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Improved Safety Information for Highway Design

This is an NCHRP digest of NCHRP Project 17-12, "Improved Safety Information for Highway Design." The project identified the critical safety information needed to support project- and policy-level decision making in highway design and to develop the fundamental architecture for systems to acquire, store, access, and use safety information in highway design. This digest is based on a draft final report prepared by Ronald C. Pfefer, Roy Lucke, Richard Raub, and Darrel Stoddard of Northwestern University and Timothy Neuman of CH2M HILL and other members of the research team.

INTRODUCTION

This digest provides details and concepts for improved safety information systems that will be of interest to highway designers, safety professionals, and information managers.

Although many call this the "Information Age," there are many areas where information has not been effectively and fully used, such as in highway design. Historically, limited information resources or the inability to link critical items of data have made it difficult to determine the safety associated with various roadway and roadside features. Consequently, explicit safety criteria for highway design have not been developed. As many DOTs have been restructured or cut back, there has been a trend toward reducing data collection and information management efforts related to highways. This project highlights the information needs to ensure that highways are built and operated safely, assesses the opportunities to apply emerging technologies to cost effectively capture and manage data, and describes concepts for information systems that would facilitate and enhance the processes to identify hazardous locations, select appropriate safety treatments, monitor system safety, and establish design guidelines and agency policies.

Highway designers lack the information to adequately reflect safety in their work because

- Data are not readily available with adequate quality to generate the desired information.
- Methods to derive information from the data are not adequate to assess potential problems and identify alternative solutions and their likely impacts.
- Information is not accessible to all users.
- Adequate tools are not available to use for making effective decisions about design, even when the designer has sufficient information.

When a highway design agency proposes plans to enhance safety and resistance arises from economic or other considerations, designers need information to

- Justify expenditures with the help of strong evidence of safety benefits,
- Withstand political pressures,
- Minimize exposure to tort-liability claims,
- Identify comparable sites to demonstrate the value of a proposed design, and
- Monitor the effectiveness of the design after implementation.

Help also is needed to assist the designer with the explanation and justification of a proposed design in a way that it can be readily absorbed and interpreted. Unfortunately, safety considerations are given low importance because of the inability to quantify expected effectiveness, especially in design decisions. This contrasts, for example, with the relative importance given to construction costs, which can be estimated with a high degree of quality and confidence (see Figure 1).

HIGHWAY DESIGN PROCESS

A generalized diagram of the highway design process appears in Figure 2, showing three levels of activity:

- Planning (system),
- Project (design), and
- System management (not the focus of this project).

Within each level, decisions are made that should involve highway safety considerations. The perspective for the decisions and the supporting information needed vary by level. This variation reflects decisions made at different points in the process as well as at levels in the organization. Usually the higher administrative levels require a lower level of detail, while employees under their supervision require greater detail.

The safety information needed at any point, however, can be classified as either

- The data needed to identify the existence and nature of safety problems at a given site, or

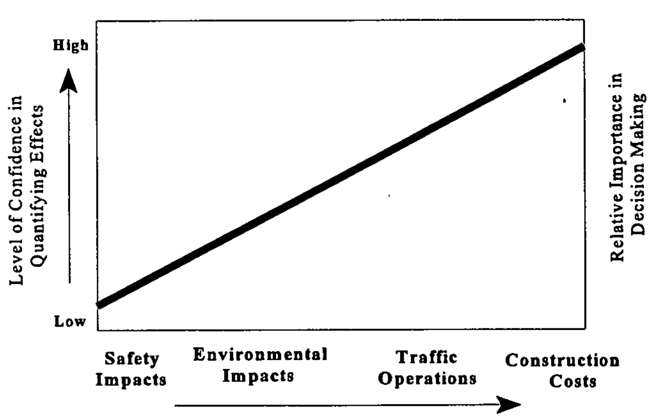

Figure 1. Relative role of safety in design decisions.

- The ability to predict the consequent safety impact of a design decision. (A "design decision" is meant to include most decisions made in the course of the entire design process.)

The difference between these two sets is the level of detail and frequency of the gathering efforts.

