. Transportation or highway agencies need safety data to support a wide range of activities, including those related to administrative and legislative issues, planning and design policy, programming of projects, and project-specific planning and design. For example, programming of planned improvements normally includes safety performance as a major criterion. Similarly, project-specific planning and design activities—including problem definition, identification of the project's purpose and need (necessary for an Environmental Assessment or Environmental Impact Statement), and development and assessment of alternatives—all require the use of

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Safety information is necessary to identify and characterize safety problems. Yet highway designers often regard data on crashes—such as location, cause, and environmental factors—as incomplete, lacking, or erroneous.

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safety data to be carried out properly. The assessment of design details, including consideration of design exceptions, often depends on evaluation of the safety trade-offs associated with building less than a full-standard design.

The public and design professionals alike are aware of the importance of safety in design. Previous research (NCHRP Report 376 *Customer-Based Quality in Transportation*) has shown that the public views safety as its highest priority. Moreover, discussions with design engineers during the course of NCHRP Project 17-12 revealed clearly that highway designers wish to address safety in their work. Despite its acknowledged importance, however, safety is often given inadequate consideration in design decisions (see Figure 1). This situation occurs because safety-related data are not of sufficient quality, because the necessary information cannot be readily produced, and because the necessary analytical tools are not available to designers. Moreover, designers typically lack all but the most basic training in highway safety; in most agencies, institutional knowledge and analytical capabilities are housed in offices or divisions separate from the design activities.

The implications of inadequate consideration of safety are significant. Designers tend to weigh those factors in which they have the greatest confidence when making design recommendations. Such factors include estimates of construction costs and quantified right-of-way impacts. Current design technology enables rapid computation of estimated construction costs and calculation of a range of different alignments. Ironically, technically complex environmental issues, such as the incremental noise impacts of designs and air quality impacts, are routinely addressed through the use of sophisticated models that assess quantitative impacts and provide precise values for assessing trade-offs. Public reaction to alternative designs also tends to carry weight. Advances in technology have helped focus public opinion in this regard. The ability to produce three-dimensional views of a design, to "drive" through an alignment for perspective, and to produce operational simulations of traffic all enhance public understanding of design alternatives.

In contrast, the state of the art of safety information and its importance in design decisions has advanced little during the past 20 years, for a number of reasons. The quality of safety data has long been suspect. Designers often regard information about crashes—such as their location, causes, and environmental factors—as incomplete, lacking, or erroneous. In addition, many designers lack formal training in highway safety. Finally, designers are taught that values contained in design standards and criteria are the minimum required for safe design practice. Designers tend to take the position that if a design meets the agency's standards, it is safe, and otherwise it either is or may be unsafe.

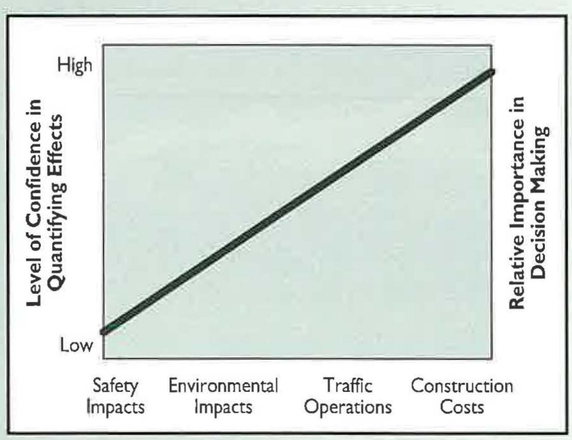

FIGURE 1 Consideration of safety and other factors in highway design.

Barriers to Effective Use of Safety Data

There are a number of barriers to the effective use of safety data in highway design. These include the way the data are collected, the way they are managed, and the way they are accessed and analyzed.

Safety Data Collection

Safety data come from a variety of sources, including law enforcement agencies and highway or transportation agencies. Under current practice, the quality of crash data derived from police reports is problematic. There are also problems with the types and quality of data collected by highway agencies on the highway environment, as well as dynamic data, such as traffic volume and speed. These shortcomings can be attributed in part to the fact that the agencies collecting the data are not doing so primarily for the purpose of safety analysis, but to meet other needs.

The main source of crash information is the police crash report. The information most important to designers—especially the location of the crash—is often missing from these reports. Because the reporting police officer has primary responsibility for securing the scene, ensuring that the injured are treated, and minimizing congestion at the crash site, he or she will probably not take the time to locate the specific points of impact or precisely record other roadway-related elements. Unfortunately, current trends in law enforcement can be expected to result in poorer-quality, instead of improved, data. Many agencies are no longer attempting to record and retain data on crashes unless a personal injury is involved or one of the vehicles requires towing from the scene.

With respect to the roadway, transportation agencies tend to focus their data-gathering efforts on infrastructure management issues, such as pavement and bridge conditions. Many data of critical importance to safety typically are not collected and maintained by highway agencies. For example, the character of the roadside is acknowledged to be among the most important factors affecting safety on two-lane rural highways. Yet few states maintain reliable records of roadside features or conditions that would be sufficient for use in design analysis or decision making.

