REPORT S2-S04A-RW-1

Naturalistic Driving Study: Development of the Roadway Information Database

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STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP 2 REPORT S2-S04A-RW-1

Naturalistic Driving Study: Development of the Roadway Information Database

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SHRP 2 Report S2-S04A-RW-1

ISBN: 978-0-309-27458-6

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ACKNOWLEDGMENTS

This work was sponsored by the Federal Highway Administration in cooperation with the American Association of State Highway and Transportation Officials. It was conducted in the second Strategic Highway Research Program (SHRP 2), which is administered by the Transportation Research Board of the National Academies. The project was managed by Charles Fay, Senior Program Officer for SHRP 2 Safety.

The research reported on herein was performed by the Center for Transportation Research and Education (CTRE) at Iowa State University, supported by Cambridge Systematics, Inc. Omar Smadi was the principal investigator. The other authors of this report are Neal Hawkins, Zach Hans, Basak Aldemir Bektas, Skylar Knickerbocker, Inya Nlenanya, Reg Souleyrette, and Shauna Hallmark of CTRE. The authors acknowledge Bruce Spear and Kevin Howard of Cambridge Systematics, Inc., for their contributions to the database design, and Val Noronha of Digital Geographic Research Corporation for his contribution to the database long-term management. The authors also acknowledge the contributions of the members of the SHRP 2 Expert Task Group on Acquisition of Roadway Information for their feedback and comments throughout the project.

FOREWORD

Kenneth L. Campbell, *SHRP 2 Chief Program Officer, Safety*

This report describes the development of the Roadway Information Database (RID), which was carried out by Iowa State University's Center for Transportation Research and Education (CTRE). The objective of the RID is to provide high-quality roadway data that are linkable to the SHRP 2 Naturalistic Driving Study (NDS) database in order to incorporate roadway characteristics into the analysis of the NDS data. The RID includes data from the SHRP 2 mobile data collection project (Safety Project S04B), other existing roadway data, and supplemental traffic operations data. Potential database users were identified to determine data and usability requirements, and roadway data elements were identified and prioritized. A mobile data collection vendor was selected using the 2008 SHRP 2 Safety Project S03 rodeo results and additional evaluation. A quality assurance plan defined data accuracy requirements and tolerances and outlined the handling of nonconforming data. Mobile data collection covered about 12,500 centerline miles in the six NDS sites, or approximately 25,000 miles in both travel directions. The final RID design is a simplified version of the revised UNETRANS network data model. Data are referenced to a national base map for a consistent centerline across the NDS sites, and users can employ dynamic segmentation to produce road segments with any variable of interest.

The objective of the SHRP 2 NDS is to reduce traffic injuries and fatalities by preventing collisions or reducing the severity of them. The SHRP 2 NDS is the first large-scale study focused on collision prevention (as opposed to injury prevention once a collision occurs) since the Indiana Tri-Level Study (*Tri-Level Study of the Causes of Traffic Accidents: Final Report,* Report DOT HS-805 085, U.S. Department of Transportation, May 1979). Vehicle use was recorded continuously during the SHRP 2 NDS. Information on vehicle travel, or exposure, can be extracted at the same level of detail as for safety-related events, such as crashes and near crashes. Hence, the SHRP 2 NDS is the first large-scale study to support detailed estimates of collision risk. Moreover, crashes are a leading cause of nonrecurring congestion, so collision prevention has added benefits in terms of reduced delay, fuel consumption, and emissions. The NDS provides objective information on the role of driver behavior and performance in traffic collisions and on the interrelationship of the driver with vehicle, roadway, and environmental factors.

The SHRP 2 Safety research program was carried out under the guidance of the Safety Technical Coordinating Committee (TCC), which was composed of volunteer experts. The Safety TCC developed and approved all project descriptions and budgets and met semiannually to review progress and approve any program modifications. The Oversight Committee approved all budget allocations and contract awards. Assistance was provided by expert task groups, which developed requests for proposals, evaluated proposals and recommended contractors, and provided guidance on many issues, such as data access policies and procedures. The decisions and recommendations of the governing committees were implemented by SHRP 2 staff as they carried out day-to-day management of the research projects.

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Executive Summary

Objective

The goal of SHRP 2 Project S04A was to design, build, and populate a Roadway Information Database (RID) with data from the SHRP 2 mobile data collection project (S04B); existing roadway data from government, public, and private sources; and supplemental data that further characterize traffic operations. The overall focus of this research was based on providing good quality data that are linkable to the SHRP 2 Naturalistic Driving Study (NDS) database and stored in a secure, flexible database that is accessible using geographic information system (GIS) tools. The RID will in essence provide the road element for safety research on the more than 5 million trips taken by the NDS participants. The data will support a comprehensive safety assessment of driver behavior and crash risk, especially the risk of lane departure and intersection collisions. The RID will enable safety researchers to look at data sets of selected road characteristics and study matching NDS trips to explore the relationships between driver, vehicle, and roadway. This capability of the RID makes it a useful tool for NDS users interested in roadway characteristics and features because it allows researchers to focus on only those NDS trips that traversed road segments containing the items of interest. In addition, the RID serves as a template on how transportation agencies can integrate data from disparate sources in an effort to improve decision making beyond just safety; and the RID has the potential to serve as a template for a national integrated database to support decision making in a performance measurement environment.

User and Data Needs

To determine the data requirements of the RID, potential users were identified. A key purpose of the user identification effort was to facilitate the design of an integrated data set with data dictionaries suitable for stakeholders who are most likely to use the RID for safety and other research. Users were categorized based on familiarity with roadway data and familiarity with GIS and spatial analyses, the type of analyses that will be conducted with the RID.

The next step was to identify the roadway data elements necessary to answer research questions using the NDS data. This effort included a broad range of safety-related research questions that users may ask. Webinars and a survey were used to refine the initial list of potential RID data elements into a prioritized list. The final list consisted of critical items necessary to help answer research questions related to run-off-road and intersection analysis. These data items were collected as part of the SHRP 2 mobile data collection project and included the following:

- Horizontal curvature:
  - Radius;
  - Length;

  - Point of curvature (PC);
  - Point of tangency (PT); and
  - Direction of curve (left or right based on driving direction).
- Grade.
- Cross slope/superelevation.
- Lanes: Number, width, and type (e.g., through, turn, passing, acceleration, carpool).
- Shoulder type/curb (and paved width, if it exists).
- All *Manual on Uniform Traffic Control Devices* (MUTCD) signs.
- Guardrails/barriers.
- Intersection: Location, number of approaches, and control (uncontrolled, all-way stop, two-way stop, yield, signalized, roundabout). Ramp termini were considered intersections.
- Median presence: Type (depressed, raised, flush, barrier).
- Rumble strip presence: Location (centerline, edgeline, shoulder).
- Lighting presence.

Collection and Quality Assurance of Data

To assist SHRP 2 in the selection of a vendor to collect these data at highway speed, the research team used the results from the 2008 SHRP 2 S03 Roadway Measurement System Evaluation (Rodeo) project, which was conducted by a separate contracting team under Safety Project S03, and supplemented these results with an additional evaluation that was conducted by the research team in 2010. This reevaluation was accomplished by documenting each vendor's ability to collect roadway geometric data and some selected inventory data features on two of the six Rodeo control sites. As a result, three vendors were invited to submit proposals to SHRP 2 in response to the request for proposals for the mobile data collection project. Fugro Roadware was the selected vendor.

The objective of the mobile data collection project was to collect high-quality data on those roads most frequently driven by NDS participants and on roads of greatest interest to safety researchers. Guidance was developed both for the allocation of total road data collection mileage apportioned to each of the six NDS sites and for allocation within each study area. Allocation within each study area was determined using a sample of GPS traces from the NDS participants' vehicles and focused on rural two-lane roads. Coverage for each NDS site is provided in Table ES.1.

A major effort throughout this project was providing coordination and quality assurance (QA) for the collection and delivery of data by the mobile data collection vendor. For this purpose, a QA plan was developed. This plan outlined the processes to ensure optimum data quality from project setup to final data delivery and acceptance by SHRP 2. In addition, the QA plan defined the accuracy requirements and tolerances for what was deemed a nonconforming product and the process to deal with a nonconforming product. The QA process involved random site visits. Ground truth reference measurements were taken in the field throughout the project period, and

Table ES.1. Miles Collected in the Mobile Data Collection Project

NDS Site	Miles Collected
Florida	4,366
Indiana	4,635
New York	3,570
North Carolina	4,558
Pennsylvania	3,670
Washington	4,277

a custom process was developed for checking and analyzing the accuracy of the mobile data by using GIS tools. In addition, to ensure the data collection equipment was operating properly, control sites were set up in each of the six NDS sites. The vendor collected data on these control sites during specific stages in the data collection cycle, and the research team verified the results against ground truth data.

The mobile data collection project covered about 12,500 centerline miles in the six NDS sites. Because data were collected in both directions of travel, a total of approximately 25,000 mi was provided. Below are summary statistics from the mobile data collection project. These data were collected consistently and within project specifications across the six NDS sites:

- 25,076 total miles of roadway data collected.
- 7,524,310 total assets, including grade and cross-slope points.
  - 44,114 curves.
  - 6,129 mi of barriers.
  - 43,195 intersections.
  - 7,376 mi of highway lighting.
  - 10,756 mi of medians.
  - 33,013 mi of paved and unpaved shoulders (this number includes inside and outside shoulders on four-lane divided roads).
  - 11,852 mi of rumble strips.
  - 518,570 total signs.

Other Data Sources

In addition to the data from the mobile data collection project, roadway data from existing public resources (e.g., Highway Performance Monitoring System [HPMS] data and comprehensive data items available from state transportation agencies) and a list of supplemental data items were acquired and included in the RID. The term "supplemental" refers to any data item that characterizes a roadway segment that was not included as part of the mobile data collection undertaken by SHRP 2 or existing roadway data acquired from transportation agencies within the six NDS sites. These supplemental items included crash histories, traffic, weather, work zones, changes to infrastructure, aerial imagery, Federal Railroad Administration (FRA) grade crossings, safety enforcement laws, and active safety campaigns. The existing and supplemental data that were acquired are estimated to cover about 200,000 centerline miles within the six NDS sites.

Database Design

The RID design is a simplified version of the revised Unified Network-Transportation (UNETRANS) network data model. Data models, technical specifications, and supporting management components were developed to define the RID and to ensure its interoperability with the NDS database. The RID was built on an underlying, route measure-based linear referencing system (LRS). Other roadway features, such as those collected as part of the mobile data collection project, have been conflated to this LRS and are represented as individual features within an Esri ArcGIS geodatabase. Each feature also possesses corresponding LRS-based route and measure values. Therefore, the RID supports both attribute- and spatial-based queries, as well as dynamic segmentation. Even though the RID is built as an Esri ArcGIS geodatabase, other GIS software users can still use the RID.

All the data contained in the RID are referenced to a national basemap, which provides a consistent centerline across the six NDS sites. This design allows the users, through the process of dynamic segmentation, to produce road segments with any variable of interest from the various data sets contained in the RID. Figure ES.1 shows an example of using dynamic segmentation to select two-lane rural curves in North Carolina with paved shoulders less than 6 ft. Figure ES.1

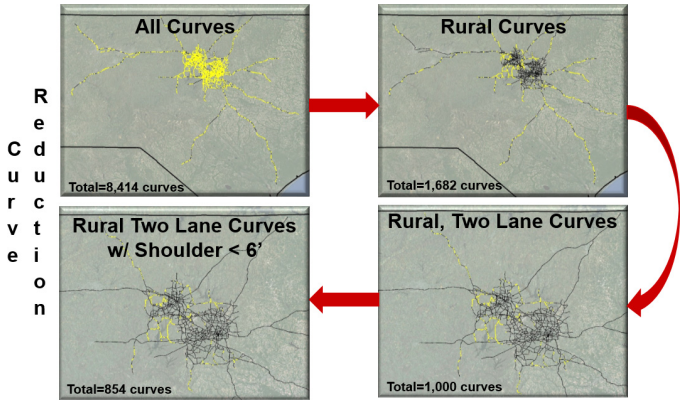


Figure ES.1. Dynamic segmentation to select a set of curves in North Carolina.

shows how out of 8,414 total curves, only 854 curves meet the selection criteria, which in turn helps focus the research questions and provide a more efficient and convenient process to request NDS data.

When the RID is completed in December 2014, a user guidance document, which includes data sources, query examples, roadway-linked NDS data examples, and a step-by-step process to integrate additional data into the RID, will be provided along with the database. In the meantime, see Appendix F, which provides a step-by-step process on selecting specific roadway characteristics using RID and dynamic segmentation.

Conclusion

Overall, the RID design and included roadway data achieved the project goals and objectives. The addition of the supplemental data to the RID enhances the users' ability to conduct a more comprehensive analysis than roadway inventory data alone could provide. Using a consistent and comprehensive road network has provided the users of the RID and NDS the ability to conduct analysis across multiple sites. In addition, the RID design provides a template that transportation agencies can use in considering how to integrate disparate data to support safety, asset management, planning, and operations activities.

CHAPTER 1

Introduction

The objective of the SHRP 2 Safety focus area is to mitigate traffic injuries and fatalities by preventing, or reducing the severity, of collisions. To support that program effort, it was decided that a major aspect of the Safety area would be to conduct a large-scale naturalistic driving study (NDS) to address the role of driver performance and behavior in traffic safety. This involves understanding how the driver interacts with and adapts to the vehicle, the traffic environment, roadway characteristics, and other environmental features. Vehicle use was recorded continuously in the SHRP 2 NDS. Information on vehicle travel or exposure can be extracted at the same level of detail as for safety-related events like crashes and near crashes. Hence, the SHRP 2 NDS is the first large-scale study to support detailed estimates of collision risk. Moreover, crashes are a leading cause of nonrecurring congestion. Collision prevention has added benefits in terms of reduced delay, fuel consumption, and emissions.

For the exposure-based analysis approach supported by SHRP 2, characteristics of interest (such as roadway parameters) needed to be available for events, such as crashes, and for comparable driving segments where collisions did not occur. Due to the cost of mobile data collection, SHRP 2 was not able to collect roadway data using mobile data collection for all roads driven by participants in the Naturalistic Driving Study (NDS). Thus, it was anticipated that additional roadway data would come from existing sources in the public and private sectors.

The goal of this research project was to design, build, and populate a Roadway Information Database (RID) with data from the mobile data collection project (S04B), existing roadway data (from public and private sources), and supplemental data to help further characterize operations. The focus of this research was on providing good quality data that is linked to the NDS database and stored in a secure, flexible database, accessible using geographic information system (GIS) tools. The RID will in essence provide the road element for safety research for the more than 5 million trips taken by the NDS participants. The data will support a comprehensive safety assessment of how driver behavior and performance might be impacted by roadway characteristics, environmental and vehicular factors, and the influence of these factors and their interactions on collision risk, especially the risk of lane departure and intersection collisions. The RID, through the use of dynamic segmentation, will enable safety researchers to look at data sets of selected road characteristics and study matching NDS trips to explore the relationships between driver, road, and vehicle. The six study sites where roadway data were collected are as follows:

- Bloomington, Indiana;
- Erie County, Buffalo, New York;
- Raleigh–Durham, North Carolina;
- Tampa, Florida;
- State College, Pennsylvania; and
- Seattle, Washington.

In order to accomplish this goal, the following objectives guided the development of the SHRP 2 RID:

- Assess user needs.
- Reevaluate mobile data collection vendors:
  - Develop short list to bid on request for proposals (RFP).
  - Determine vendor capabilities.
- Develop project specifications for data collection and delivery.
- Conduct pilot data collection and evaluation on initial 900 centerline miles (out of 12,500 total centerline miles) to refine processes and data accuracy requirements, while assuring that data were sufficient for safety analysis.
- Conduct data discovery for existing roadway and supplemental data from government, public, and private sources.

- Develop a data collection strategy for roadway information that complements the SHRP 2 NDS data and supports exposure-based risk analysis, as well as other safety analyses.
- Provide coordination and quality assurance for the collection and delivery of data by the mobile data collection contractor.
- Acquire national basemap, existing roadway, and supplemental data.
- Design, develop, and populate the SHRP 2 RID.
- Manage the RID for the duration of the SHRP 2 program, including the following:
  - Supporting data analysis efforts requiring roadway data.
  - Developing basic long-term recommendations for database management after the SHRP 2 program.

This report briefly explains the tasks completed by the project team to achieve these objectives. The report presents information on the identification of data requirements, the data collection plan, the data discovery and acquisition effort for existing roadway and supplemental data, the quality assurance process on the mobile data collection project, the database design, database demonstration, and conclusions. Further details on project tasks are presented in the appendices.

CHAPTER 2

Identification of Data Requirements, Resources, and Data Collection Capabilities

The ability to conduct effective research and exposure-based risk analysis depends on successful data collection and database design. For a project like the development of the RID, which will support the largest naturalistic driving study ever completed to date, this required identifying and prioritizing the essential data for collection, determining the capabilities to collect these data, establishing the required accuracies per data element, and refining a quality assurance process to ensure data integrity. Development of the RID involved a progressive process with significant feedback from the research community to address the following questions:

- Who are the potential users and stakeholder groups for the roadway data and GIS tools?
- What are the roadway data elements necessary to answer research questions using the RID and NDS data sets?
- What should the priorities be for collecting these data, existing data sets, or mobile mapping?
- What GIS needs are critical in maximizing user access to the RID data, given the range of user capabilities?

