Integrated Road Information System

Improved Road Condition Reporting

Study SD2001-15
Executive Summary

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The work was performed in cooperation with the United States Department of Transportation Federal Highway Administration.
This report documents the design considerations and logical architecture of the South Dakota Road Condition Reporting System (RCRS). It details the database structure and entity relationships between the numerous data elements necessary to construct the RCRS. The study also reviews existing road condition reporting systems and contrasts these systems relative to criteria established by South Dakota RCRS stakeholders.

Process and data flow diagrams are developed using information engineering methodology. A context diagram is presented showing the external relationships to the RCRS. The process model includes a Level 0 data flow diagram showing details of the information flow between the primary processes. The data model includes entity relationship diagrams that show data major components and actions that exist between the entities. Data tables depicting the database schema are included in detail within the appendix and further define relationships between entities.

The report describes the client application data entry interface with graphical examples. The flow of data to end users is presented along with recommendations for next generation research and development activities that will enhance the RCRS.

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EXECUTIVE SUMMARY

PURPOSE OF STUDY

The growth in public demand for improved safety and mobility during travel has been fostered by the existence of advanced traveler information systems such as South Dakota’s 511 Traveler Information System that provides weather and road condition information. Unfortunately, the resolution, both spatially and temporally, of the road condition information fails to match that of the weather information, and in many situations the road condition information, because of its age or due to rapidly changing conditions, is of little use to the traveler. The challenge of providing appropriate and timely road condition information is largely focused upon the high degree of manual processing necessary to collect, collate, organize, and distribute the information. Due to the excessive human resources needed to complete this task, the frequency of providing road information is only three times daily.

The purpose of the project SD2001-15 was to develop and demonstrate an efficient, effective, and timely mechanism for the collection and distribution of road condition information.

OBJECTIVES

The objectives of this study were to:

- Determine whether existing road condition information systems, including the Highway Condition Reporting System (HCRS) and the Condition Acquisition and Reporting System (CARS), satisfy South Dakota’s requirements for a flexible information management system that complies with national Intelligent Transportation Systems (ITS) standards.
- Design, consistent with state information technology standards and methodology and with existing and emerging national Intelligent Transportation System standards, a logical and physical architecture for road and weather information.
- Deploy for statewide use an operational road and weather database that can accept multiple manual and automated feeds and support multiple dissemination mechanisms.
- Propose, test, and evaluate automated procedures for acquiring timely, location-specific road condition observations using present best communication methods and planned improvements to South Dakota’s state radio system.

RESEARCH TASKS

The South Dakota Department of Transportation (SDDOT) retained the UND Aerospace Foundation and its subcontractor, Meridian Environmental Technology, Inc. to conduct the project. The Road Condition Reporting System research efforts consisted of eleven tasks:

1) Meet with the project’s technical panel to review project scope and work plan.
2) Through review of available documentation, assess and compare the capabilities of available road condition information systems, including HCRS and CARS.
3) Using methodology acceptable to South Dakota’s Bureau of Information & Telecommunications (SDBIT) and to the Federal Highway Administration (FHWA), define and document the logical and physical architecture of the road and weather information system that is based on a relational database structure, can accept a variety of manual and automated input sources, and can feed information to various output media, including telephony, web sites, facsimiles, and e-mail.

4) Upon the project technical panel’s approval of the defined architectures, construct (possibly through adoption or modification of HCRS or CARS) an operational relational database that will support existing and future reporting and dissemination procedures.

5) Define and construct output processes that extract, summarize, and disseminate information to various output media (including telephony, web sites, facsimile, and e-mail) in various resolutions (by region, by road segment, and by mileage reference marker).

6) During the winter of 2001-2002, conduct a pilot test of the operational database, using existing methods for acquiring and disseminating road condition and weather information.

7) Identify, assess, and recommend evaluation plans for new or improved methods—such as expanded pools of reliable reporters, automated reporting, and use of standard protocols—for reporting road and weather conditions.

8) Upon approval of the project’s technical panel, conduct operational field trials of recommended methods for reporting road and weather conditions.