SAFETY DATA NEEDS

This NCHRP project has sought to define a system for delivering information and assistance to decision-makers in the process of highway design, which will allow them to better incorporate safety considerations.

Data are used to generate information which, in turn, can be used to help make decisions. For example, needs studies and preliminary design include asking, "Does a safety problem exist, and if so, what are its attributes?" The answer helps the designer make decisions about which choices of improvements may be best. However, answering this one question requires that coordinated and summarized data be presented in a way that is useful to the design decisionmaker.

The information must be flexible to meet varying needs. An administrator who is deciding on allocation of investments for a state or city does not need the same information for a decision as the designer who is seeking to understand the nature of the crash patterns at a site. Although each may use the same data, the information derived from the data should be quite different. The content of data stores from which the decisionmakers draw should be comprehensive enough to provide for the needs of the project engineer and yet flexible enough to allow aggregation of measures for planning and programming activities.

The design community is not alone in its search for improved quality of safety data and systems to support decision making. Many agencies and organizations seek the same data and similar levels of quality. Partnerships can be formed to support improved quality of data of joint interest. Cost sharing, as well as the joint use of other resources, can help achieve common objectives. Each agency often has the need for data or some form of assistance from other agencies. Cooperation often results in a synergistic effect on operations.

Traditional primary sources of safety data include

- Crash reports,
- Roadway inventories, and
- Traffic volume measurements.

In addition, there are several other sources that provide valuable safety data for design, including records of

- Maintenance,
- Pavement management,
- Citizen and patrol officer comments, and
- Medical treatment of injured passengers and drivers.

There are a number of issues related to the quality and accessibility of these data that must be resolved before adequate information can routinely be generated to support highway design.

The issues of data collection and management include

- Lack of incentives for patrol officers to get quality crash data;
- Conflict of officers' roles at crash scene, and perceived need to find fault;
- Inadequate officer training for required judgements;
- Editing done remotely from the source;
- Highway inventories cover only a limited part of system, and nationwide, the inventory systems are inconsistent;
- Lack of systems integration;
- Inadequate or imprecise location identification;
- Inadequate tools to get some data; and
- Reliance on nonfield sources for highway inventory.

The following are issues concerning data usage:

- Most safety information systems are not designed for end-user access and, when available, are not user-friendly;
- Technically difficult to have an intuitive interface for a complex system;
- Lack of system coordination and integration a barrier to use;
- Poor coding of crash data requires reliance on narrative and diagram;
- Most designers are not well trained in analytical methods; and
- Knowledge about relationship between safety problems and effective design requires improvement.