2.1 Identifying Data Users' Characteristics

The strategy for identifying data users began with distinguishing between users who will conduct their own analysis as opposed to those who will use predefined data sets and analysis tools. This information helped ensure that the appropriate data elements were identified and collected as part of the SHRP 2 data collection effort. In addition, the information aided in understanding the range of users of the data so that data sets, data integration tools, data dictionaries, and other products that resulted from this effort were available.

Users were then further defined based on several factors, including level of familiarity with roadway data and familiarity with GIS and spatial analyses. This process helped the research team focus the RID design.

2.2 Identification of User Groups

After identifying the users' characteristics, the research team identified specific groups of users and stakeholders who will use the SHRP 2 RID.

Researchers who will use the RID data set will come from a wide range of backgrounds, including the following groups:

- Federal, state, and local agencies that use roadway data for decision making;
- Leading universities in transportation safety;
- Consulting engineering companies who conduct safety research;
- Traffic/highway safety engineers;
- Human factors researchers;
- Policy analysts;
- Statisticians;
- Social science researchers;
- Epidemiologists;
- Psychologists;
- Crash reconstructionists;
- Enforcement personnel;
- Emergency response personnel;
- Trade organizations;
- Asset management experts; and
- Highway operations experts.

The users that most affected the RID design (including which data to collect) were the safety researchers with roadway data knowledge and expertise focusing on the roadway agencies (federal, state and local). Appendix A gives a detailed report on this effort.

2.3 Identifying Data Needs

This section describes the effort to identify the roadway data elements necessary to answer research questions using the SHRP 2 NDS. This effort included a broad range of safety-related research questions that may be asked by users. Appendix A gives a detailed report of this effort.

The research team developed a comprehensive initial list of potential roadway data elements that may be relevant to a variety of analyses and uses with the NDS data. The team developed this list after conducting an exhaustive literature review to determine roadway data elements that have been identified in safety analyses and considering data necessary to answer the research questions related to intersection or lane departure crashes (high-priority research areas for SHRP 2).

After the initial list was developed, the team obtained additional information from the relevant user groups. This information was obtained in several ways. First, the team reviewed roadway data elements that had been included in the following:

- Highway Safety Information System (HSIS), managed by the University of North Carolina Highway Safety Research Center under contract with the Federal Highway Administration (FHWA);
- Model Inventory of Roadway Elements (MIRE), maintained by Vanasse Hangen Brustlin, Inc., and the University of North Carolina Highway Safety Research Center under contract with FHWA; and
- Model Minimum Uniform Crash Criteria (MMUCC), funded by the National Highway Traffic Safety Administration (NHTSA) and jointly managed by NHTSA and the Governors Highway Safety Association with input from other offices in the U.S. Department of Transportation.

Data elements included in those inventories that had not already been identified were added to the list. A webinar was held in September 2010 that also solicited feedback from potential users.

The initial list of roadway data elements was quite extensive, and, given limited resources available for mobile data collection, it was necessary to prioritize roadway data elements. The research team used a hybrid webinar/survey approach to refine the initial list and come up with a prioritized list. The list was further refined by the team based on expertise and feasibility analysis. The final list consisted of two tiers of critical items (Tier 1 and Tier 2), which were collected as part of the SHRP 2 mobile data collection project. The two tiers of data are as follows:

- Tier 1
  - Horizontal curvature: Radius, length, point of curvature (PC), point of tangency (PT), and direction.
  - Grade.
  - Cross slope/superelevation.
  - Lane information: Number, width, and type (e.g., through, turn, passing, acceleration, carpool).
  - Shoulder type/curb (and paved width, if it exists).
  - Speed limit sign location (R2–4 Series).
  - Intersection location.
- Tier 2
  - Intersections: Number of approaches and control (uncontrolled, all-way stop, two-way stop, yield, signalized, roundabout). Ramp termini are considered intersections.
  - Median presence: Type (depressed, raised, flush, barrier).
  - Rumble strip presence: Location (centerline, edgeline, shoulder).
  - Lighting presence.

After the mobile data collection started, SHRP 2, in cooperation with FHWA, added two additional items to the previous list: all *Manual on Uniform Traffic Control Devices* (MUTCD) signs and information about guardrails and barriers. Additional information is provided in other sections of this report.

2.4 Identification of Data Resources

Throughout the project, the research team focused on identifying and acquiring data from Tier 1 and Tier 2 data items from publicly available resources and SHRP 2 contacts at state and local transportation agencies. Additional data were also sought for supplemental data items. The intention was to include as much of the prioritized data items as possible in the RID for future safety research. Appendix A gives a detailed report of this effort.

2.5 Determining Capabilities of Mobile Data Collection Vendors

In order to select a vendor to collect the mobile data, SHRP 2 completed the Roadway Measurement System Evaluation (Rodeo), which was conducted by a separate contracting team under Safety Project S03. Project S03 was part of a prequalification stage for the mobile data collection project. Ten vendors participated in the Rodeo. However, the Rodeo results were not sufficient for SHRP 2 to confidently develop a short list of vendors that would respond to a data collection request for proposals (RFP).

To support SHRP 2 in this effort, the project S04A research team completed a task with the objective of further evaluating the capabilities of the vendors who participated in the Rodeo. This was accomplished through documenting each

vendor's ability to collect roadway geometric data and some selected inventory data features on two of the six Rodeo control sites (6S and 7N). Seven out of the original 10 Rodeo vendors participated by completing three data collection runs for each of the two roadway segments identified. The seven data features collected for each roadway segment included roadway section (location/length), horizontal curve, grade, cross slope, lane width, paved shoulder width, and speed limit signs. The data submitted by each vendor were evaluated for accuracy and precision. The vendor evaluation results were presented to the SHRP 2 Expert Task Group (ETG) on Acquisition of Roadway Information at a meeting in Washington, D.C. The ETG members scored each vendor based on whether they were positive, neutral, or negative for each data element and the importance level of that data element. Possible scores ranged from −18 (worst performance) to +18 (best performance). The ETG members made the recommendation to qualify three of the seven vendors based on the data presented, minimum accuracy requirements, and data item importance level. Details of this effort are presented in Appendix B. Based on the results of the evaluation, SHRP 2 issued a data collection RFP (Project S04B) to the qualified vendors and the ETG selected the contractor based on a combination of qualifications, past experience, and cost.

CHAPTER 3

Data Collection Plan for the Mobile Data Collection Project

3.1 Introduction

The research team built the RID from two primary sources of data. These sources included new roadway data collected through the mobile data collection project (about 12,500 centerline miles), which was quality assured to meet minimum accuracy requirements, and acquired roadway and supplemental data provided by the departments of transportation (DOTs), local agencies, and private vendors within each state and study area. Of these data sources, the mobile collection provided the highest level of attribution, granularity, and spatial accuracy. However, as illustrated in Figure 3.1, the cost of the mobile data collection presented a limitation on extent (coverage) due to time and resource limitations.

The research team developed a plan with SHRP 2 to use the available funding for mobile data collection while ensuring adequate coverage. Between NDS sites, the criteria for determining what percentage of road miles were collected included the number of NDS participants at a given site, the availability of secondary sources of data, the study area size, and economies of scale. Within each study area, allocation was based on GPS traces of the NDS participants (which roads were being used and at what frequency), recruit maps (participants' self-reporting of typical travel patterns), and road classification. The final allocation focused on a mix of urban and rural roads with an emphasis on rural two-lane roadways, a high priority for safety research.

Given that the mobile data collection was concurrent with the NDS data collection, the roads driven by NDS participants and the total number of miles of road frequently driven by the recruits was estimated from available, though limited, GPS trace data. Considering this, SHRP 2 and the research team developed a strategy to collect the data in two primary phases, with the first phase constrained to less than half of the total coverage of 12,500 centerline miles (or 25,000 data collection miles because data was collected in both directions of travel). The following sections describe the principles followed in the selection of roads in these two phases of mobile collection (years 2012 and 2013). However, prior to these phases of data collection, an initial pilot data collection phase of about 900 centerline miles (or 1,800 data collection miles) was completed in 2011 to assess the collection process and the minimum accuracy requirements developed for the data collection. This pilot phase was critical to the success of the mobile data collection effort. In addition to the pilot and two primary phases, a third phase, or clean-up round, was programmed by SHRP 2 to ensure that mobile data was collected on those sections of roads where NDS participants were involved in a crash.

3.2 Allocation Guidance: Between NDS Sites (How Many Miles?)

This section describes the criteria used to determine the allocation of total mileage for mobile data collection in each of the six NDS sites. The following criteria were used:

- Other things being equal, if a study area had more NDS participants, mileage was proportionally increased compared to other NDS sites.
- Other things being equal, if a study area had little or no secondary-source road data (e.g., highway authority databases), especially for rural two-lane roads, mileage was increased. In general, more detailed secondary information was available for the state-owned or state-maintained roads in most states. Table 3.1 provides the percentage of state-owned or state-maintained roads in each of the NDS sites.
- Other things being equal, if an NDS site was larger in area (a proxy for the average length of trips), more miles were collected. Table 3.2 shows the size of each NDS site. This resulted in North Carolina having more miles collected than New York, even though there were fewer participants.

Even though crash history was not used to determine the mileage split between sites, crashes occurring during the NDS

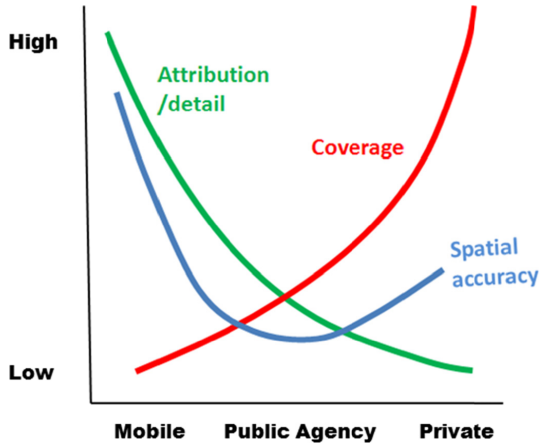


Figure 3.1. Data detail, coverage, and accuracy by source.

Table 3.1. Percentage of State-Maintained Roads in Each NDS Site

Area	Percentage
Tampa, Florida	21%
Central Indiana	10%
Durham, North Carolina	64%
Erie County, New York	11%
Central Pennsylvania	33%
Seattle, Washington	7%

Table 3.2. Geographic Area for Each NDS Site

Study Site	Area (mi²)
Tampa, Florida	4,865
Central Indiana	3,590
Durham, North Carolina	6,490
Erie County, New York	5,456
Central Pennsylvania	6,722
Seattle, Washington	10,060

study period were identified, and roads where crashes occurred were collected in a clean-up round in fall 2013.

3.3 Allocation Guidance: Within Sites (Which Roads?)

As stated previously, the assignment of roads for mobile data collection was to be on those roads where NDS participants were driving, as well as a focus on rural two-lane roads.

As GPS traces from the NDS participants' vehicles became available, mobile data collection routes were assigned accordingly. The following process was used to determine the roads to be collected at each site:

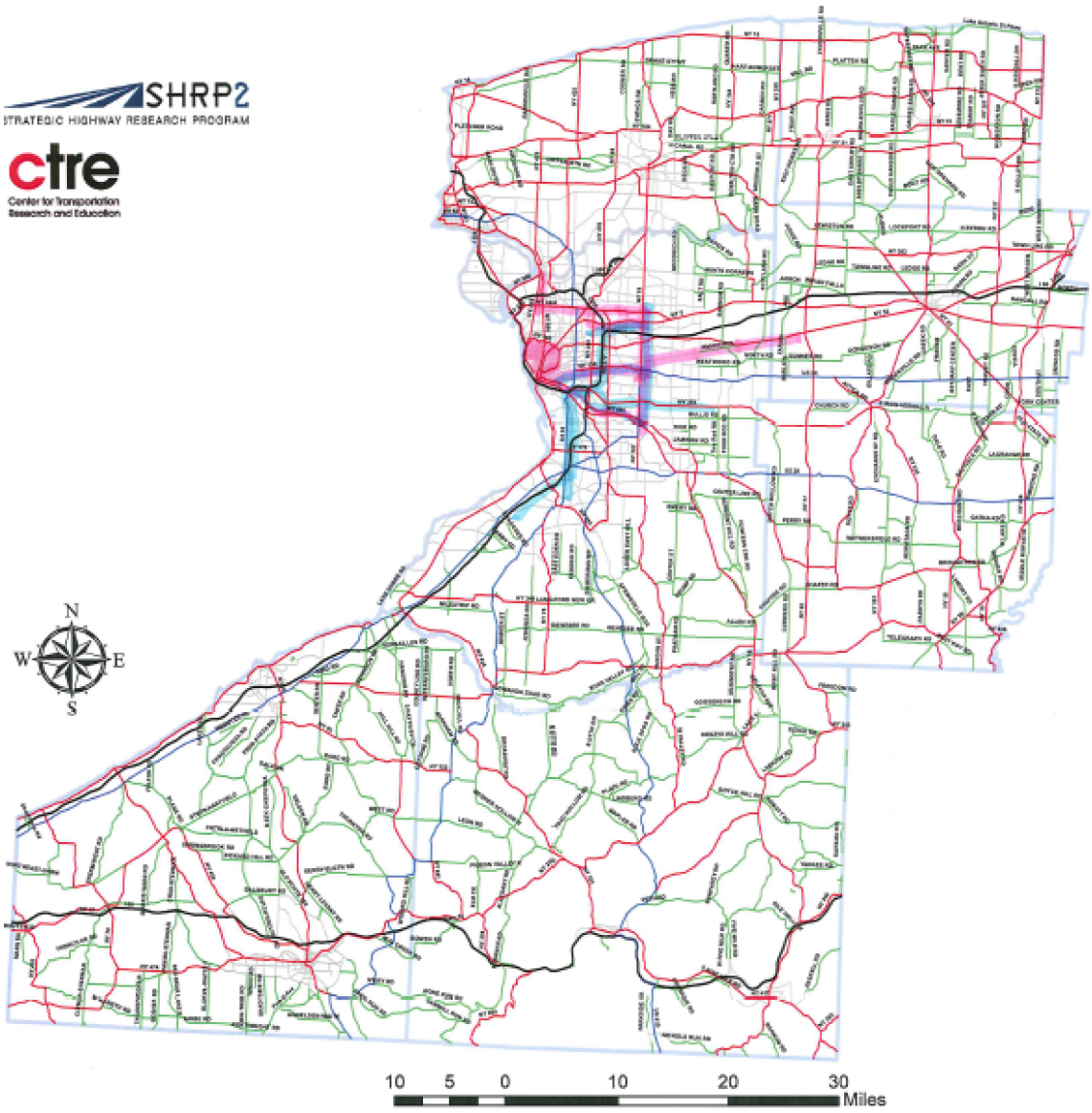
1. Total miles covered by NDS participants;
2. Miles of two-lane rural roads; and
3. NDS participant route maps.

Depending on the amount of mobile data collection mileage available in each study area, all commonly used rural, two-lane routes were covered. In other cases, NDS participants' route maps (collected by the site contractors) were used to identify/confirm collection routes. An example participant route map is shown in Figure 3.2. The figure shows routes regularly used (work or school) in pink and routes that are used for less frequent activities in blue.

To select the individual routes at each site, the research team used a combination of initial GPS traces from Virginia Tech Transportation Institute (VTTI) and participant route maps. The following describes the route selection process for the three years of data collection:

- *Pilot phase.* In 2011, available GPS traces from the NDS participants were limited. Given this situation, the research team and SHRP 2 decided to do a pilot data collection to assess the data collection process and assess minimum accuracy requirements. Limited GPS trace data (see Figure 3.3 for an example) were provided for three sites: Tampa, Florida (FL), Raleigh/Durham, North Carolina (NC), and Buffalo, New York (NY). NDS participants' maps were also used to confirm/select additional routes in 2011. In total, 1,800 miles (or 900 centerline miles) were collected in these three sites.
- *Phase 1.* In 2012, more extensive GPS traces were available for FL, NC, NY, and Seattle, Washington (WA), while limited GPS trace data were provided for Bloomington, Indiana (IN) and State College, Pennsylvania (PA). A second mobilization of the data collection vans to FL, NC, and NY finished the collection effort for these three sites, except for the clean-up round. One mobilization to WA completed all the data collection for that site, likewise except for the clean-up round. About half the miles in IN were collected during this phase of data collection.
- *Phase 2.* In 2013, GPS traces for PA and additional GPS traces for IN were provided. The data collection plan covered the rest of the miles in IN and all the collection miles in PA.
- *Phase 3 (clean-up round).* In 2013, and after the data collection plans for Phases 1 and 2 data collection efforts were finalized, an analysis of NDS participant crashes was conducted by Virginia Tech Transportation Institute (VTTI) to

Erie County / Buffalo Study Area Map



Route Identification

We have provided you with a map of the major, rural roads in the Erie County/northeastern New York area and two highlighters. We would appreciate you highlighting the roads that you typically use.

Please do not indicate the actual locations of your home and work. Please use a major intersection (two intersecting roads on the provided map) as the beginning and ending of your trips. If the roads that you typically use are not presented on the map, you do not need to add them.

Please use the **Red highlighter** to indicate the roads that you typically travel on to and from work and/or school (if you are student).

Optional: Please use the **Blue highlighter** to indicate the roads that you typically travel on to and from other frequent activities (at least once per week).

Your information will be combined with the information of other participants to help identify roads where the study team will need to collect more detailed roadway information. Your highlighted map will be destroyed once these roads have been identified.

Thank you for your participation.