9) On the basis of effectiveness, practicality, and resource demands as demonstrated through the field trials and other analysis, recommends procedures to be deployed for reporting road and weather conditions.

10) Prepare a final report and executive summary of the research methodology, findings, conclusions, and recommendations.

11) Prepare and present an executive presentation to the Department’s Research Review Board at the conclusion of the project.

**Significant Findings**

The research resulted in several areas of significant findings. The first of these were the identification of criteria desired by state stakeholders for defining the South Dakota Department of Transportation Road Condition Reporting System (RCRS), including:

- infrastructure to support statewide road condition reporting;
- capability for rapid updating of information using a structured database management system;
- support for multiple points of information distribution;
- ability to handle current data sources including:
  - road conditions
  - road construction and maintenance
  - incidents
o emergency management events

- ability to handle future possible sources of information and distributions;
- use of rule sets supporting consistent reporting of local, geographically specific data;
- support for manual and automated data sources;
- support for multiple points of entry of data;
- reliability with long mean time between failures;
- easy to use software requiring minimal training;
- conformance to SDBIT software design standards including:
  o Microsoft SQL Server database support
  o MS Windows client software composed in Visual Basic.

After criteria were established to define the SDDOT RCRS, a thorough review was performed to evaluate whether existing road condition reporting systems satisfied the SDDOT RCRS criteria and any could be adopted to expedite implementation and minimize the implementation costs. The review of existing systems focused on two widely adopted systems, the Highway Condition Reporting System and the Condition Acquisition and Reporting System. After a comprehensive review and application of the defined criteria for the SDDOT RCRS, it was recommended to the project Technical Panel that no existing system would meet the rigorous criteria for SDDOT. A recommendation was submitted and approved by the Technical Panel to develop a new RCRS to meet the SDDOT criteria. The specifics of the recommended client-server development were:

- building a custom database and platform independent client data entry and manipulation system;
- use of open source software and operating systems;
- an SQL-compliant database;
- all database access methods using database-independent access libraries, which will isolate the chosen database applications program interface (API) and transform it into one that is common to any database.

A major part of the road condition reporting system development process involved completing a logical and physical architecture of the SDDOT RCRS. This logical architecture consists of various processes, data flows, terminators, and data stores. Criteria used to define the architecture included:

- establishing a relational database for all road conditions;
- conformance, to the fullest extent possible, to the Traffic Management Data Dictionary standard;
- geographical reference to South Dakota’s entire state highway network.

The overall design of the logical architecture is captured in a context diagram depicting the relationship of the external elements to the RCRS (Figure 1) and a Level 0 Data Flow Diagram that depicts the logical arch (Figure 2).
The data stores found within the Data Flow Diagram represent the central challenge associated with the RCRS design. Due to the complex relationships that resulted between the various data types found within the architecture, creating appropriate database schemas to effectively represent the data and their interdependencies required significant design efforts. Considerable interaction with SDDOT personnel ensued to design a database schema that satisfied current and future data requirements. The data types incorporated in the architecture included:

- road network definition;
- incident/condition type definition;
- incident/condition location definition;
- incident/condition time/duration/recurrence definition.

These elements were analyzed to generate a database schema that included a series of 33 tables spanning six categories:

- Situation [Traffic Management Data Dictionary (TMDD)] Tables;
- Road Network Tables;
- User Administration Tables;
- Episode Report Tables;
The resulting logical architecture was implemented as a database that was populated with data from existing state linear referencing systems, maintenance characteristics, and relevant elements from the Traffic Management Data Dictionary (TMDD)\(^1\). The latter provided commonality with other road condition reporting systems and represents the emphasis within the RCRS to conform to evolving national standards.

Testing of the database with server and client applications occurred during the 2003-04 winter resulting in widespread testing and evaluation beginning during summer 2004. The resulting graphical user interface (Figure 3) was developed as a Citrix application to provide an efficient and effective method of data entry. The compact tool set supports broad user requirements and rapid delineation of features at the area, shop, unit or highway segment level. The application has completed rigorous testing and was deployed statewide in October 2004.