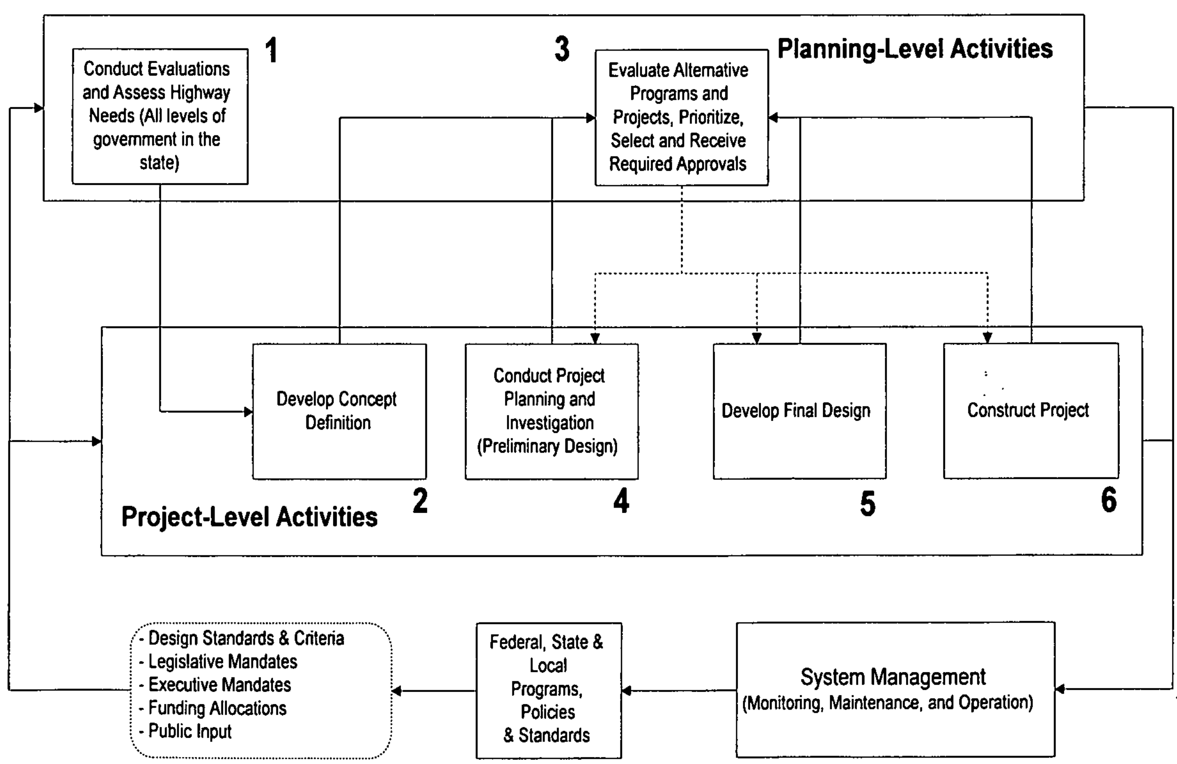

Figure 2. Schematic of highway planning and design.

TECHNOLOGICAL OPPORTUNITIES

New technologies offer the potential to address many of the issues associated with improving safety data for use in highway design. At the national, state, and local levels, technological strategies are being tested and evaluated to improve the quality and efficiency of data collection and management. For these technologies to be feasible or effective, however, certain organizational and institutional actions must be taken. There are some issues that cannot be resolved solely with technology, but are also related to the "human" factors.

Some applicable technologies are in a more mature state of development and application than others. Technology, however, usually develops faster than the ability of organizations to absorb it. Examples of applicable technologies are listed below:

- Portable computers (voice recognition, pen-interface, and graphical user interface);
- Data readers (radio-identification chips, smart cards, magnetic stripes, and bar-code readers);
- Artificial intelligence;
- Location technologies (global positioning systems, map matching/dead reckoning, cellular phones, and Loran-C);
- Laser-based measurement;
- Digital photography (single camera, stereo camera, and aerial imaging); and
- Vehicle internal monitoring and reporting systems ("black box").

Some general conclusions about technology, applicable primarily to crash, highway, and traffic data include

- Technologies address most, but not all, issues.
- A single technology can help resolve more than one issue.

Even with improved technology, the current manner in which patrol officers collect data at crash scenes is not desirable, particularly in urban areas. Desirable elements, which help resolve many of the issues associated with *field data collection*, include

- A computer-based instrument for *directing* data collection and its recording,
- Automated assistance in establishing location,
- Automated methods for taking measurements, and
- Systems that allow two-way communication between field data-collection instruments and data stores (e.g., cellular linkages and satellite upload).

Desirable elements to resolve many of the issues associated with *data management* include

- Automated data reduction and entry;
- Extensive automated error-trapping and correction systems, preferably in field devices, and operating in real time;
- Use of modern database management systems;
- Use of a full range of graphical user interfaces, allowing integrated access to a wide range of data; and
- Automated assistance for the management of the data.

Desirable elements to resolve many of the issues associated with providing *decision support capabilities* include

- Comprehensive use of graphical user interfaces, including computer-aided design and drafting systems (CADD), geographic information systems (GIS), and virtual reality;
- An artificial intelligence core to act as the "central processor" of the system; and
- An extensive analytical capability, with emphasis on models that predict the impact of a design decision on safety.

DESIGN DECISION SUPPORT SYSTEM (DDSS) FOR SAFETY

Major business institutions, driven by the need to compete effectively, continually promote the evaluation of aids for improved information and decision making, including

- Technology applied to build data stores and warehouses;
- Technology applied to create more useful tools for organizing, displaying, and interpreting the information that can be derived from extensive data sets; and
- Organizations adapting to make use of the new technology.