Road Type Signing

- Interstate
- US
- NY
- County
- Urban
- Counties

Figure 3.2. Sample NDS participant route map. Pink highlight indicates typical work/ school routes; blue highlight indicates other common routes.

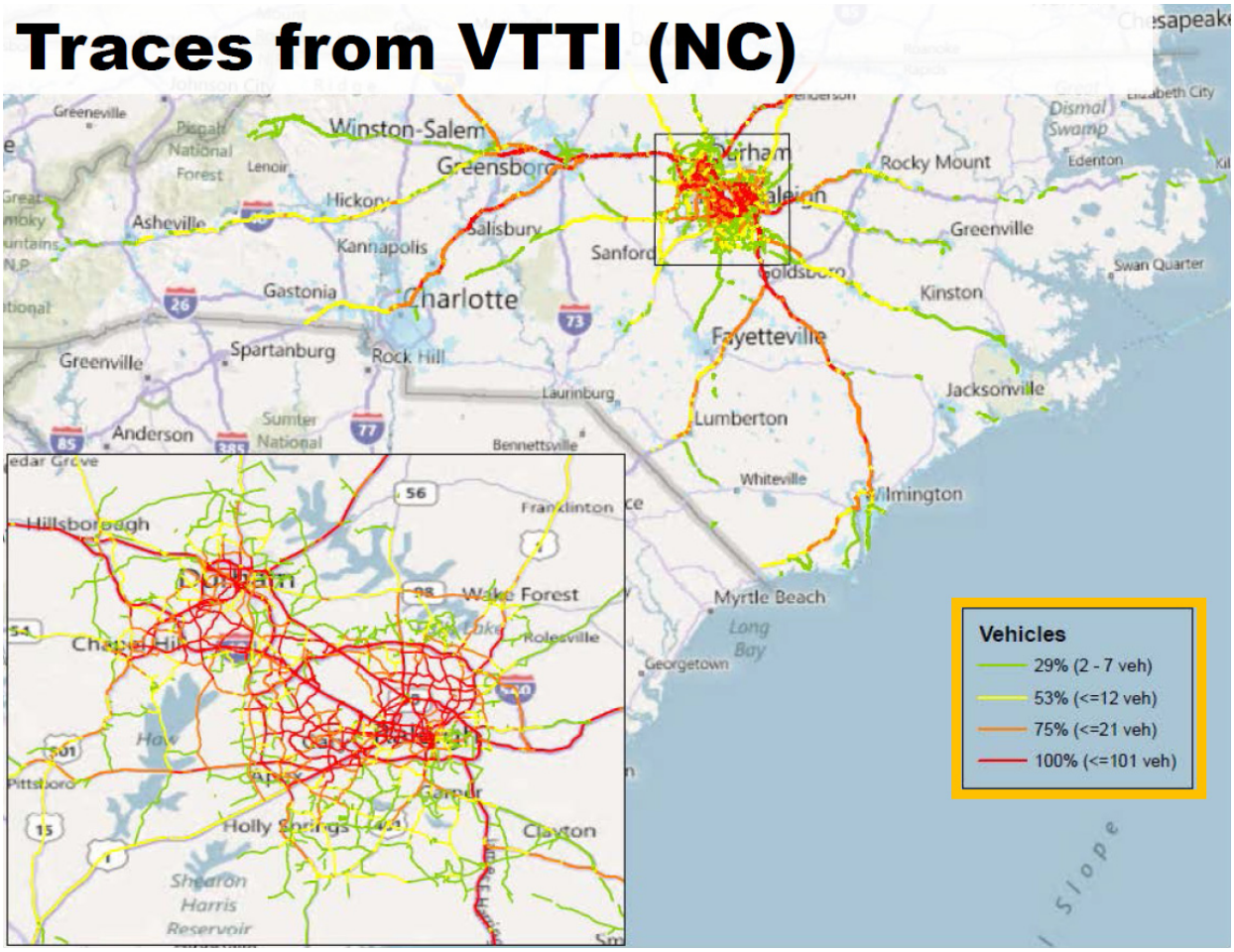


Figure 3.3. Example GPS traces from North Carolina in 2011.

assess whether the mobile data were collected on roads where these crashes occurred. Several crashes in five sites (IN, NC, NY, PA, and WA) did not have roadway data. A clean-up round of data collection was conducted and additional miles in the five sites were collected to complete the mobile data collection effort for the SHRP 2 Safety study. Note these were crashes that were known to VTTI at the time of the analysis, not the final crash count for the NDS.

3.4 Data Collection

This section covers the actual data collection of the mobile data project. Once the data collection plan for each of the NDS sites had been approved by SHRP 2, this information was provided to the mobile data collection vendor, Fugro Roadware (Fugro). Fugro then developed the initial routing package and worked with the research team on finalizing the routes to be driven before mobilizing equipment to a specific NDS site and proceeding with the actual data collection. The research team continued to coordinate with Fugro throughout the data collection period.

Figures 3.4 through 3.9 present the roadways collected using the mobile van for each study site over the 3-year data collection period. The figures show the percentage of rural and urban roads collected. A rural segment is geographically located outside of a 2010 U.S. Census Bureau–recognized incorporated place or designated place. An urban segment is geographically located within a 2010 U.S. Census Bureau–recognized incorporated place or designated place. See http://www.census.gov/geo/reference/gtc/gtc_place.html for formal descriptions of incorporated places and census-designated places (CDPs).

The following gives the total number of miles collected for each site, for a total of just above 25,000. Figure 3.10 shows the six study sites' data collection plan in comparison to the total miles in the United States.

- Florida: 4,366 mi.
- Indiana: 4,635 mi.
- North Carolina: 4,558 mi.
- New York: 3,570 mi.
- Pennsylvania: 3,670 mi.
- Washington: 4,277 mi.

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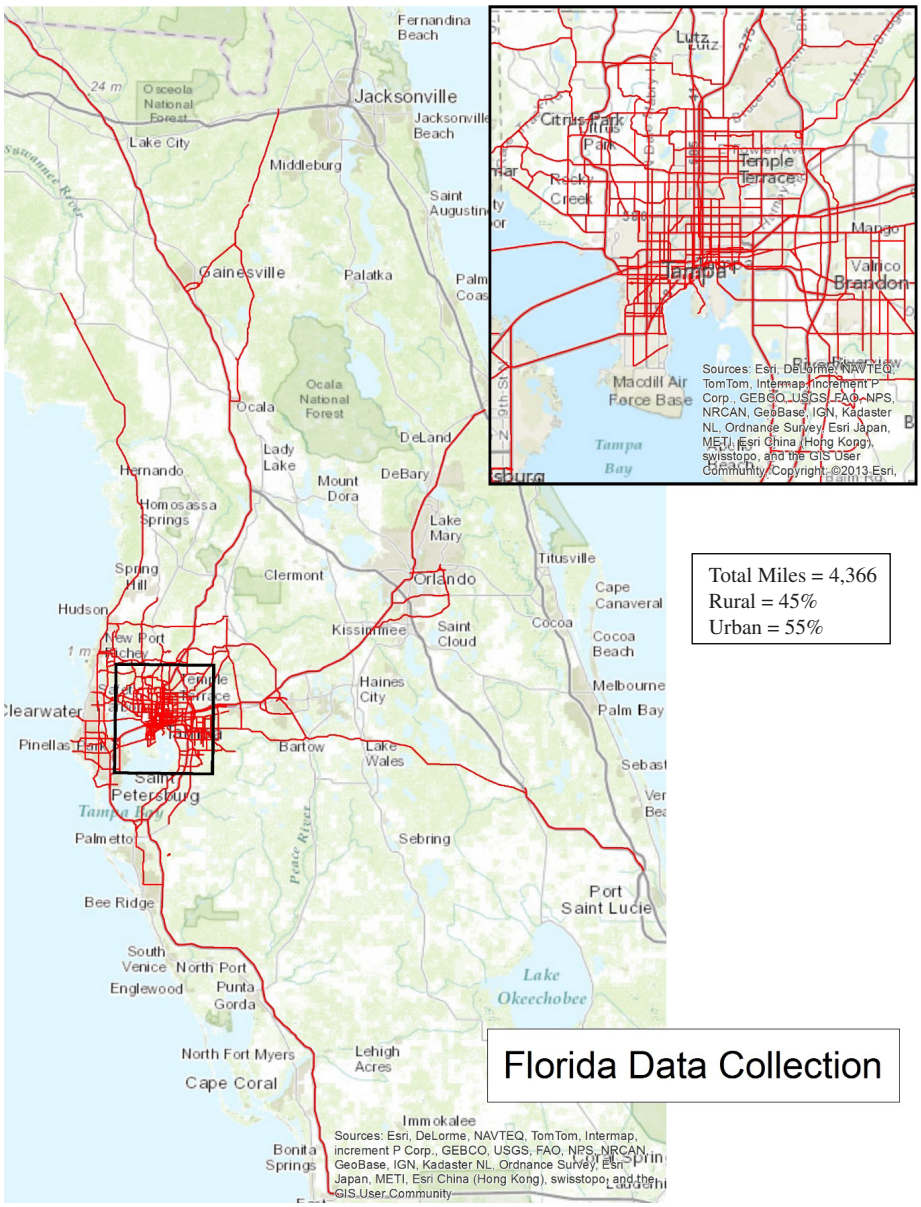


Figure 3.4. Florida data collection plan.

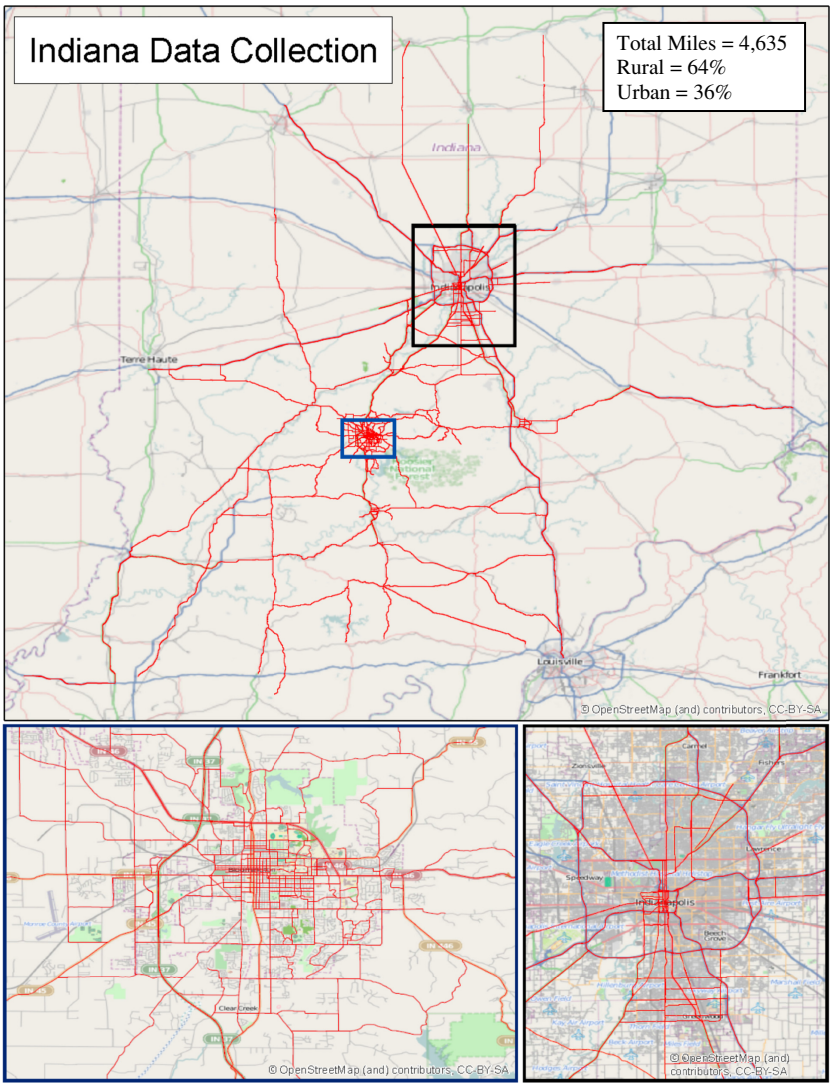


Figure 3.5. Indiana data collection plan.

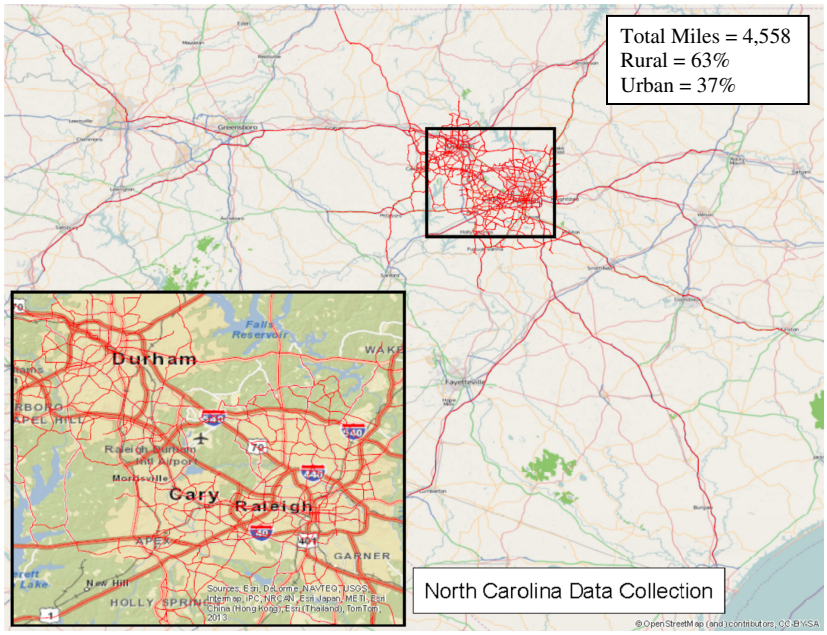


Figure 3.6. North Carolina data collection plan.

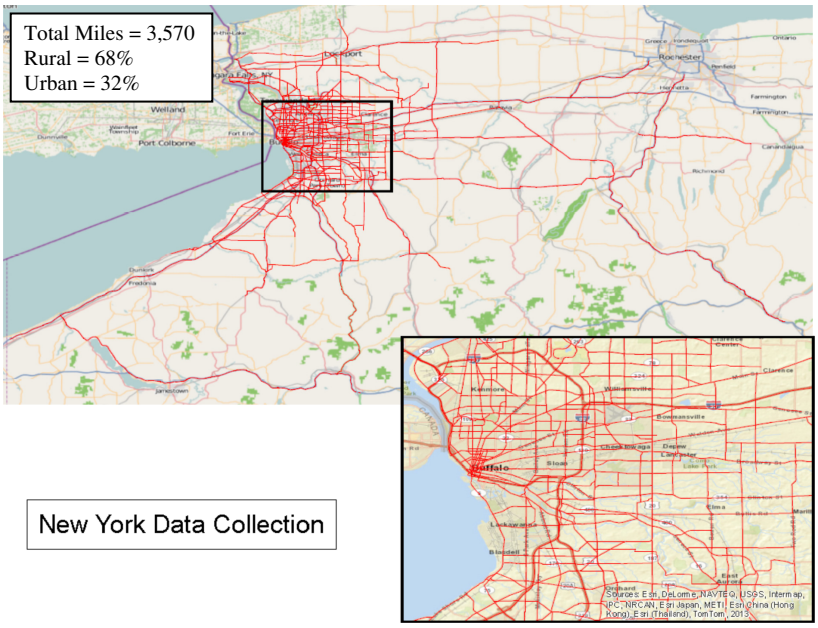


Figure 3.7. New York data collection plan.

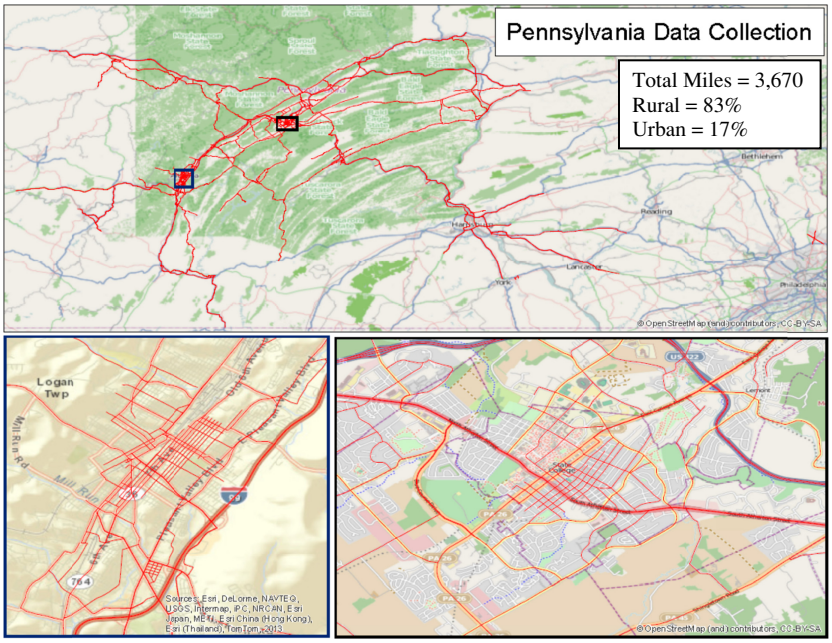


Figure 3.8. Pennsylvania data collection plan.