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\(^1\) IEEE 1489-1999 Version 0.1.0 Draft Standard for Data Dictionaries for Intelligent Transportation Systems. Institute of Transportation Engineers, 525 School Street SW, Suite 410, Washington, DC, 20024
Output processes were developed to automatically feed information from the RCRS database to the SD 511 Traveler Information System, regional and corridor road condition summaries, and the Automated Commercial Vehicle Permitting System. These processes permit the rapid dissemination of RCRS information to promote public benefit and safety. The resulting information is a tremendous enhancement to the spatial and temporal coverage over previous methods. Feeds to SafeTravelUSA, a web site which presents regional road conditions, are under development to provide a web interface to RCRS information.

CONCLUSIONS

The Road Condition Reporting System project provided a sophisticated, state-of-the-art method of collecting and disseminating road conditions, construction and incident information in a timelier and spatially appropriate manner. The work yielded an operational system that will promote safety for travelers and a better exchange of information to the public in general. The project was initially projected to be completed in one year. However, the complexity of designing a system that would accommodate current and future data sources required considerable interaction with SDDOT personnel and vision as to
how a database could be extensible to handle next generation data input and output. In addition, the level of database preparation and population exceeded the original estimates. This was particularly true with regards to the South Dakota road network database where discrepancies in the geospatial data did not permit direct incorporation within the RCRS database. Considerable effort was required to resolve these discrepancies, which significantly delayed the project completion. However, the resulting road network GIS is not only an excellent addition to the RCRS, it has provided a benefit to the SDDOT in general.

Several summary conclusions from the project include:

1. The generation of information with high spatial and temporal resolution requires special attention to details within the database design and high quality geospatial and attribute data to populate the dataset.

2. A well designed data entry methodology and associated graphical user interface are crucial to the acceptance of an application that involves a high degree of user interaction. While the database design will determine the extensibility of the information to end users of the system, having a method of input that facilitates user acceptance will largely determine whether the resulting system will be given the opportunity to succeed.

3. The successful completion of a project of this nature requires the commitment of a broad range of stakeholders all dedicated to maintaining a high degree of quality and end user support. To this end this project had such commitment from all participants and the resulting product should provide years of benefit to South Dakota.

RECOMMENDATIONS

The further growth of information systems supporting improved information regarding the current state of the road network will be needed to keep pace with the demands of travelers and technologies that can use the information to further surface transportation products and services. The scale of information will continue to grow finer in time and space. This demand has already outpaced the capabilities of most states to manually produce the information to support these systems. Hence, it is recommended that the following efforts be considered for enhancing the work provided within this project.

Recommendation 1: The South Dakota Department of Transportation should pursue development of automated and semi-automated road condition reporting methods.

An expansion in the volume of road condition information will require both the time of field personnel and data entry personnel to support the use of the data within a road condition system unless improved methods are developed to more effectively incorporate these data within the RCRS. This can be done in two levels.

The South Dakota Bureau of Information and Telecommunications is in the process of awarding a contract to enable digital data support from radio systems distributed across South Dakota within SDDOT vehicles. With this system available it will be important to consider methods by which effective communications to the RCRS can be completed that will reduce dramatically the requirement for manual computer operator entry of information to the RCRS database. This capability for automated data entry will promote greater spatial and temporal details and provide for improved efficiency and safety from the RCRS. However, unknowns in the level of digital data support from state radio suggest efforts must also
include methods for automated data entry that go beyond State Radio and include alternate means that consider other cost effective and efficient procedures. The use of automated data entry will require the solution of problems associated with three distinct areas: 1) data submission in a field environment; 2) data transmission and reception from remote vehicles and locales; and 3) translation and assimilation of received data into the present RCRS database.

The first of these research areas involves understand the most appropriate methods for remote entry from a field environment. This includes understanding data entry environments that will exist, such as SDDOT maintenance vehicles, SDDOT non-maintenance vehicles, and law enforcement vehicles. Depending upon which of these environments are chosen the type of data entry may vary due to the nature of data being entered and the capabilities of the personnel entering the data. This will likely define the form of data transmission and reception that will be possible. The reception of data has been included for situations where a feedback is required to the field data entry either as confirmation of successful transmission or the need to react to data submitted.