The commercial world recognizes information as a critical corporate resource. A state or local government unit is, in essence, a corporate entity with similar needs for information to support decision making, which at all levels affects the performance of the entity. Intelligent decisions are made on the basis of high-quality information and the ability to know what to do with it. Quality, in turn, depends to a great extent on the quality of the underlying data.

The design process is one part of the overall set of services provided by state or local government. Many key decisions are being made throughout the process, which will affect millions. A solid decision support system is needed to assist decisionmakers throughout this process. In particular, this project has focused on the need for a decision support system to enhance the consideration of highway safety in decision making.

The general concept for a design decision support system (DDSS) is shown in Figure 3. It includes the following basic modules:

- *User interface,* which is highly graphic and intuitive, and as technology advances, will use voice and even eye movement as inputs for commands.
- *Decision support*, in its ultimate form, will assist the user at each step of the system. Thus, the user can request help in formulating an inquiry for the system, analyzing the results of the inquiry, interpreting the findings, identifying countermeasures, performing evaluations, and presenting results. This module will ultimately become the "central processing unit" for the system.
- *Design analysis* includes a collection of tools and techniques for analyzing data and designs to help the designer identify potential problems and alternative design strategies and evaluate alternative designs.
- *Data,* which may be in the form of a data mart or data warehouse, serve the needs of all users. These data are supplied by a collection and management function that, although strictly external to the DDSS, is critical for effectively implementing the system.

Potential benefits of an improved system are substantial, including increased productivity of design, more informed and better documented decision making through better reflection of safety considerations, and improved safety on the highways. Specific examples of likely impacts of the DDSS on the conduct of analyses for a design project are outlined in Table 1.

The cost of many of the basic elements can be shared across all state and local agencies desiring to use this system, because some elements will be common to all implementations of it. In the meantime, many aspects of the system are immediately feasible to implement; some states already have some components in place. Therefore, the cost of even an initial implementation depends on the specific context in which the system will operate.

Several initiatives already exist at the federal, state, and local levels to use technology for improving the quality of basic safety data needed by the safety community. Needs also exist to

- Synthesize and disseminate the findings;
- Widen the focus from improving the quality of crash data to include emphasis on acquiring better data about physical, control, and traffic features of the highway;
- Integrate nontraditional safety data, such as maintenance activities, citizen comments, and pavement management files;
- Address the increased pressure on law enforcement to eliminate reporting of crashes with property damage only;
- Overcome underlying resistance to change within many institutions, especially at the state level, including the adoption of new technologies; and
- Establish a comprehensive framework for system improvement within which new methods and technologies would operate.

FHWA currently has under way a major initiative to develop an Interactive Highway Safety Design Model (IHSDM).[1] This project has the goal of developing a systematic approach for assessing the safety implications of design decisions in a CADD environment at the planning and design levels for reconstruction and new construction. Considerable effort continues to build this model. This commitment at the federal level further emphasizes the importance of providing quality safety data to users and doing so within an effective environment. Although IHSDM is continually evolving, its present definition further highlights outcomes identified in this NCHRP project including

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[1] Paniati, J. F. and True, J., "Interactive Highway Safety Design Model (IHSDM): Designing Highways with Safety in Mind." *Transportation Research Circular 453*, Transportation Research Board, Washington, D.C. (Feb. 1996) 6 pp.