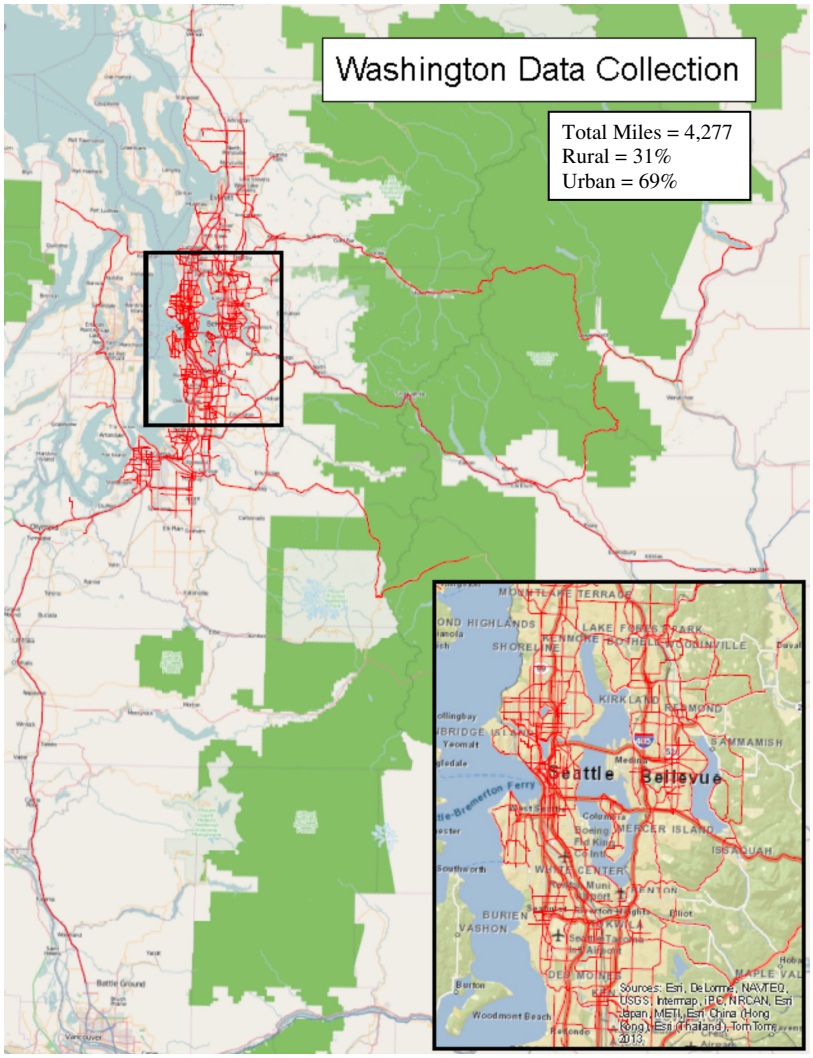


Figure 3.9. Washington data collection plan.

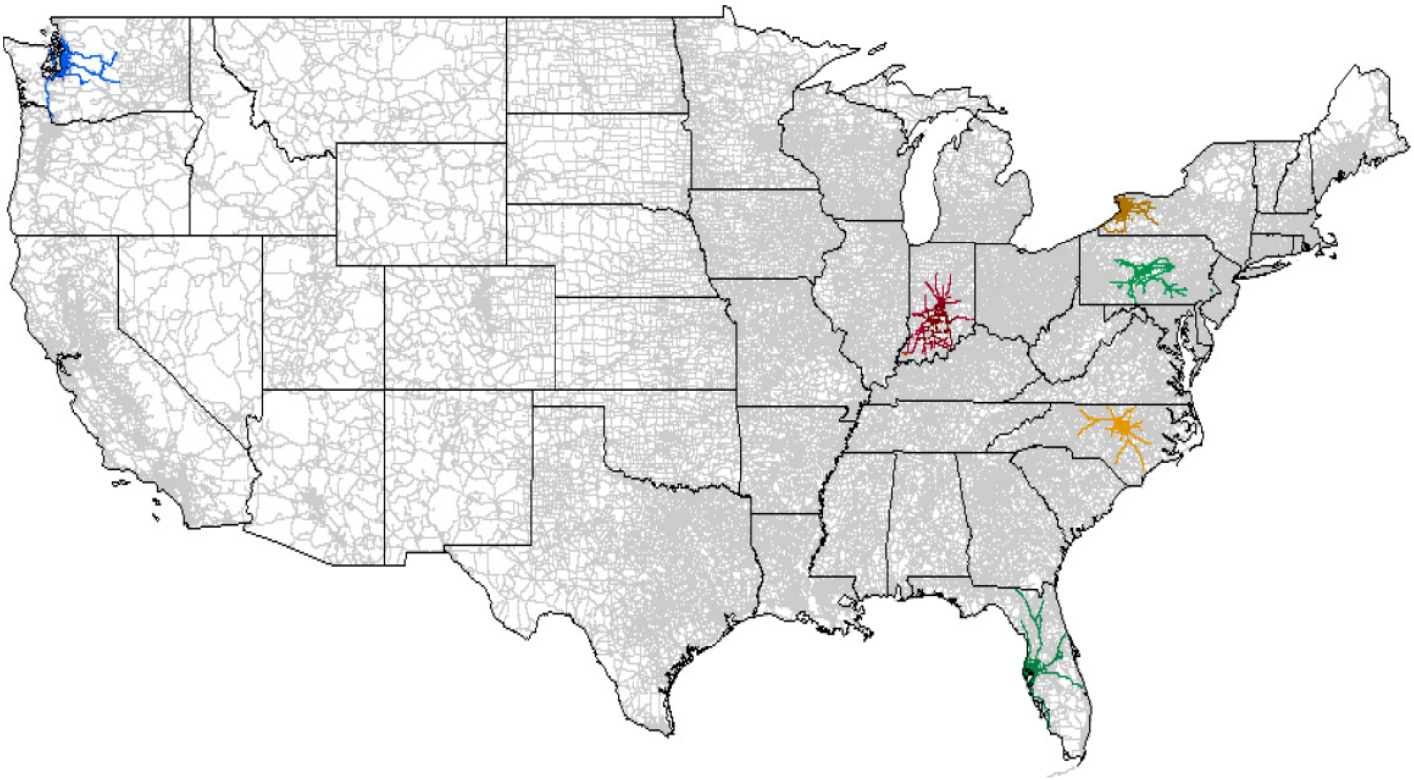


Figure 3.10. Miles collected per NDS site.

(continued from page 13)

3.5 Data Collection Requirements

The mobile data collection contractor, Fugro Roadware, was required to collect the following roadway attributes. Fugro drove the right lane in each direction.

- Horizontal curvature:
  - Radius;
  - Length;
  - PC;
  - PT;
  - Direction of curve (left or right based on driving direction).
- Grade.
- Cross slope/superelevation.
- Lanes: Number, width, and type (e.g., through, turn, passing, acceleration, carpool).
- Shoulder type/curb (and paved width, if it exists).
- All MUTCD signs.
- Guardrails/barriers.
- Intersection: Location, number of approaches, and control (uncontrolled, all-way stop, two-way stop, yield, signalized, roundabout). Ramp termini are considered intersections.
- Median presence: type (depressed, raised, flush, barrier).
- Rumble strip presence: location (centerline, edgeline, shoulder).
- Lighting presence.
- Videolog.

Table 3.3 provides a summary of the initial required minimum accuracy requirements that were developed in the RFP for the mobile data collection project. Curve minimum accuracy requirements were further modified after the pilot data collection in 2011 (see Table 6.1). The pilot data collection conducted in 2011 was critical toward

Table 3.3. Initial Required Minimum Accuracy

Data Element	Accuracy Requirement
Curvature length	50 ft
Curvature radius	50 ft
PC	25 ft
PT	25 ft
Grade (+ or –)	1.0%
Cross slope/superelevation	1.0%
Lane width	1 ft
Paved shoulder width	1 ft
Inventory feature location (signs and barriers)	7 ft

establishing the data collection process, determining feasibility of minimum accuracies, and testing the quality assurance process.

3.6 Project Management Plan

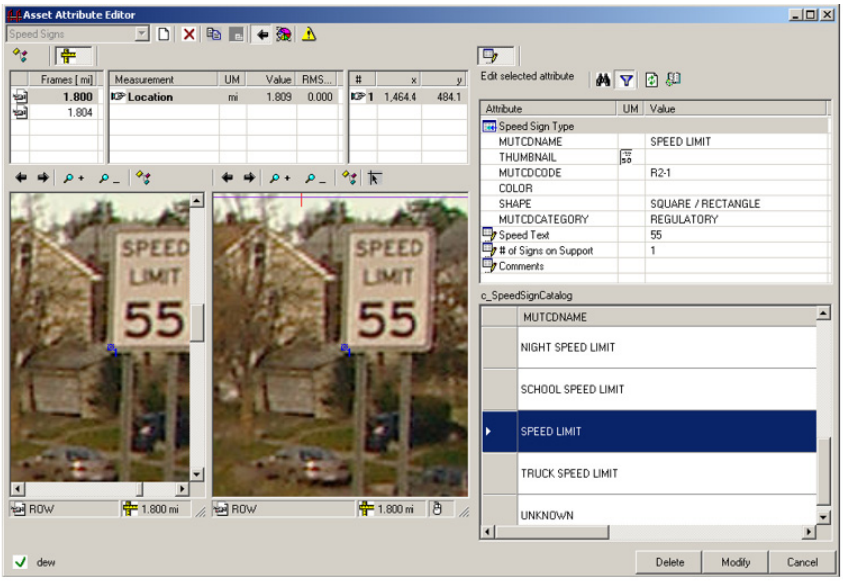
The two contracting teams (Iowa State University and Fugro) followed a management plan, approved by SHRP 2, that included a communication plan, delivery schedule, data delivery format and procedures, an asset-marking guide, and a data dictionary to ensure smooth communication among project stakeholders and timely delivery of data by the mobile data contractor.

The communication plan outlined the requirements based on roles for each of the members of the project team, which was composed of one key member from SHRP 2, the Iowa State University research team, and Fugro Roadware, supported by their respective internal teams. The communication matrix clearly identified the who, what, when, and how in terms of how specific communications were to take place in order to keep all interested parties well informed and clear of any ambiguities that could render the information confusing or inaccurate. Figure 3.11 shows the communication matrix.

In addition to the communication plan, the two contractors developed a data collection and delivery format manual.

Type of Information	Prepared By	Distribution List	Purpose of Communication	Frequency	Transmittal Method
Kick Off Meeting	S04A, S04B	Project Team, Project Sponsor	Clarify goals and objectives, individual roles and responsibilities	Once at project start-up	Meeting in D.C.
Monthly Reports	S04B	SHRP 2	Discuss status, issues and concerns related to the Project	Monthly	Email
Quarterly Reports	S04B	SHRP 2	Communicate issues/concerns, schedule, deliverables, milestones, etc.	Quarterly	Email
Project Schedule	S04B	S04A, SHRP 2	Document and monitor key tasks, milestones, issues/concerns. Document site data acquisition, delivery, and re-runs	Monthly	Email, Project Web Page
Quality Control Plan	S04B	S04A, SHRP2	Document the quality control procedures for data collection including calibration, collection procedures, and retrospective examination prior to submission	Once at project start-up	Email, Project Web Page
Data Collection Routes	S04A	SHRP 2, S04B	Database of routes to be collected, in a GIS enviroment, for each of the study sites.	Delivered a minimum of 3 weeks in advance of data collection per site.2011 (NY, NC, FL), 4-6 weeks in advance of collection 2012 (All), 2013	Email, Project Web Page
Control Site Identification	S04A	SHRP 2, S04B	List of control sites for each study site to be evaluated according to S04B's contract	Minimum of one week In advace of the first data collection for each site	Email, Project Web Page
Data Collection Schedule	S04B	S04A, SHRP 2	Document site data acquisition, delivery, re-runs, and control site survey information	Weekly Updates	Initially this will be by a scheduled conference call. As the project progresses,
Control Site Data Submission	S04B	S04A, SHRP 2	Collected data from control sites	One week after start of data collection.	Email, Project Web Page
Control Site Quality Assessment	S04A	SHRP 2, S04B	Feedback on control site data quality	One-weeks after submittal from S04B	Email, Project Web Page
Random Assessment	S04A	SHRP 2, S04B	Feedback on the quality of collected data	As needed	Email, Project Web Page
Data Delivery	S04B	S04A	Delivery of all data collected and formatted according to the roadway information database	Minimum of 500 miles every two weeks based on the data delivery schedule	Email, Project Web Page
Initial Overall Data Quality Assessment	S04A	SHRP 2, S04B	Feedback on quality for all collected data based on automated processes	Two-weeks after submittal from S04B	Email, Project Web Page
Overall Data Quality Assessment	S04A	SHRP 2, S04B	Feedback on quality for all collected data including control sites and random checks	Two-months after submittal from S04B	Email, Project Web Page
Invoice Request	S04B	SHRP 2, S04A	Submit invoice for payment based on overall data quality assessment	Once per month	Email, Project Web Page
Change Requests	S04B	SHRP 2, S04A	Communicate, receive approval and document status of all change requests.	As Needed	Email, Conference call

Figure 3.11. Mobile data collection project communication matrix.



Attributes:

Speed Sign Type: R2-1, R2-2P, R2-3P, R2-4A, R2-4P, S5-1, W13-1P, W13-2, W13-2H, W13-3, W13-6, W13-7, or Unknown.

Speed Text: Enter the speed as stated on the sign. No need to include MPH.

# of Signs on Support: Identify the total number of signs located on the same support as the extracted Speed Limit sign. This field will always be populated with AT LEAST the number 1.

Comments: This field is open for any comments you may have relating to the asset being extracted.

Figure 3.12. Mobile data collection manual.

Figure 3.12 shows an example for capturing speed limit sign location and message information.

Data deliveries from the mobile data collection vendor to the Iowa State University research team were provided in batches of approximately 500-mile increments every two weeks, based on a preestablished delivery schedule. These deliveries were in Microsoft Access format and were uploaded directly to the project FTP site. Right-of-way (ROW) images from the videolog were delivered on portable media to the research team. Following each delivery, the research team proceeded with the data quality assurance process, which is discussed later in the report under the chapter on Mobile Data Quality Assurance.

CHAPTER 4

Database Design and Development

4.1 Database Design

This section discusses the general design approach without reference to specific details. Refer to Appendix C for the details of the database design. Also discussed in this section are the development details as they relate to the final database design. The RID database design was completed by Cambridge Systematics, Inc., which served as a subcontractor to the research team.

The objectives of the database design and development component of this project were to develop the technical specifications and supporting management components for the RID, develop data models to define the RID, and ensure its interoperability with the NDS data.

As such, the RID is designed to efficiently store the entire set of roadway data collected as part of the mobile data collection project along with additional data acquired from each of the six NDS sites. The design provides a high level of flexibility in the attributes that can be stored and in the method by which those attributes are located relative to the road network. The following were considered during the design of the RID:

1. A standard road network framework was established for each of the six study area sites. This road network framework is a topologically connected geospatial database and uses a standard link-node design to depict each road segment and intersection. Note that the road networks were extracted from the Esri StreetMap Premium road network.
2. From this road network framework, a framework route system was created where each route is stored as a unique linear feature. Each route was calibrated over its entire length (i.e., the start of the route has measure 0, the measures increase along the route, and the final measure is equal to the total length of the route).
3. Location events (i.e., signs, intersections, extents of lanes, horizontal curves) would be located using a route/measure linear referencing method (LRM).

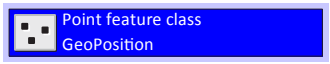
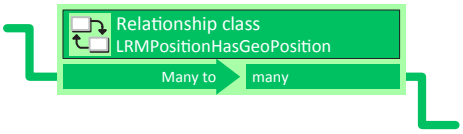
A spatially enabled database, or geodatabase, is a database designed to store, query, and manipulate geographic data, including points, lines, and polygons. The geodatabase includes a number of classes used to store attribute and spatial data, relationships between classes, and domains of valid attribute values. Table 4.1 provides brief descriptions of the classes found in the RID geodatabase.

The design of the RID database is a simplified version of the revised Unified Network-Transportation (UNETRANS) network data model proposed by Butler (2008). This data model offered several advantages:

- It allows route overlaps (i.e., when a single road segment has two or more route designations) to be handled by creating the framework routes independent of preexisting route designations. Alternative route designations (e.g., I-95, US-1) are then stored as linear events of the framework route.
- It allows geographic positions to be referenced against multiple routes using different linear referencing methods.
- It provides flexibility by storing all simple route events within a single table. These simple route events, called aspects, normally only require a single attribute descriptor (e.g., functional class, pavement width, number of lanes).
- Complex route events (e.g., intersections, signs, alignments), called elements, that require multiple attribute descriptors are stored in custom tables.
- It treats all route events, whether they are aspects or elements, in a similar manner.

Based on the requirements of the project, the data contained within the RID database were published into a

Table 4.1. RID Geodatabase Classes

Class	Description
Table	The Table class is the basic data storage mechanism consisting of columns, referred to as fields, and an unordered collection of rows. All point and linear event data are stored in tables.
Feature	The Feature class is similar to the Table class, but it is spatially enabled, allowing it to store geometry. The spatial geometry field can be one of a number of different types, including points, lines, and polygons.  Examples of Feature classes include roads and routes.
Relationship	The Relationship class defines the links between fields in two Table/Feature classes. The Relationship can simply relate the two fields in a one-to-one or one-to-many cardinality, or it can be attributed to differentiate many-to-many cardinal relationships. 
Domain	The Domain classes provide valid values for the Table and Feature class fields. The Domain classes can be of two types: • Coded: The Domain defines the list of valid choices for the field. • Range: The valid values are defined using minimum and maximum values.

denormalized data warehouse (storing individual roadway attributes in their native extents) designed to improve data query and retrieval speeds.