The methodologies recommended for investigation of data input directly from field sources include the following (forms of possible data transmission supported are listed in parentheses):

- PDA—Portable Digital Assistant, an interactive handheld interface allowing selection and input of menu driven information, with telecommunication (Cellular or Radio);
- Smart Cellular Phone—Automated Global Positioning System (GPS) data and interactive conditions menu system directed at an Interactive Voice Recognition (IVR) system for input of information, with telecommunications (Cellular);
- Satellite Phone—Automated GPS data and interactive conditions menu system directed at an IVR system for input of information, with telecommunications (Satellite);
- Radio—Interactive menu system directed at an IVR system for input of information, with telecommunications (Radio);
- Cellular—Interactive menu system directed at an IVR system for input of information, with telecommunications (Cellular);
- Mobile Reporting System—Small portable computer for input of information, with telecommunications (Cellular or Radio).

**Recommendation 2: SDDOT should expand the present RCRS to support maintenance activities collection and reporting in conjunction with Maintenance Decision Support.**

The current efforts to develop and deploy a Maintenance Decision Support System in South Dakota will require the detailed depiction of road state as well as the location and details of winter maintenance activities ongoing at all times. The maintenance activity data collection has a parallel development path to those identified above for semi-automated and automated road condition reporting. The expansion of the RCRS data collection to include maintenance activity data collection to support Maintenance Decision Support Systems is recommended. Various vendor solutions presently exist to integrate in-vehicle maintenance efforts and the expansion of these technologies is accelerating. Methods should be developed to promote these efforts such that an economy of scale with the automated road condition information collection can be realized.
Recommendation 3: SDDOT should pursue a leadership position in the emerging national vehicle information infrastructure (VII) efforts.

A major national effort is underway to develop methods of exchanging information from commercial and private vehicles with the roadside environment. This effort will yield significant opportunities for enhancing data quality and timeliness throughout the road network. The technologies South Dakota will pursue, if the above recommendations are followed, will establish the State as a national leader in the exchange of information from the vehicle to the roadside. The lessons learned would be of significant benefit to the states where little consideration has yet to be given to maintenance issues within VII. It is recommended that appropriate representative from South Dakota routinely participate with the VII effort and such demonstration projects as appropriate be established in South Dakota to highlight the efforts of the RCRS and MDSS efforts relative to VII.

Recommendation 4: The South Dakota Department of Transportation should adopt the RCRS as its definitive database for road conditions.

The completion of the RCRS represents a major effort by the South Dakota Department of Transportation to establish a comprehensive database supporting the collection, management, and dissemination of information associated with the South Dakota road system. The database provides the capability for immediate system updates and distribution through database updates. The RCRS represents the state-of-the-art in road condition reporting. The adoption as the definitive database for road conditions will ensure that the most appropriate information is provided to support safety and mobility.

Recommendation 5: The South Dakota Department of Transportation should promote the use of the RCRS by other public safety organizations within South Dakota.

The RCRS is presently limited to input and viewing by South Dakota Department of Transportation personnel. However the RCRS provides a significant resource for use by public safety organizations across South Dakota. The capability of the RCRS to immediately distribute road condition information to a broad array of end users makes it a valuable resource for disseminating critical emergency information Statewide. Access to the RCRS for viewing current conditions will provided public safety organizations a means to facilitate appropriate responses to changing road conditions that impact these organizations and the public they serve. The input of emergency information by first responders, principally the South Dakota Highway Patrol, will enable a more effective and timely distribution of information related to rapidly changing road conditions.

Recommendation 6: The South Dakota Department of Transportation should update the South Dakota Statewide ITS Architecture to reflect the implementation of the RCRS.

The South Dakota Statewide ITS Architecture is a statewide vision for transportation systems integration. The architecture is a reflection of how existing and future systems respond to opportunities and operational needs of the transportation system and the organizations and individuals using the system. The implementation of the RCRS represents a significant addition to existing operational capabilities of the transportation system that should be documented within the Statewide ITS Architecture. Inclusion of the RCRS in the updated architecture will enable the capabilities of the RCRS to become better integrated into future transportation system designs.