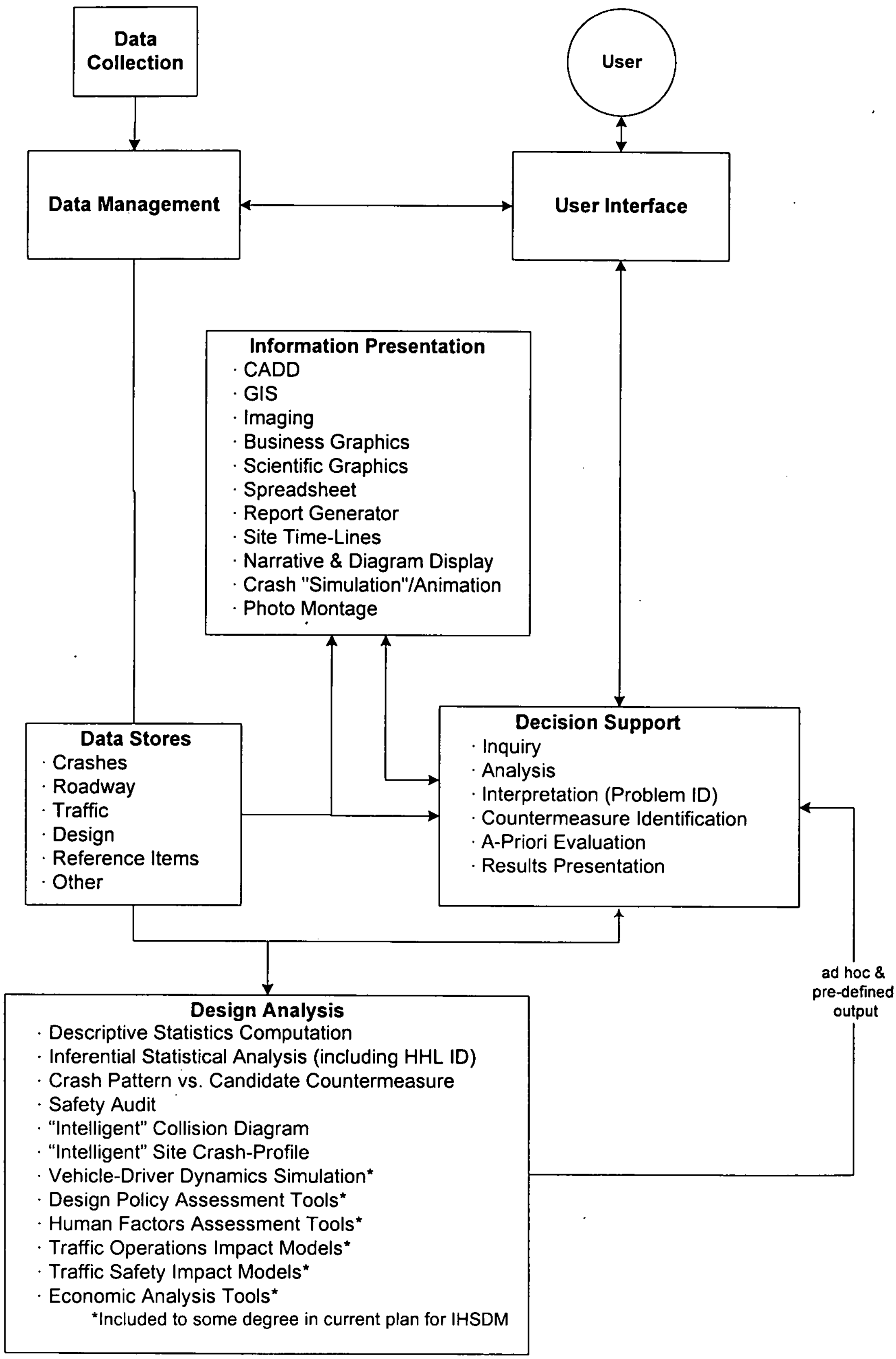

Figure 3. Generalized concept for a design decision support system.

TABLE 1 Examples of impact on safety analyses for a design project with implementation of the DDSS concept

Current Practice	Becomes	Improved Practice Using the New System
Extensive manual assembly of safety data tabulations from different offices within and outside the design agency, requiring hundreds of staff hours	→	Direct access to a comprehensive data warehouse, within a CADD/GIS environment
Manual inspection of hard copy of crash reports, often from microfilm record, to correct coding errors	→	Pre-screened data to minimize errors in data, including proper location of the crash, plus immediate access to digital images of crash reports, within CADD/GIS environment
Labor-intensive translation of tabulations of key data into calculated fields and graphics using independent spreadsheets and graphics software	→	Integrated statistical routines, business graphics, and advanced data-visualization software, including intelligent collision diagrams plotted on actual geometry and highway-attribute timelines
Lack of historical traffic data and history of site geometry	→	Data warehouse with records of all available traffic counts, and a continual, up-to-date history of physical attributes of the site
Lack of safety models and limited flexibility of data systems to provide support for positions taken regarding the hazards at the site and the effectiveness of proposed improvements	→	A suite of design analysis models to assess existing and proposed designs from a variety of perspectives, thereby producing documentable and defendable estimates of safety impacts of alternatives
Support for decisions regarding which data to use, how to analyze them, what conclusions may be drawn, and how to arrive at recommended improvements, must come from the staff or specialists having limited availability	→	A central decision-support function within the system to provide the user with guidance at every step of the analysis
If any decision tools are applied, they are done manually	→	A suite of decision tools, using the latest developments in decision science, directly accessible, and information generated by the system, based upon the previous work of the designer