4.2 RID Data Model Examples

The following sections describe the RID data model and provide examples, which include alignment, aspects, and domains. A complete description of the data model is included in Appendix C.

4.2.1 Alignment

The road alignment (horizontal curves) is defined using several related attributes and is stored separately as a linear event against the routes (Figure 4.1).

4.2.2 Aspects

Simple route events, called aspects, normally only require a single attribute descriptor (e.g., functional class, pavement width, rumble strip location). As such, they can be stored within the same table, Aspect, that provides the following (see Figure 4.2):

- The spatial location for the route event;
- The type of the event (which infers the event value type); and
- The event value.

This structure is identical to the current data model developed by FHWA for submission of the 2012 Highway Performance Monitoring System (HPMS) data.

4.2.3 Domains

The domains within the RID define the valid values for a subset of the fields within the S04A data model and are used for efficiency because they allow numeric IDs to be stored within the tables rather than repeated strings.

The domains fall into two categories:

1. Fixed domains: The values within the domain do not change between RID databases.
2. Dynamic domains: The values within the domain are dynamically populated based on the loaded data.

4.2.3.1 Fixed Domains

Fixed domains are shown in Figure 4.3.

4.2.3.2 Dynamic Domains

The codes listed within dynamic domains are dynamically inserted by scanning the S04B databases to determine unique values for the associated fields. Dynamic domains are shown in Figure 4.4.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
Alignment

Alignment

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
AlignmentID	GUID	No			0	0	38	Unique identifier
LRMPositionID	GUID	No			0	0	38	Identifier for LRMPosition
Tangent	Short integer	No	0	TrueFalse	0			Tangent
Radius	Long integer	No			0			Curve radius
CurveDirectionID	Short integer	No		Direction	0			Curve direction
SuperElevation	Double	Yes			0	0		Super-elevation
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No		DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Figure 4.1. S04A alignment data model.

4.3 Ongoing/Long-Term RID Management

The RID is static (reflecting what the roadway looked like during the NDS study period), and there is no need to maintain the database in the sense of updating or refreshing content. Long-term management of the RID may take the form of migrating data to newer and more efficient database software, which will probably emerge over the next 10 to 30 years.

Additional maintenance tasks are to ensure the physical functioning of data storage and to protect the system from hazards. Assuming that the data are hosted by a commercial service provider, state DOT, or research institution as contemplated above, these are routine aspects of hosting.

4.4 RID Operation Procedures

The RID was built on an underlying, route-measure-based linear referencing system (LRS). Other roadway features, such as those identified in the mobile data collection project, have been conflated to this LRS and are represented as individual features within an Esri ArcGIS geodatabase. Each feature also possesses corresponding LRS-based route and measure values. Therefore, the RID supports both attribute-based and spatial-based queries, as well as dynamic segmentation (examples of such queries are provided in Appendix F). Dynamic segmentation may be used to overlay multiple, independently maintained, and disparate data sets to identify locations satisfying specific conditions. Appendix F provides a step-by-step example of how the process can be used to answer a research question.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
Aspect

Aspect

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
AspectID	GUID	No			0	0	38	Unique identifier
LRMPositionID	GUID	No			0	0	38	Identifier of the LRMPosition
AspectTypeID	Short integer	No		AspectTypes	0			Aspect Type ID
ValueNumeric	Double	No			0	0		Aspect numeric value
ValueText	String	No					32	Aspect text value
ValueDate	Date	No			0	0	8	Aspect date value
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1	DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Table
AspectType

Aspect Type

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
AspectTypeID	Short integer	No	-1		0			Unique identifier
Name	String	No					32	Name of the Aspect
FieldTypeID	Short integer	No	1	FieldTypes	0			Aspect data field type
GeometryTypeID	Short integer	No	1	GeometryTypeID	0			Aspect geometry type
DomainTypeID	Short integer	Yes		DomainTypes	0			Aspect domain
RangeMin	Double	Yes			0	0		Minimum range value
RangeMax	Double	Yes			0	0		Maximum range value
CodedValueTable	String	Yes					128	Coded Value Domain table name
UseOffset	Short integer	Yes		TrueFalse	0			Use LRM offset?

Figure 4.2. S04A aspects data model.

Coded value domain
AspectTypes

Description *Name*
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Code	Description
1	Route Name
2	AADT
3	Functional Class
4	Lighting
5	Median Strip
6	Rumble Strip
7	IRI
8	Speed Limit

Coded value domain
Datums

Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
1	State Plane
2	WGS 84
0	Unknown

Coded value domain
Direction

Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
-1	Left
0	None
1	Right

Coded value domain
DomainTypes

Description *Domain Types*
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Code	Description
0	None
1	Range
2	Coded Value

Coded value domain
GeometryTypeID

Description
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Code	Description
1	Point
2	Polyline

Range domain
InterectionNumApproaches

Description
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Minimum value	Maximum value
0	10

Coded value domain
LocationMethod

Description *Method used for*
Field type *locating the polyline*
Split policy *Short integer*
Merge policy *Default value*

Code	Description
1	End points on same route
2	End point on adjacent routes
3	Shortest path
-1	Original and Conflated polyline length differ by more than 20%
-2	End point(s) failed to snap to network within tolerance
-3	Failed to find shortest path between end points

Coded value domain
OffsetDirections

Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
0	None
1	In
2	Out
3	North
4	East
5	South
6	West
7	Toward
8	Away From

Figure 4.3. Fixed S04A domains. (Continued on next page.)

Coded value domain
FieldTypes

Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
1	Short Integer
2	Integer
3	Long Integer
5	String
6	Float
7	Double
8	ObjectID
9	DateTime
10	GUID
11	XML
12	Blob

Coded value domain
Referents

Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
0	None
1	Edge of Pavement
2	Face of Curb
3	Back of Curb
4	Back of Sidewalk
5	Edge of Right of Way
6	Centerline of Road
7	Centerline of Ditch

Coded value domain
SideCode

Description
Field type *String*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
L	Left Side Only
R	Right Side Only
B	Both Sides & Street
S	Street Only
N	Both Sides & Not Street
U	Unknown
C	Center

Coded value domain
TrueFalse

Description
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Code	Description
-1	True
0	False
1	True

Figure 4.3. Fixed S04A domains. (Continued from previous page.)

Coded value domain
BarrierPostMaterial

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
BarrierTreatmentType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
BarrierType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
IntersectionControlType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
MedianType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
ShoulderType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
SignMUTCDName

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
SignMUTCDCode

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
SignMUTCDCategory

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Figure 4.4. Dynamic S04A domains.

CHAPTER 5

Existing Data Acquisition

The RID includes two broad types of data: (1) new data collected and quality assured by SHRP 2 under the mobile data collection project discussed in previous sections of this report and (2) existing data acquired from public and private sources. The existing data include roadway inventory data from state DOT files, as well as HPMS, Federal Railroad Administration (FRA) grade crossings, and supplemental data, such as traffic, weather, and crashes. This chapter discusses the acquisition of existing and supplemental data. Figure 5.1 illustrates the varied data sources.

The original research approach proposed development of a standardized data assessment matrix for this effort. This was completed, in part, for the larger data providers (or resources), typically state DOTs. Local agency data were evaluated a bit more broadly. An overarching consideration in the data evaluation was if, or how, existing state and local roadway data may be used. The existing data evaluation was done in parallel with the RID design and helped inform the RID design on the following issues:

- Is a consistent level of accuracy, coverage, and feature resolution for the roadway centerline framework required across all six sites? Alternatively, is the best available centerline data from each site sufficient? Consistency across all six sites would most likely require obtaining commercial roadway data.
- What is the minimum level of positional accuracy that can be accepted to meet the needs of researchers who will be using the roadway data?
- Will researchers be expected to use linear referencing methods to link attribute data to the roadway geometry? Alternatively, should the roadway database incorporate this linkage implicitly?
- If linear referencing methods are employed to link attributes to the roadway geometry, are multiple LRS, developed by the state or local agencies, used? Alternatively, is a single, consistent LRS developed for use at all six sites?
- How should roadway geometry features, such as horizontal curves or grades, be defined?
- Should the centerline geometry collected by the mobile data collection vendor be integrated into the roadway databases for each site?

5.1 Existing Data

In conjunction with the mobile data collection and supplemental data effort, the project team also determined the characteristics, availability, and suitability of existing roadway inventory data and useful spatial representations for each of the six study site areas.

5.1.1 Identify Possible Data Providers

SHRP 2 and the research team contacted data providers at each site, usually a state DOT, and introduced the NDS and S04 projects.

The research team developed a simplified data discovery worksheet (Figure 5.2), based on the SHRP 2 Prioritized Rodeo Data Elements Lists (Assets, Geometric Features, Intersections, Pavement Conditions, Roadway Inventory), and shared this worksheet with the contacts made at each site. The worksheet served as a means to initially assess the availability and extent of various roadway characteristics, as well as those possessing these data. It was separated into three primary areas: (1) roadway-attribute data of interest, (2) roadway system and extent, and (3) contact information, used to identify data providers within the DOT and other agencies.

5.1.2 Conduct Site Visits

After making initial contact with data providers, SHRP 2 and the research team conducted site visits to further discuss the NDS and S04 projects. Participants included state DOT staff and/or staff from other agencies, such as cities, counties, and

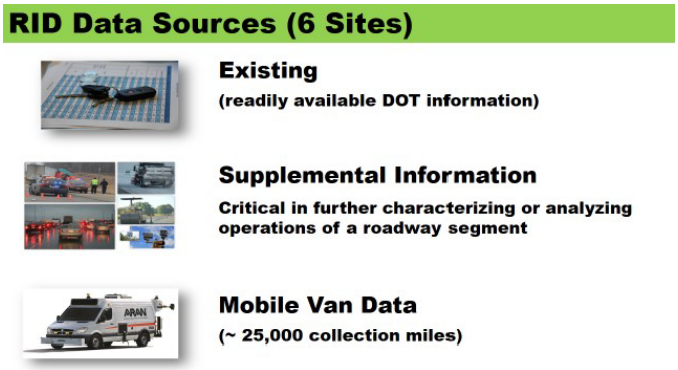


Figure 5.1. RID data sources.

metropolitan planning organizations (MPOs). During these visits, an attempt was made to obtain additional information about available resources and data providers. Ideally, a primary contact at each agency was established during these meetings to coordinate future requests and activities.

SHRP 2 and the research team also attempted to obtain additional contacts, or data providers, through several means: (1) from those attending a site visit meeting, (2) by interacting with those who were not in attendance but were provided as a contact, and (3) through Internet searches. An attempt was made to obtain additional information regarding data sources and availability from these new contacts.

5.1.3 Evaluate Data and Metadata

Following the site visits, the research team tried to obtain and evaluate as much metadata (captured from data dictionaries) and attribute data as possible from pertinent agencies at each site. Sometimes this required contacting agencies that had not been previously involved in the data discovery process.

Given these considerations, the data evaluation process was loosely based on the crash data improvement program (CDIP) guide (http://safety.fhwa.dot.gov/cdip/). This guide was established to assist in identifying, defining, and measuring the characteristics of data quality within state crash databases. However, the research team felt that it was extensible to this effort, focusing on the six data quality characteristics of timeliness, consistency, completeness, accuracy, accessibility, and integration. A primary challenge of the evaluation was that data must be evaluated not only independently but also within each site and among all sites. This being considered, the research team first had to determine whether possible roadway attributes of interest were available or existed within the sites and, if so, for which systems. For example, a given attribute may only be maintained on the state system or by only one county within an NDS site covering multiple counties. Additionally, since the roadway characteristics of interest had not been fully identified at the earlier stages of the project, attributes of interest were broadly defined and assumed. The following are some of the considerations and

		Roadway System (Owner) & Data Extent												Agencies, Offices and/or Contacts			
		State			County			Municipal			Other						
		Compre-hensive	Road Class*	Sample	Compre-hensive	Road Class*	Sample	Compre-hensive	Road Class*	Sample	Compre-hensive	Road Class*	Sample	State	County	Municipal	Other
Roadway Characteristics	Number of lanes																
	On-street parking																
	Pavement markings																
	Median																
	Rumble strips/stripes																
	Speed Limit																
	Shoulder																
Roadway Features	Intersections																
	Driveways																
	Bridges/approaches																
	Rail crossings																
	Ramps																
Geometric Features	Grade																
	Cross slope																
	Horizontal curvature																
	Vertical curvature																
Roadside Features	Barrier systems																
	Obstacles																
	Sidewalk																
	Signs																
	Street lighting																
Pavement Features	Edge drop-off																
	Condition																
	Skid/friction																
Additional Data	Crashes																
	Roadway safety projects																
	Traffic																
	Workzones																
	Weather																
	Enforcement/education projects																

Figure 5.2. Data discovery worksheet.

challenges associated with assessing the six data quality characteristics:

- *Timeliness.* Data must be available for the NDS time frame. Data sets under development and available during the NDS time frame was taken into consideration.
- *Consistency.* Uniformity may be greatly impacted by the various standards and protocols employed by the multiple agencies involved.
- *Completeness.* As with consistency, completeness may vary not only among agencies but also among data elements within agencies. Some agencies collect and maintain data for only a portion of the public roadways (e.g., state-maintained roads, federal aid eligible).
- *Accuracy.* Are SHRP 2 mobile data collection project accuracy requirements satisfied? Sometimes, the accuracy of the data may not be clear or well documented or may be influenced by several sources.
- *Accessibility.* Accessibility to researchers may be affected by data licensing and sharing agreements.
- *Integration.* Integration describes the feasibility and/or ease of linking or integrating potentially disparate data sets with the mobile data, the NDS data, and other pertinent data available within and among the sites.

5.1.4 Findings

Site or DOT visits were conducted in five of the six states: New York, Pennsylvania, North Carolina, Indiana, and Washington. A webinar was held with state DOT staff in Florida.

State DOT staffs were primarily involved in meetings in New York, North Carolina, and Washington. Both state and local representatives participated in the Pennsylvania and Indiana meetings. A second meeting in New York, predominantly involving local staff, was held at the Greater Buffalo-Niagara Regional Transportation Council. A second meeting was also held at the Centre County MPO, Pennsylvania, involving MPO staff.

Through these meetings, and additional networking and discovery, more than 130 individuals participated, were identified as contacts, and/or were contacted during the data discovery task. Table 5.1 presents the number of contacts for each state.

Data discovery worksheets were shared with meeting participants and sent to individuals or agencies identified as possible data providers, primarily local agencies. A description of the NDS accompanied the data discovery worksheets. Unfortunately, the response rate was not particularly high with local agencies.

Some of the originally proposed evaluation strategies were determined to be more applicable to database design and specifications and potentially excessive, given preliminary findings in working with some agencies. States would often request a list of specific attributes needed for NDS, as well as details about these attributes. This could not be provided at the time, because the attribute list was preliminary, and the data discovery worksheet was purposely vague in this regard. Additional challenges were presented when coordinating with multiple offices or data providers within the same agency. Because the specific data needs were not known, it was impractical to investigate all the nuances of each of the data sets of possible interest.

Table 5.1. Number of Individuals Contacted for Data Discovery by State

State	Number of Contacts
New York	23
Pennsylvania	37
North Carolina	16
Indiana	11
Florida	20
Washington	24

Since agencies, particularly state DOTs, provided various levels of data or metadata, additional emphasis was placed on evaluation of publicly available data. Given the existing availability of these data, limited challenges should exist in making such data available to researchers, and, therefore, they may be viewed as the minimum available. In other words, existing data sharing standards and procedures are already established. In some cases, these data sets represent much of the readily usable, internally maintained data. An assessment matrix was prepared for the aforementioned state data. It focused on the following elements:

- *Area.* Total area (in square miles) for all counties included in the study area.
- *Total centerline miles.* Total centerline miles of all (public) roads within the study area (obtained from either Topologically Integrated Geographic Encoding and Referencing [TIGER] or a statewide all-roads data source).
- *Average road density.* Total centerline miles/area.
- *Roadway centerline data source.* Name and URL for the roadway centerline databases.
- *Total centerline miles in study area.* Total centerline miles included in the roadway database for all counties in the study area.

- *Percentage of centerline miles represented.* Total centerline miles included in the roadway database/total centerline miles of all roads in the study area.
- *Included road classifications.* Road functional classes included in (or excluded from) the database.
- *Source of line geometry.* Primary source of digitized line geometry (e.g., 1:24,000 maps, orthoimagery, kinematic GPS).
- *Positional accuracy.* Estimate of horizontal positional accuracy, based on data sources.
- *Update frequency.* Frequency of release of published versions of the database (from metadata).
- *Last update.* Date of most recent update (from metadata).
- *Routable network.* Initial qualitative assessment regarding whether the database incorporates network topology.
- *Database format.* Available GIS data format (typically Esri shapefile).

5.1.5 Existing Data Elements in the RID

The final data elements included were selected mostly by providing any available data that satisfied data quality requirements to transportation safety researchers. Overall, the variability and coverage of data items varied from state to state, and some were available for only one or few states. However, the research team did not want to limit the data set by trying to provide a common list among states; therefore, a data dump from the state DOTs was obtained. In addition to data resources from state transportation agencies, Esri StreetMap Premium for ArcGIS was also included in the RID (e.g., roadway attributes include street name, functional class, speed limit, number of lanes, direction of travel).