Most agencies also do not inventory geometric features, such as horizontal and vertical alignment and intersections, in sufficient detail for use by a designer engaged in safety analysis. Yet these elements, too, are acknowledged to be associated with the frequency and severity of crashes. Similarly, although most agencies maintain traffic data, those data generally are not of sufficient quality to support safety decisions. Data on volumes of intersection movement and vehicle speeds are often lacking. Moreover, the frequency with which traffic volume data are updated may be sufficient for such applications as pavement management systems, but not for use in safety analyses.

Safety Data Management

Several aspects of data management must be improved if the barriers to effective use of safety data in design are to be overcome. Areas for improvement include establishment of linkages between databases, use of information not traditionally accessed by designers, and maintenance of historical files.

Valuable data are maintained for purposes unrelated to highway safety. These data are potentially useful for safety analyses but often are inaccessible. Examples include maintenance records (guardrail replacement, for example), pavement and bridge management systems, trauma records, and citizen complaints to police or highway agencies. Such data could offer insights to designers or safety analysts, but are typically not linked to safety data systems.

Most agencies do not maintain long-term records of changes in geometric conditions, traffic volumes, or other related conditions for specific locations. The ability to link geometric data with historical traffic and crash records is often limited to the last 5 years or so. The maintenance of time lines showing the progression of activity and operations over long periods is therefore not possible. If accessible to designers, these data would provide support for time-series analyses and other, more sophisticated before-and-after evaluations of the effectiveness of site-specific improvements, and would thereby enhance decision making for future designs.

A significant problem exists in location referencing systems for crash and other data. In many cases, the location reference is not precise enough or is missing. As a result, the analyst may be unable to generate the desired information because it is impossible to make a connection between historical crash patterns and related conditions (even given that the necessary data are available in the roadway inventory). Even if such linkage were possible, making the connection would be very time-consuming, and as noted, records often do not contain adequate information about longitudinal highway geometry. If the analyst wished to evaluate a change in geometry at a site, for example, a time-series analysis would probably be appropriate, requiring 10 years of data. However, the roadway inventory might not include history files, so the analyst would be unable to determine whether and when related changes to the highway had been made. Moreover, as discussed earlier, the analyst might not have traffic or other data available that would be of value in considering design changes.

Roadside character is one of most important factors affecting safety on two-lane rural highways, yet few states maintain records of roadside features or conditions that are sufficiently reliable and complete for use by highway designers.

Access to and Analysis of Safety Data

A designer who wants to conduct a thorough safety analysis must collate data from several independent sources, only some of which may be computerized. Usually, access to these data is not direct, but through some external office. Once the desired data are in hand, the designer, who is often not trained in the proper conduct of safety analyses, must decide how to deal with the data to generate meaningful information. Even if the designer can do this successfully, there remains the challenge of summarizing and presenting the resulting information in a useful manner. An agency could alleviate some of these problems by providing analysts to assist the designer. Nevertheless, many of the factors discussed above lead to two outcomes, neither of which should be viewed as optimal:

◆ Little, if any, quantitative analysis of safety data is done.

◆ The analysis that is done is performed only once. There is no opportunity to try more than one approach to the analysis, so that different perspectives can be obtained.

Addressing Safety Data Issues

A comprehensive approach is needed to address the problems discussed above. Such an approach must include development of an institutional framework within which safety decision making can be enhanced. Advances in technology for both data collection and management offer many cost-effective opportunities. Ensuring that data collection programs reflect sensitivity to the safety-related data needs of designers must also be part of the solution. Organizational strategies are needed as well, aimed at increasing the importance assigned to safety information.

Role of Technology

Most agencies employ to a limited extent technologies that could optimize their use of safety data. Technologies—including those for sharing of databases and for analytical and decision support—can be applied to data collection, management, and communication. With the advent of computer-aided engineering, highway agencies now have the ability to build and maintain detailed inventories of their systems by direct reference to computer files of as-designed roadways. It is likely that fewer than half of the states use portable computers, global positioning equipment, instrumented vehicles, and geographic information systems to support data collection. Even fewer use technologies aimed at improving data management, such as optical devices for reading forms and distributed databases for minimizing duplication and maximizing efficiency. There has been an increase in experimentation with new technologies among the states; some states, for example, link crash reports and medical data, and use modeling tools or decision support systems. Nonetheless, agencies are not yet taking full advantage of the powerful computer-aided tools now available.

Technology offers agencies an opportunity to improve the quality of data with less effort or cost than is currently being expended. In gathering data on traffic volumes, for example, computerized signal systems already in place can be exploited to monitor intersection turning movements, vehicle classifications, and speeds. Such data, captured and made accessible to a safety information system, could relieve agencies of having to conduct expensive manual or other counting programs that yield fewer data.