- Assessing the safety implications of design decisions in a CADD environment at the planning and design levels for reconstruction and new construction;
- Assisting designers in identifying underlying problems associated with the safety history at a site, including use of expert systems and appropriate statistical techniques;
- Developing a system that integrates the analytical and decision-making functions for application throughout the entire design process; and
- Assisting the designer in documenting the results of the analysis and design work.

RECOMMENDED IMPLEMENTATION PLAN

The 1997 *AASHTO Strategic Highway Safety Plan* includes strategies for improving information and decision support systems to enhance the consideration of highway safety in design. The recognition of this need by a national group of experts that produced the plan emphasizes the importance and urgency of moving ahead with many of the concepts and approaches resulting from this research. The endeavor will fit well within current national efforts to improve safety management systems (SMS).

The proposed DDSS will generate high levels of interest in the design community, but it will be necessary to demonstrate the potential power of the system through practical demonstrations in the design process and actively involve the design community with the ongoing effort of the broader highway safety community to solve problems with the collection and management of quality safety data.

The major steps that may be taken at the national, state, and local levels to begin the implementation process are as follows:

1. Demonstrate the system's value to interested agencies and organizations
   a. Develop or simulate key elements of the system
   b. Hold technical sessions to present the concept
   c. Produce materials to further support initiating a cooperative development and implementation effort
2. Get the stakeholders together and cooperating
   a. Within a particular governmental agency
   b. Nationally
3. Establish areas of common need
   a. Identify common elements that may be jointly developed at a national and/or state level
   b. Tailor additional elements to local needs
4. Establish organizational mechanisms to share resources and costs to produce a system
5. Formulate a development and implementation program, carefully reflecting ongoing efforts, such as the initiative of FHWA to develop the IHSDM
6. Solicit support at the highest levels of state and/or local government
7. Provide appropriate levels of funding to develop programs

In some states and local communities, portions of the system concept already have been implemented and are regularly used. Current systems, especially those recently upgraded, are doing an effective job of demonstrating what can be accomplished. The improvements envisioned here are to be evolutionary, occurring within the context of SMS, but with emphasis on meeting the needs of the design community. Portions of the system would be added to existing systems, particularly at times where such systems are being modified and updated. Legacy data may be difficult, in some cases, to carry forward into the new context. New automated methods for dealing with this are being developed because so many information systems are currently dealing with the problem. In such cases, however, it may be that the old data will have to be replaced by the new data over a period of several years.

Some research and development efforts are necessary to (1) demonstrate the nature and usefulness of key system elements; (2) assess, through field applications, technologies and related activities that would support or facilitate the development of the DDSS; and (3) develop a comprehensive, long-range program to support DDSS tools.

Many of the elements of the proposed system are of interest to those outside the design community as well. Therefore, research, development, and demonstration efforts may already be programmed for some of the recommended initiatives. For example, in addition to their study of crash-reporting technologies mentioned above, FHWA has begun to consider safety-audit methods.

MATERIALS IN THE FINAL REPORT

The final report to be published as *NCHRP Report 430* provides details about the data needs, applicability of new technologies, and concepts for the use of improved information systems. In addition to these broad issues, the final report provides a 20-page data dictionary table that covers the data elements associated with crash reports, traffic operations, roadway geometric characteristics, and traffic control devices. The report also provides an assessment of 13 emerging technology groups across the more than 60 issue items that were identified during the project. These issues include the potentials for the new technologies to address the various needs of highway safety designers.

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