Table 5.2 presents a cross reference of mobile data items collected to available state information. The information indicates that a majority of S04B data items were not available in the existing data resources. When data items were available, such as shoulder type or median presence, the data were available only for state-maintained roads.

Table 5.3 lists general data items besides mobile van data that were identified in state data resources and included in the RID. Again, coverage and availability of a particular data item among states vary, but any data item that could potentially be useful for future safety research was therefore kept in the database.

A broad listing of data elements from state transportation agencies included in the RID is as follows (the coverage is typically state-maintained roads):

- Florida: 2010 Florida Traffic Information and Highway Data (extensive database including access control type, access management, bridges, facility crossing names, functional classification, interchanges, intersections, maximum speed limits, median type, median width, number of lanes, pavement conditions, railroad crossings, rest areas/welcome areas, roads with local names, road status, surface width, annual average daily traffic, portable traffic monitoring sites, telemetered traffic monitoring sites, traffic signal locations, truck traffic volume, weigh-in-motion locations), and Pasco County sign inventory.
- Indiana: Bridges, traffic count station averages, friction, pavement condition, curves, functional classification, international roughness index, lane information, shoulder information, median information, speed limits, texture, traffic section, truck traffic volume.
- North Carolina: Roadway characteristics, pavement condition, electrical service points, signal locations, traffic volume data.
- New York: Roadway inventory system, structures (bridges, culverts), pavement information.
- Pennsylvania: Bridges, intersections, pavement information, traffic information, sign inventory, roadway characteristics, intersections.
- Washington: Roadway characteristics, pavement markings, alignment, rumble strips, roadside inventory, freight goods transportation system, traffic information, bridge, culverts.

5.2 Supplemental Data

For the purpose of this report, the term "supplemental" refers to any data item that characterizes a roadway segment that is not included as part of the mobile data collection undertaken by SHRP 2 or existing roadway data being acquired from transportation agencies within the six NDS sites. Many of these supplemental data items can be considered basic descriptive elements in transportation analysis and as such are of considerable interest to the transportation research community and the SHRP 2 Safety and Reliability programs.

The RID includes a number of features that physically describe the roadway setting (e.g., curvature, grade, cross slope, lanes). There are, however, a number of other roadway variables that are critical to further characterizing a roadway or analyzing the operation of that roadway segment. As part of the supplemental data effort, both the SHRP 2 Safety and Reliability programs had overlapping data needs that were considered in determining the data to acquire, though the safety program requirements were the primary priority. For example, the exposure associated with a roadway segment is a common component of safety and reliability analysis. Exposure can include traffic composition and volume levels. Drivers are also impacted by changes in operations due to the impacts of seasonal weather, major public events, operating and posted travel speeds, and enforcement. System reliability is regularly

Table 5.2. Mapping of Mobile Data Items versus Available State Information

					Florida	Washington	Pennsylvania	North Carolina	New York	Indiana
Tier 1	Alignment	Tangent			State+, PI, central angle, compass bearing, degree of curve	State	No	No	No	On-system only by curve class and location
		Curve	Radius			State	No	No	No	
			Length			State	No	No	No	
			PC	Lat		State	No	No	No	
				Long		State	No	No	No	
			PT	Lat		State	No	No	No	
				Long		State	No	No	No	
			Direction		State+	State	No	No	No	
	Grade				Grade classes for HPMS only	State	No	No	No	No
	Cross slope				Horizontal HPMS segments only	No	No	No	No	No
	Superelevation				No	State	No	No	No	No
	Lane		Number		State+ for through lanes	State	State+	State+	State+	State
			Width		Total through lanes surface width	State	Derived	State+	Pavement width, state+	Yes
			Type		Through (state+) auxiliary (only state)	State	State+	State+	No	Auxiliary lane incomplete
	Shoulder		Type		State highway system, HPMS, SIS	State	State+	State+	State+	State
			Width if paved		State highway system, HPMS, SIS	State	State+	State+	State+	State
	Signs		Lat		Pasco County	No	State+	No	No	No
			Long		Pasco County	No	State+	No	No	No
			Message		No	No	Yes	No	No	No
			MUTCD Code		Pasco County	No	No	No	No	No
			Number of signs on post		Pasco County	No	No	No	No	No
	Intersection		Location		State and county roads	State	State+	No	No	No
Tier 2	Intersection		Number of approaches		No	State	From segments	No	No	No
			Control type		No	State	No	No	No	Only signalized state
	Lighting				No	No	No	No	No	No
	Median		Presence		State+	State	Yes	State+	State+	State+
			Type		State+	State	Yes	State+	State+	State+, different classification of median types
	Rumble strip		Presence		Limited outside shoulder	State	No	No	No	No
			Location		Limited outside shoulder	State	No	No	No	No

Note: State+ = data available on all state roads and some additional roads.

Table 5.3. Existing Data Items from the States, Excluding Mobile Data Items

	Florida	Washington	Pennsylvania	North Carolina	New York	Indiana
Signals	State	State	State	State, partial	No	State, partial
Average annual daily traffic (AADT)	State (also truck volume)	State (also truck volume)	State (also truck volume)	All highways functionally classified above local	State, AADT, DDHV, volume/capacity ratio, % trucks	State, section averages, also truck
Pavement condition	Very poor, poor, fair, good, very good (all principal arterial roads and some additional)	Very poor, poor, fair, good, very good (state)	No	Alligator cracking, transverse cracking, rut, ride, patch, faulting (state)	Pavement score, IRI, rutting, dominant distress, overlay, crack sealing (state)	Friction, IRI, and texture (on interstate roads)
Friction	No	State	State	No	No	State
Bridges, culverts	Bridges, begin/end, FHWA#	Bridges, begin/end, FHWA#	Bridges, begin/end, FHWA#	No	Bridges, culverts, shape file (bridge characteristics, condition)	No
Posted speed limit	State	State	State	State	State	State
Pavement surface type	State	State	State	State	State	Major collector and above (state), partial
Functional classification	State+	State+	State	State	State	State
Access/access control	All roads functionally classified higher than local	State	State	State	State	No
Interchanges	Principal arterials, location and type	Under crossings	Yes	No	No	No
Intersections	State, location, surface and description	State, control type, illumination, and configuration	State	Number in a segment	No	Signalized, state
Railroad crossings	Yes	Yes	Yes	Yes	Yes	Yes
Rest areas	Yes	Yes	No	No	No	No
Vertical alignment	Only adequacy, HPMS segments	State	No	No	No	No
Terrain	HPMS segments	Yes	No	Yes	Yes	No
Tunnels	No	Yes	No	No	No	No

Note: IRI = international roughness index; state+ = data available on all state roads and some additional roads; HPMS = Highway Performance Monitoring System.

impacted by the frequency of roadway disruptions due to construction, closures, incidents, or other capacity reduction factors. The supplemental data will aid researchers in conducting a more comprehensive analysis of driver, vehicle, and roadway interactions and full utilization of the NDS and RID databases. These data will also allow for conducting before-after evaluations of new safety programs, initiatives, and laws introduced or changed during the period of the SHRP 2 program in each NDS site.

The supplemental data effort initiated with a feasibility study before SHRP 2 gave permission to proceed with data acquisition. The feasibility study addressed the availability and cost of acquiring data items specific to the SHRP 2 Safety and Reliability focus areas and integrating these data into the SHRP 2 RID (see Appendix D for details). An initial list of more than 30 potential supplemental data items was expanded to include roughly 125 items within four categories, including safety, reliability, common items to both safety and reliability, and policy. Input from both safety and reliability professionals helped to narrow this comprehensive list down to approximately 32 items. Using this prioritized list as a starting point, the research team contacted agency staff within the six NDS sites and private data sources and recommended 20 data items for acquisition across the six NDS sites.

Table 5.4 presents the top-priority data items acquired by the project team that are included in the RID. Figure 5.3 provides a description of these data. In this figure, each data item is described with the spatial coverage, frequency of data sets, and time of coverage.

Table 5.4. Data Items for Supplemental Data

Priority	Item	Category
1	Crash data	Common
	Traffic information: AADT	Safety
	Aerial imagery	Common
	Speed limit data	Safety
	Speed limit laws	Policy
	Cell phone and text messaging laws	Policy
	Automated enforcement laws	Policy
	Alcohol-impaired and drugged drivers laws	Policy
	Graduated driver licensing (GDL) laws	Policy
	State motorcycle helmet use laws	Policy
	Seat-belt use laws	Policy
	Local climatological data (LCD) from NOAA	Common
	Cooperative weather observer/other sources	Common
2	Winter road conditions (from DOTs)	Common
	Work zone	Common
	511 information	Common
	Traffic data: continuous counts (annual traffic report [ATR])	Safety
	Traffic data: short duration counts	Safety
	Changes to existing infrastructure condition	Safety
	Roadway capacity improvements	Common

#	Item	Priority	Category	Description	Data Type	Data Frequency	Time Period of Interest
1	Crash Data	1	Common	State's official crash file.	GIS State/County	Yearly	2006-2013
2	Traffic Information - AADT		Safety	Computed AADT by site or segment.	GIS Statewide	Yearly	2011-2013
3	Aerial Imagery		Common	Aerial imagery at 1 meter resolution which can be associated with Geographic Information Systems (GIS).	1 Meter Resoultion Image County Based	Single Year	Between 2011-2013
4	Speed Limit Data		Safety	Posted speed limit by location, and if available advisory and special restrictions along with changes during the SHRP2 NDS period	GIS Statewide	Single Year	Between 2011-2013
5	Speed Limit Laws		Policy	Any increase or decrease to the maximum statutory speed limit over the two-year duration on state roads.	State Summary Document	Yearly	2011-2013
6	Cell phone and text messaging laws		Policy	Laws which prohibit hand-held cell phone use and/or texting while driving.	State Summary Document	Yearly	2011-2013
7	Automated enforcement laws		Policy	Laws which enable or prohibit the use of automated speed enforcement, red light running cameras, or other devices.	State Summary Document	Yearly	2011-2013
8	Alcohol-Impaired and Drugged Drivers laws		Policy	Laws enacted that prohibit driving while impaired, publicizing and enforcing those laws, and punishing the offenders.	State Summary Document	Yearly	2011-2013
9	Graduated driver licensing (GDL) laws		Policy	Laws specific to GDL (nighttime hours, number of passengers, cell phones, learners permit, seat-belt use, etc).	State Summary Document	Yearly	2011-2013
10	State motor cycle helmet use laws		Policy	Laws covering helmet use for both driver and rider and if there are any differences by specified ages.	State Summary Document	Yearly	2011-2013
11	Seat Belt Use laws		Policy	Primary enforcement belt use laws permit seat belt use law violators to be stopped and cited independently of any other traffic behavior. Secondary enforcement laws allow violators to be cited only after they first have been stopped for some other traffic violation.	State Summary Document	Yearly	2011-2013
12	Local Climatological Data (LCD) NOAA		Common	A monthly NOAA summary from major airport weather stations that includes a daily account of temperature extremes, degree days, precipitation and winds. Also included are the hourly precipitation and abbreviated 3-hourly weather observations.	Access Database by Station	Monthly	2011-2013
13	Cooperative Weather Observer/Other Sources		Common	Hourly precipitation amounts obtained from recording rain gages located at National Weather Service, FAA, and cooperative observer stations which includes inches to tenths at local standard time; includes maximum precipitation for nine time periods for some stations; these data are final quality controlled copy and have a 4 to 6 month time lag. National Climactic Data Center Storm Event data which includes storm events by county including tornadoes, thunderstorm winds, and hail. Clarus data where available. Weather Underground (personal weather station information) data if available including (daily high/low/avg; Temp(F), Dew Point(F), Humidity(%), Sea Level Pressure (in), Visibility (mi), Wind (mph), Precip (in).	Access Database by Station	Monthly	2011-2013
14	Winter Road Conditions (DOT)	2	Common	Winter Travel Advisory by road segment and time. When available this will include roadway and segment limits; Roadway Status (clear, wet, snow, ice, severe, closed); Pavement Condition; Weather Condition; and date/time of last update	GIS Statewide	Yearly	2011-2013
15	Work Zone		Common	Data including location, limits, time period, and if available the impact to travel (minimal, moderate, severe).	GIS Statewide	Yearly	2011-2013
16	511 Information		Common	Includes Incidents/closures; Weather/Alerts; Winter Weather Operations and Advisories; Special Events; Bridge and Tunnel Status; Construction; Travel Speeds (e.g. <30mph, 30-49mph, >50mph) where available.	GIS Statewide	Yearly	2011-2013
17	Traffic Data-Continuous Counts (ATR)		Safety	Continuous count data from permanent equipment which operates 365 days a year.	GIS Statewide	Yearly	2011-2013
18	Traffic Data-Short Duration Counts		Safety	Short count data from portable equipment which typically operates from 2 days to 7 days. These counts usually vary in frequency per location from every year to up to 5 years in between counts.	GIS Statewide	Yearly	2011-2013
19	Changes to existing infrastructure condition		Safety	Data documenting changes to infrastructure condition such as overlays or replacements that improve condition without adding capacity or changing geometry.	GIS Statewide	Yearly	2011-2013
20	Roadway Capacity Improvements		Common	Data documenting major operational and capacity enhancements such as additional lanes, intersection treatments, traffic control, traffic signalization, reversible lanes, designated lanes, roundabouts, etc.	GIS Statewide	Yearly	2011-2013

Figure 5.3. Supplemental data collection description.

CHAPTER 6

Mobile Data Quality Assurance

To ensure the collection and delivery of good quality data to support the SHRP 2 goals and objectives, the research team developed a quality assurance plan for the new data provided by the mobile data collection project. The quality assurance plan outlined the processes to ensure optimum data quality from project setup through to final data delivery, including the accuracy requirements and the tolerances for what was deemed a nonconforming product. In addition, the quality assurance plan defined the process in the event that there was a nonconforming product delivered by the mobile data contractor. In the event that delivered data fell outside of these tolerances, the mobile data vendor was required to take adequate corrective actions, which could have included reprocessing or re-collection of the nonconforming data. All collected data passed the quality assurance guidelines and no re-collection was required. The team used the initial phase of the data collection (pilot study) to address all the quality issues, and thus no further corrective action was necessary afterward.

6.1 Quality Assurance Process

A major and continuous task conducted by the research team was the mobile data quality assurance process. The objective of this task was to ensure that the mobile data conformed to the accuracy requirements. Based on the pilot testing, the initial accuracy requirements (Table 3.3) were revised as shown in Table 6.1. For each NDS site, and for each project year (2011, 2012, and 2013), the project team collected information that would be used as part of the quality assurance process.

The quality assurance included two processes performed simultaneously: one analyzing roadway features and the other analyzing alignment. The first process used control sites and random sites (described below) where all roadway features were collected. These roadway features were as follows (Figure 6.1):

- Intersections (location, type, number of approaches, control type);
- Signs (MUTCD code, speed limit value, image);
- Highway lighting (presence);
- Lanes (type, width);
- Medians (presence, type);
- Shoulders (type, width);
- Rumble strips (presence, type);
- Grade and cross-slope values; and
- Barriers (barrier type, start/end treatment type, post material, rub rail).

The second process analyzed the alignment (tangent, curve) for the accuracy of the radius. For the control sites, the curvature data was obtained from the DOTs. For the random sites, this process was completed using the GPS traces from the mobile data collection vendor to determine the chord and length of curve, which was used to determine the radius (Section 6.5 provides the details for this process).

6.2 Quality Assurance Field Data Collection

6.2.1 Site Visits

Two types of site visits were conducted by the team: control sites and random sites visits. Both site visits collected all the roadway features. Random site visits were typically 4-day visits to an NDS location where the team drove the majority of the data collection routes, collecting roadway attributes at random locations. Control site visits were done on pre-identified road segments. Each state contained both a rural and an urban control site, which were a couple of miles in length and had a desired combination of curves, tangent sections, and roadway features.

6.2.1.1 Random Site Visits

For each NDS site location and each year of data collection (2011, 2012, and 2013), random site visits were used to collect roadway features. During the visit, the field team drove along

Table 6.1. S04B Data Accuracy Requirements

Data Element	Minimum Accuracy Requirement (+/−)
Curvature radius	100 ft (curves less than 1,500 ft radius) 250 ft (curves between 1,500 ft and 6,000 ft radius) Within 13% (curves over 6,000 ft radius)
Curvature length	100 ft (curves less than 1,500 ft radius) 250 ft (curves above 1,500 ft radius)
PC	50 ft
PT	50 ft
Grade (+ or –)	1.0%
Cross slope/ Superelevation	1.0%
Lane width	1 ft
Paved shoulder width	1 ft
Inventory features (signs) location	7 ft

a majority of the data collection routes, stopping randomly to collect all the roadway-attribute data at that location. Between 50 and 100 random sites were collected for each site visit, based on the number of data collection miles during that time. The team collected a representative sample of data, in terms of coverage and roadway attributes. The total number of random sites per study site is as follows:

- Florida: 206.
- Indiana: 244.
- New York: 211.
- North Carolina: 346.
- Pennsylvania: 199.
- Washington: 206.