Need for Design Decision-Support System

Even if data quality and management were improved through strategies such as effective use of the latest technologies, the current highway design process would still lack a comprehensive means of providing easy access to the data and analytical support. A design decision-support system for safety is needed to address these needs (see box page 27). The framework for such a system should incorporate several elements, including a user interface, decision-support module, information presentation module, and design analysis module.

The user interface should be as intuitive as possible for both end-users and managers. Many designers work with computer-aided engineering systems, and the user interface should be designed to permit seamless operation within that environment.

In the envisioned design decision-support system, end-users (designers) would interact with the system primarily through the decision-support module, which would provide an "intelligent" core to the system. The information-presentation module would contain the basic software needed to display information either derived directly from the data stores or generated from the design-analysis module. The latter module would provide an arsenal of tools for the analysis of existing and proposed designs. It would be able to draw upon the best analytical tools available at any given time to facilitate identification of the underlying factors contributing to highway crashes. Those tools would allow the designer to investigate the data to the level of detail desired by performing a series of inquiries, each of which would probe further into the details available in the dataset.

For the envisioned system to be fully useful, new approaches to information display would be needed. For example, a collision diagram has historically been used to support analysis of the safety of a site. However, much could be done to enhance this traditional tool. An "intelligent" collision diagram could be created using the computer-aided engineering environment to plot symbols on accurate drawings of the site, with colors and other graphic devices used to highlight patterns and certain over-represented types of crashes. As another example, a time-line format could be used to present a variety of information about a given site. The juxtaposition of a selected set of crash, roadway, and traffic data could result in new insights about the dynamics of the location under study.

Analytical tools for testing and assessing proposed designs will also be needed. Such tools might include simulation of vehicle–driver dynamics, human factors–based design analysis procedures, models for predicting operational and safety outcomes of alternative designs, and economic analysis tools. The work under way by the Federal Highway Administration on developing an Interactive Highway Safety Design Model (IHSDM) will produce many of these tools. FHWA's IHSDM research program is a multiyear, multimillion dollar effort aimed at developing working tools for highway design support.

Organizational and Institutional Considerations

Even if tools such as those discussed above were available, organizational and institutional issues could limit their usefulness. Key among these issues is the need for an umbrella authority to integrate the various collectors, managers, and users of safety data.

The lack of such an authority results in unintegrated data files and computer tools, as well as dependence on data sources not oriented to the needs of the design community. Specific organizational and institutional strategies might include the following:

◆ *Policy actions*—giving safety data the status of strategic enterprise data; establishing safety-performance measures; requiring state and local agencies to participate in oversight of safety-data collection; and allowing access to high-precision, high-level, remote imaging for use in obtaining the data needed to document the physical highway environment.

◆ *Organizational actions*—reorganizing agencies to facilitate the efficient and effective collection, management, and use of safety data; establishing entities to provide specialized data and decision-support services, including quality assurance of data; and organizing state and local agencies into a cooperative safety-data collection and management function.

◆ *Legislative actions*—establishing and authorizing data collection and management functions with oversight over enterprise-strategic data for users within the state; and enacting legislation to enable the collection of data on real-time, on-board vehicle dynamics from vehicles involved in crashes.

◆ *Funding actions*—funding technological advances, comprehensive research, and training in the use of safety data; establishing mechanisms for cooperative funding of enterprise strategic safety data; and instituting performance-based funding for highway projects.

continued on page 42

Design Decision-Support System

Impact on Safety Analyses

Current Practice	Improved Practice
◆ Extensive manual assembly of safety data tabulations from different offices within and outside the design agency, requiring many hundreds of staff hours	◆ Direct access to a comprehensive data warehouse within a computer-aided design/geographic information system environment
◆ Manual inspection of hard copies of crash reports from microfilm records to correct coding errors	◆ Prescreening of data, including crash location, to minimize errors; immediate access to digital images of crash reports within a computer-aided design/geographic information system environment
◆ Labor-intensive translation of tabulations of key data into calculated fields and graphics using independent spreadsheets and graphics software into which data must be manually keyed	◆ Integrated statistical routines, business graphics, and advanced data-visualization software, including intelligent collision diagrams plotted on time lines of highway geometry and attributes
◆ Insufficient historical traffic data and history of site geometry	◆ Data warehouse with records of all available traffic counts and an up-to-date history of the physical attributes of a site
◆ Insufficient safety models and limited flexibility of data systems to provide support for positions taken on the hazards at a site and the effectiveness of proposed improvements	◆ Suite of design analysis models enabling assessment of existing and proposed designs from a variety of perspectives, making it feasible to produce a documented and defensible estimate of the safety impacts of alternatives
◆ Staff or specialists providing support for decisions on data use and analysis, conclusions to be drawn, and recommended improvements	◆ Central decision-support function within the system, providing the user with guidance at every step of the analysis
◆ Manual application of decision tools	◆ Suite of decision tools incorporating the latest developments in decision science, directly accessible with information generated by the system, based on the designer's previous work