Before each site visit, maps were prepared by the GIS experts on the team to be used by the field team (Figure 6.2). The maps contained the data collection routes during that time and Continually Operating Reference

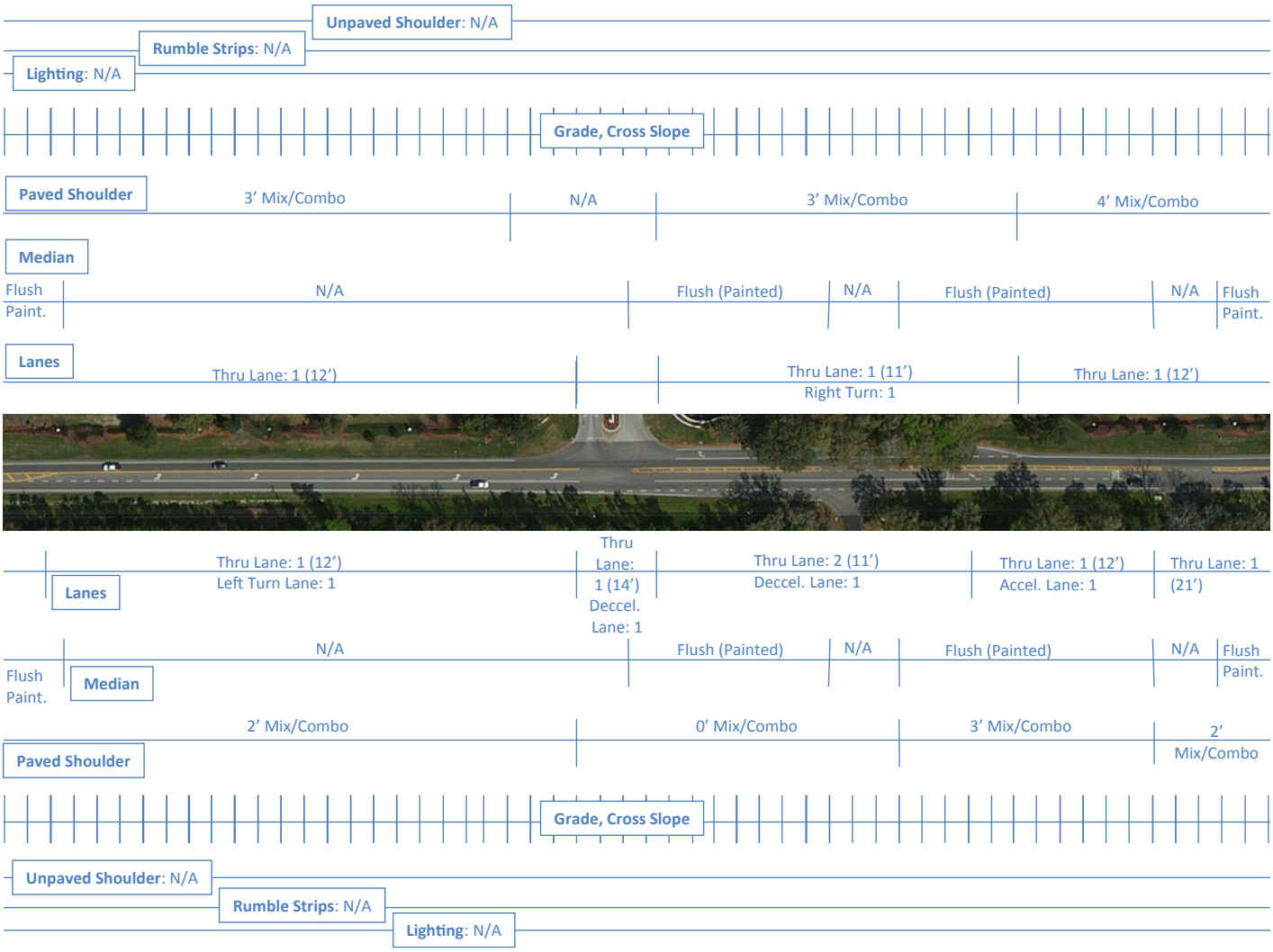


Figure 6.1. Roadway features on a road segment.

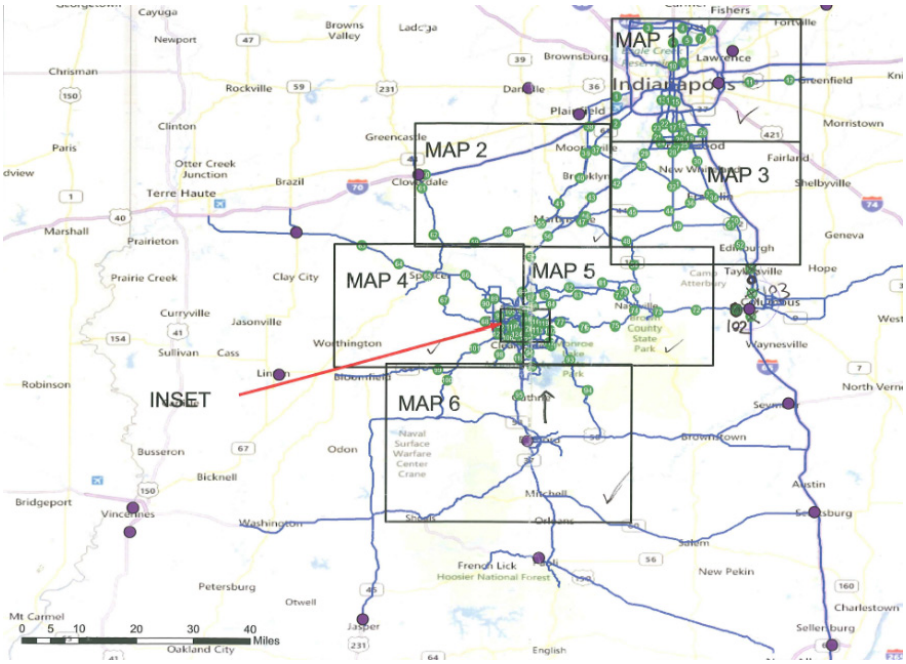


Figure 6.2. An example map prepared before a site visit.

Station (CORS) locations, which were used to ensure accuracy with the GPS data. These maps were used in the field to select random points for data collection and verify complete coverage of the data collection routes. These maps were also loaded on a Trimble GeoExplorer 6000 Series GPS data collection device, which was used in the field to enter roadway-feature locations, selected attributes, and images (e.g., sign faces).

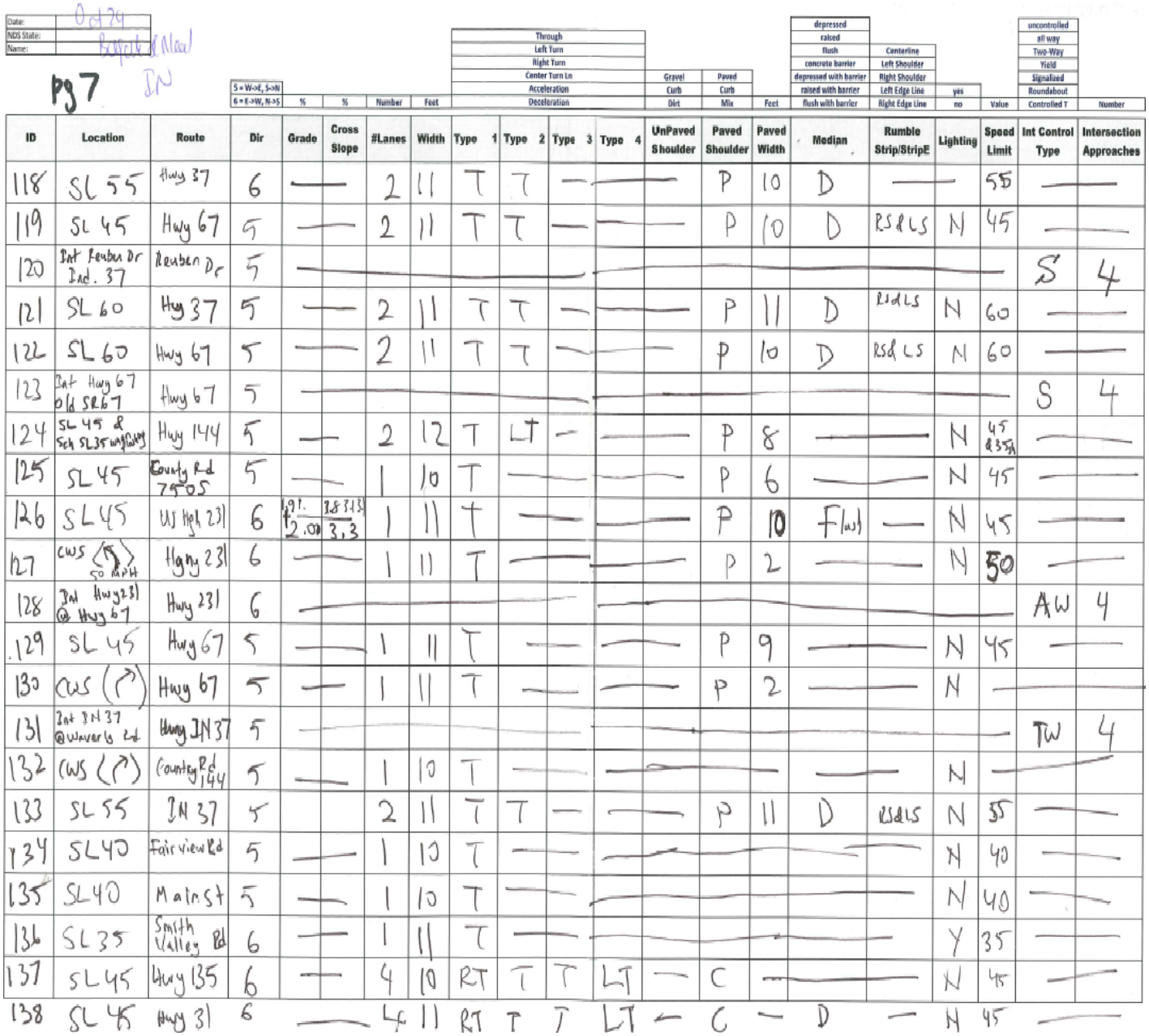
The process at each random point consisted of capturing the location from the GPS receiver by averaging 100 position readings within Esri ArcPad. All roadway features were also documented. Each random point collected was given an ID to allow for joining the GPS data and roadway-feature information. Images could also be taken with the GPS-enabled device for reference during the quality assurance process. A form, shown in Figure 6.3, would then be filled out referencing all the roadway features' attributes. During the process of selecting a random point, the field team made sure to get a representative sample of each of the roadway attributes.

6.2.1.2 Control Site Visits

Each NDS study location had two control sites, which were used for all the data collection years. The control sites were selected in cooperation with the DOT in each study area. The control sites had complete curve information (PC, PT, radius, and length). These pre-identified road segments, which are a couple of miles in length, were located in an urban and rural environment. The sites included a combination of curves and roadway features for the quality assurance process. The control sites were collected by the mobile vans before every deployment to the specified data collection routes, at the end of data collection, or if the equipment was nonoperational for an extended period of time. This resulted in a detailed quality assurance process of the data for every year. Figure 6.4 shows a map of the control sites in Washington. Detailed curve information was also collected as part of the control visit.

The control site visits collected data in a fashion similar to that used for the random sites with the GPS-enabled device and a form for documentation of the roadway features. The difference between control and random sites is the number of data collection points. Points were collected at every sign, intersection, and barrier, as well as random locations along predefined sections within each control site. At each of these points, all other roadway features were collected as well. This gave detailed data for the control site that would be compared with the mobile data collected. The collected data were then linked to mobile data for quality assurance.

No horizontal alignment data were collected along the control or random sites by the Center for Transportation Research and Education (CTRE). For all control sites, horizontal curve parameters, including PC, PT, curve radius, and curve length, were obtained from the respective state departments of transportation in the form of as-built plans and preconstruction surveys.



Date: Oct 24
NDS State:
Name: Bogart & Neal
IN
Pg 7

5 = W->E, S->N
6 = E->W, N->S

Through
Left Turn
Right Turn
Center Turn Ln
Acceleration
Deceleration

Gravel / Curb / Dirt
Paved / Curb / Mix

depressed / raised / flush / concrete barrier / depressed with barrier / raised with barrier / flush with barrier

Centerline / Left Shoulder / Right Shoulder / Left Edge Line / Right Edge Line

yes / no

uncontrolled / all way / Two-Way / Yield / Signalized / Roundabout / Controlled T

ID	Location	Route	Dir	Grade %	Cross Slope %	#Lanes Number	Width Feet	Type 1	Type 2	Type 3	Type 4	UnPaved Shoulder Feet	Paved Shoulder	Paved Width	Median	Rumble Strip/StripE	Lighting	Speed Limit Value	Int Control Type	Intersection Approaches Number
118	SL 55	Hwy 37	6	—		2	11	T	T	—	—	—	P	10	D	—	—	55	—	—
119	SL 45	Hwy 67	5	—		2	11	T	T	—	—	—	P	10	D	RS&LS	N	45	—	—
120	Int Reuben Dr Ind. 37	Reuben Dr	5	—							—								S	4
121	SL 60	Hwy 37	5	—		2	11	T	T	—	—	—	P	11	D	RS&LS	N	60	—	—
122	SL 60	Hwy 67	5	—		2	11	T	T	—	—	—	P	10	D	RS&LS	N	60	—	—
123	Int Hwy 67 & old SR67	Hwy 67	5	—							—								S	4
124	SL 45 & Sch SL35 wayfinding	Hwy 144	5	—		2	12	T	LT	—	—	—	P	8	—	—	N	45 & 35 sch	—	—
125	SL 45	County Rd 750S	5	—		1	10	T	—	—	—	—	P	6	—	—	N	45	—	—
126	SL 45	US Hgh 231	6	1.97 / 2.00	2.8 3.4 3 / 3.3	1	11	T	—	—	—	—	P	10	Flush	—	N	45	—	—
127	CWS (↱) 50 MPH	Hgny 231	6	—		1	11	T	—	—	—	—	P	2	—	—	N	50	—	—
128	Int Hwy 231 @ Hwy 67	Hwy 231	6	—							—								AW	4
129	SL 45	Hwy 67	5	—		1	11	T	—	—	—	—	P	9	—	—	N	45	—	—
130	CWS (↱)	Hwy 67	5	—		1	11	T	—	—	—	—	P	2	—	—	N	—	—	—
131	Int IN 37 @ Waverly Rd	Hwy IN 37	5	—							—								TW	4
132	CWS (↱)	County Rd 144	5	—		1	10	T	—	—	—	—			—	—	N	—	—	—
133	SL 55	IN 37	5			2	11	T	T	—	—	—	P	11	D	RS&LS	N	55	—	—
134	SL 40	Fairview Rd	5	—		1	10	T	—	—	—	—	—	—	—	—	N	40	—	—
135	SL 40	Main St	5	—		1	10	T	—	—	—	—	—	—	—	—	N	40	—	—
136	SL 35	Smith Valley Rd	6	—		1	11	T	—	—	—	—	—	—	—	—	Y	35	—	—
137	SL 45	Hwy 135	6	—		4	10	RT	T	T	LT	—	C	—	—	—	N	45	—	—
138	SL 45	Hwy 31	6	—		4	11	RT	T	T	LT	—	C	—	D	—	N	45	—	—

Figure 6.3. An example form used in random site visit.

6.3 Linking Field Data to Mobile Data

Before linking field and mobile data, the field GPS data were differentially corrected using Trimble GPS Pathfinder software. Automatic carrier and code processing corrections were made using the nearest available base provider (CORS site). Esri shapefiles representing the corrected positional data were also created. All field attribute data were entered into a database and joined to the corrected shapefiles. Then, the data collected at the random and control sites were linked to the mobile data. The research team developed a process to link the data collected at random site visits to the data provided by the mobile data collection project. A custom GIS module was developed and used to link site visit data points and attributes to mobile data layers, which are presented by each roadway feature (Figure 6.5). The GIS module used a semiautomated process in which the user (quality assurance analyst) would select the closest mobile data roadway features to the random point for each layer and then run the script to join those attributes in a Microsoft Access database. Attributes for the mobile data could then be compared to random site data to verify accuracy requirements (Figure 6.6).

Figure 6.4. Control sites in Washington.

Only one roadway feature would be assigned to each random point for all layers, when present, except rumble strips and lighting, because they presented segments and not points. Rumble strips were selected along both sides of the lane, if present, and given a prompt to define the rumble strips as a set. Lighting was selected along both sides of the road for analysis. For the control sites, multiple runs were conducted by the mobile data collection vans. In these cases, one roadway feature for each layer present was assigned for every run. This verified the accuracy for each of the runs through the control site.

The GIS module also had input features to flag roadway features that had ambiguity and needed further review. Ambiguity occurred when a discontinuity occurred in the roadway feature, and the research team was notified to go back and investigate if there were differences. This review was used when the QA analyst was unsure about what roadway attribute to select. The research team would then further investigate before moving forward with the quality assurance.

6.4 Accuracy Analysis

With the field data linked to the mobile data, the quality assurance analysis was conducted for each of the NDS sites for each year roadway data were collected. The same process was used in the analysis for the random sites and the control

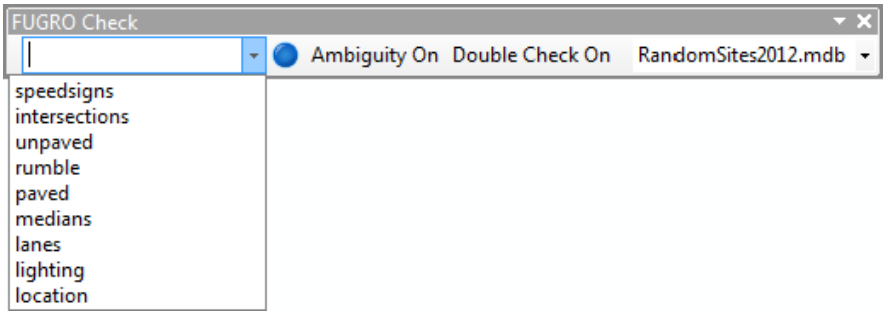


Figure 6.5. GIS module to link data.

sites. The only difference was that the control sites compared each of the runs through the control site.

The linked data allowed for easy comparison of the random sites data to the mobile data. Each of the roadway features was analyzed independently to verify the accuracy of the designated attributes. If any differences occurred, the ID for that attribute would be noted and confirmed using the ROW images that were collected at 21 ft intervals (Figure 6.7). If an error was confirmed, a report was created with a detailed location and the discrepancy. A final report from each site was provided to the contractor so that the issues could be investigated and addressed. The majority of the

Figure 6.6. Linking random site control data to S04B data.

Figure 6.7. An example of an ROW image.

issues were identified during the pilot testing, and no further corrections were needed.

The grade and cross-slope data set (location layer) was the first step of the quality assurance evaluation. The location layer is present along all the roadways collected. The first step was to verify that location data were present for all the random sites. Any point without location data was flagged and brought to the contractor's attention. After the coverage was evaluated, the absolute difference in the grade and cross slope were compared.

Intersections were analyzed to verify that the intersection was identified correctly and within a reasonable distance (150 ft or less) from the field-collected location. The control type and number of approaches were also verified for accuracy. Highway lighting and rumble strips were both evaluated for presence. The type of rumble strip was also verified for accuracy. The lanes data set was evaluated to determine any difference between the lane widths, assessing the required 1 ft accuracy. The lanes data were also evaluated for total number of lanes and correct classification of all lane types. For medians, presence and the type were analyzed. Shoulders were divided into two roadway features: paved and unpaved. Paved shoulders were evaluated for the width of the shoulder being within the 1 ft acceptance, as well as the shoulder type. Width for unpaved shoulders was not a data type required for this project. They were evaluated for correct classification of shoulder type only. All signs were evaluated to verify that the sign was identified and within 7 ft of its field-collected location. Speed signs were analyzed to verify that the speed limit text was correct and whether the sign was regulatory or advisory. All other signs were evaluated for correct MUTCD code, as well as any other additional text. Guardrails were evaluated for accuracy of the begin/end treatment type, the guardrail type, and the post material.

Charts were developed for each roadway feature discussed above, presenting the number of attributes collected at the random sites in comparison to the linked mobile data. Example charts are shown in Figure 6.8. The figure shows an accuracy comparison for speed limit signs (message and location). As can be seen from Figure 6.8, both items meet the minimum accuracy requirements (95% passing). A detailed example of the quality assurance process for Pennsylvania is provided in Appendix E.

6.5 Curve Quality Assurance

The second part of the quality assurance process involved the curve analysis. The alignment data set contained several curve attributes, including whether the record (roadway extent) was a horizontal curve or tangent. For all horizontal curves, the begin/end points, direction, length, and radius were provided. The curves were separated into three radius ranges: less than 1,500 ft radius, 1,500 ft to 6,000 ft radius, and greater than 6,000 ft radius. Each of the ranges had different accuracy requirements, as presented in Table 6.1.

For the control sites, mobile-collected curve PC, PT, radius, and length were compared to the corresponding DOT-provided alignment attributes. For the random curve evaluation, the GPS traces from the mobile data collection were used to identify random curve locations, and then the radius was calculated (using the method described below) and compared to the mobile alignment data for quality assurance.

The process to determine the radius of a curve was developed by Hans et al. (2012) using the curve length and chord length to calculate the radius of the curve (Figure 6.9). This technique, known as the long chord method, was reported to yield a root mean squared error (RMSE) of 19.5%, and the coefficient of determination was 0.90. This provided an accurate measure of the radius, in comparison with the ground truth, with 95% of the radii values with an error less than 30% and 68% of the radii with an error less than 5%.

Within Esri ArcGIS, points within a horizontal curve were selected from the mobile data collection GPS traces. The selected points were joined together, forming a polyline. The length of the polyline was calculated, as well as the straight-line distance from the curve begin and end (i.e., chord). These values were used to compute the curve radius.

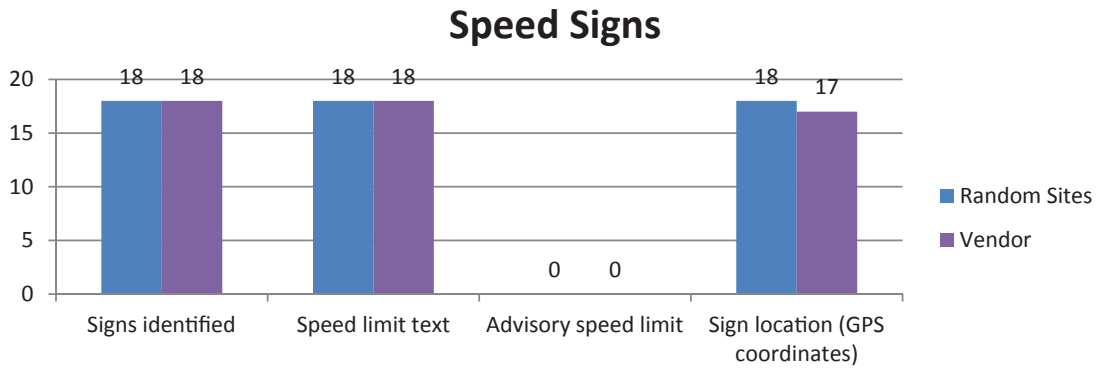
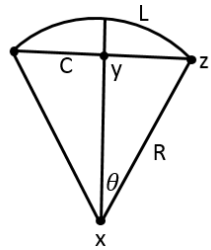


Figure 6.8. Comparison charts example.



$L = 2R\theta$

$\frac{C}{2} = R\sin\theta; see\ triangle\ xyz$

$\frac{C}{L} = \frac{\sin\theta}{\theta}$

$f(\theta_n) = \frac{\sin\theta_n}{\theta_n} - \frac{C}{L}$

$f'(\theta_n) = \frac{\cos\theta_n}{\theta_n} - \frac{\sin\theta_n}{\theta^2{}_n}$

$\theta_{n+1} = \theta_n - \frac{f(\theta_n)}{f'(\theta_n)}; n = 0,1,2, \ldots$

$D = \frac{5729.579}{R}$

$L = curve\ length$
$C = chord\ length$
$R = curve\ radius$
$D = curve\ degree$
$\theta = \frac{\Delta}{2}; \Delta = deflection\ angle$

Figure 6.9. Radius calculation for quality assurance (Hans et al. 2012).

CTRE.Radius <= 1500 ft.

For 2 of 63 observations (3%) |CTRE.Radius-Fugro.Radius|>100 ft.

<=1500	63	
ABS DIFF <=100 FT	61	96.8%
ABS DIFF >100 FT	2	3.2%

1500 ft. < CTRE.Radius < 6000 ft.

For 8 of 181 (4%) observations |CTRE.Radius-Fugro.Radius|>250 ft.

1500<CR<6000	181	
ABS DIFF <=250 FT	173	95.6%
ABS DIFF >250 FT	8	4.4%

Figure 6.10. Curve radius quality assurance check.

Curves were selected randomly, with equal frequencies of curves in each radius range. After initial selection of the curves, the radius values were calculated. Multiple iterations were completed until a sufficient number of curves were selected in each radius range. The resulting curves, with calculated radius values, were spatially joined to the mobile alignment data for quality assurance.

A statistical analysis was completed for the curves to determine the distribution of the differences between the calculated radius and the mobile-collected radius. Any major differences in radius were further investigated to determine any errors in the calculation process or spatial assignment of curves. The final summary of the three radius ranges were then compiled similarly to the method shown in Figure 6.10 to verify that the curves met the radius accuracy requirements. As can be seen from Figure 6.10, the minimum accuracy requirements were met for all radius values (less than 1,500 ft and between 1,500 ft and 6,000 ft).

CHAPTER 7

Conclusions

This SHRP 2 project dealt with the design and development of the RID. The research team was able to design and build the RID with data from the mobile data collection project, existing roadway inventory data from public and private agencies, and supplemental data to support the safety mission of SHRP 2. The RID was designed to accommodate disparate data sets, store these data in the most natural format, and facilitate integration of these data, as well as a linkage with the NDS vehicle and driver data. The RID provides context for a substantial part of the more than 5 million NDS trips and will enable researchers to study the impact of roadway data on safety.

As with any other effort, there were some challenges and lessons learned throughout the process. The following describes the challenges faced and the lessons learned:

1. The SHRP 2 Safety study was the largest of its kind to date, and building the RID to address multiple research questions was complex and required major tradeoffs between cost, time requirements, and complexity of the system. The research team used existing safety literature, SHRP 2 Safety projects that developed research questions, and input from researchers covering a wide range of safety research to develop a list of critical roadway attributes to be collected.
2. The discovery of existing data (whether state, local, or private sources) proved beneficial to the RID. There were challenges in terms of data access and sharing for nonstate DOT data that limited the amount of data that ended up being acquired as part of the RID.
3. Evaluating mobile data collection technology and services is not a trivial task. Knowledge of the users' requirements, funding constraints, and accuracy requirements is critical to selecting the right contractor for the job. In the end, the team, in cooperation with SHRP 2, was able to qualify three contractors to submit proposals for roadway data collection.
4. With six study sites around the United States, it was critical to use a consistent roadway network to build the linear referencing system for the RID. Using the Esri/NAVTEQ road network made it possible to integrate and link data from different sources for the RID and enabled the linking of the RID and NDS data.
5. Developing a process for selecting roads for the mobile data collection in each site allowed the research team to optimally allocate the collected miles between sites and within each site. Using GPS traces from the volunteer drivers made it possible to select roads where NDS participants drove. Using GIS tools was critical to making this process work smoothly and efficiently.
6. Collecting quality data was deemed paramount to the success of the RID. Even though only the data collected through the mobile data collection project went through the quality assurance process, these data will provide researchers with the most accurate roadway information available across multiple sites. The quality assurance process was the result of constant communication and coordination between the team conducting the quality assurance and the team collecting the data.
7. The pilot data collection effort was a key aspect in successfully acquiring the mobile data on such a large and dispersed scale. This small-scale effort provided the research team with the necessary information to improve and customize the process for routing, collecting, processing, and conducting quality assurance.

References

Butler, J.A. 2008. *Designing Geodatabases for Transportation.* Esri Press, Redlands, CA.

Hans, Z., R. Souleyrette, and C. Bogenreif. 2012. *Horizontal Curve Identification and Evaluation.* Iowa Department of Transportation and Midwest Transportation Consortium.

APPENDIX A

User Needs Assessment

The user needs assessment effort for the project included four components:

- Identify user/stakeholder groups who will use the roadway data and geographic information system (GIS) tools when accessing the Roadway Information Database (RID).
- Identify roadway data elements necessary to answer research questions using the naturalistic driving study (NDS) data.
- Prioritize roadway data elements to be either acquired through existing data sets or collected under the mobile mapping data collection project (S04B).
- Solicit user/stakeholder feedback on development of GIS tools to use the RID.

A.1 Develop Candidate List of Relevant Roadway Data Elements

After identifying the user/stakeholder groups, as described in Chapter 2 of the report, the next step in this task was to identify roadway data elements necessary to answer research questions using the SHRP 2 NDS data. This included a broad range of safety-related research questions that may be asked by users identified in the previous subtask, including those required for the SHRP 2 analysis projects (S08). The result was an exhaustive list of roadway data elements that were candidates for inclusion in the RID.

A.2 Refine Candidate List

The team used this candidate list as a starting point in the process to define what data elements were to be included in the RID. An exhaustive literature review was conducted to determine the roadway data elements that have been identified in safety analyses as being related to intersection or lane departure crashes—the high-priority areas for SHRP 2.

The literature identified roadway data elements that have been shown to have a correlation with crash frequency or severity and determined which elements have already been identified by researchers as being relevant. Data elements may contribute positively or negatively to crash risk. Although a large number of sources were consulted, information from 55 journal papers or reports contributed to the process of refining the candidate list of data elements. The literature review was also used to prioritize data elements, as described in another section in this document.

The team next considered data necessary to answer the research questions posed in completed SHRP 2 projects. Researchers for the SHRP 2 S02 project, Integration of Analysis Methods and Development of Analysis Plan, assembled research questions from SHRP 2 projects S01 and S05 researchers, resulting in a set of 448 research questions. Questions were synthesized and prioritized into eight global research topics.

The S04A team reviewed the 448 research questions with a focus on the eight topic areas. Relevant data elements identified in the questions were added to the candidate list. The following is an unranked list of the eight topic areas identified by S02 researchers (Boyle et al. 2012):

- How do driver interactions with roadway features influence the likelihood of lane departure crashes?
- How do driver interactions with intersection features (configuration and operations) influence crash likelihood?
- What is the influence of driver impairment (e.g., alcohol) on crash likelihood?
- How does driver distraction influence crash likelihood?
- How does driver fatigue affect crash likelihood?
- How do aggressive driving behaviors influence crash likelihood?
- How do advanced driver support systems influence crash likelihood?

- What variables or pre-event factors are the most effective crash surrogate measures, what explanatory factors are associated with crashes or crash surrogates, and what analytical models can be developed to predict crashes or crash surrogates?

The first two questions deal specifically with roadway features. The first focuses on lane departures, which is typically a rural issue. The second deals with the relationship between intersection features, driver behavior, and crash likelihood. Intersections can be either rural or urban. Roadway features related to lane departures and intersections were the highest priority.

Five of the remaining six research questions focused on driver behavior. Although roadway factors can exacerbate negative driver behavior and increase crash likelihood, no specific roadway features were identified in the research questions. The last question relates to developing crash surrogates. No roadway features were specifically identified for this question.

A.2.1 Solicit Additional Feedback and Finalize the List of Data Elements

After the candidate list was developed, the team obtained additional information from the relevant user groups identified previously. This information was obtained in several ways. First, the team reviewed roadway data elements that had been included in the Highway Safety Information System (HSIS), Model Inventory of Roadway Elements (MIRE), and the Model Minimum Uniform Crash Criteria (MMUCC). Data elements included in those inventories not already identified were added to the list. A webinar was held in September 2010 that also solicited feedback from potential users.

A.2.2 Data Elements and Priorities from MIRE, MMUCC, and HSIS

Several user groups have already contributed significantly to identifying important roadway data elements for safety analyses. Many users were involved in development of MIRE, MMUCC, and HSIS. MIRE was developed to define critical safety data inventory elements for state and local agencies in order for them to conduct their own safety analyses, as well as those necessary for them to take advantage of FHWA's Interactive Highway Safety Design Model (IHSDM) and SafetyAnalyst (Council et al. 2007; MIRE 2010).

The MIRE effort identified the first set of elements by reviewing data elements from IHSDM and SafetyAnalyst, the Highway Performance Monitoring System (HPMS), the Traffic Safety Information Management System (TSIMS) of the American Association of State Highway and Transportation Officials (AASHTO), and MMUCC, as well as the team's knowledge of state inventory databases, the team's knowledge of efforts related to development of the Highway Safety Manual, and the MIRE project team's knowledge of data needed for safety analyses not traditionally included, such as pedestrian, bicycle, and roundabout safety.

The MIRE effort also provided a priority for the data elements identified (priorities in MIRE are listed as "1st," "2nd," and "do not recommend") based on data requirements for the safety tools described above, requirements for MMUCC, consideration of whether states were already collecting the element, and the team's knowledge of what may be included in existing and future safety analyses and tools. When relevant, the difficulty of collecting the data was considered.

The MMUCC is a set of voluntary guidelines to help states collect the consistent, reliable crash data necessary to improve highway safety; establish goals and performance measures; monitor the progress of programs; and allocate resources for enforcement, engineering, and education.

The criteria include the minimum variables that should be used to describe a motor vehicle crash to make informed decisions leading to highway safety improvements. Elements were included if they were deemed necessary for highway safety decision making. MMUCC was developed by some of the leading traffic safety experts in the United States. These included representatives from safety, engineering, emergency medical services, law enforcement, and state and federal agencies (MMUCC 2010; *MMUCC Guideline* 2008).

Because HSIS, MIRE, and MMUCC include data elements that have been exhaustively reviewed by national, state, and local transportation agencies; traffic safety experts; law enforcement; and emergency medical services around the country, the team felt that this provides sufficient representation from these groups regarding which data elements are important in safety analyses.

A.2.3 Solicitation of Additional Feedback

The team presented the methodology to develop the candidate list of roadway data elements discussed in the previous step at the July 2010 SHRP 2 Safety Research Symposium in Washington, D.C. The team received a few comments about additional data elements, which were added to the list.

The next step was to conduct a survey to solicit feedback. A list of questions was developed in Survey Monkey, which asked respondents to review the initial list of roadway data elements and then add any additional items that they felt were necessary. A list of safety professionals who had attended one annual SHRP 2 Safety Research Symposium from 2008 to 2010 was obtained, and attendees were invited to participate in the survey. Invitations were sent to 177 people in July 2010. The survey was available for approximately two weeks. Eleven people responded to the survey.

Table A.1. User Groups Responding to Survey

User Group	Respondents
National safety or roadway agency (i.e., FHWA, NHTSA)	2
State highway agency	1
Traffic safety researcher (university or consultant)	2
Human factors researcher	1
Asset management expert	2
Insurance group	1
Other • Pedestrian advocate • Automotive ITS researcher	2 1 1

The first question asked respondents to identify which user category best represented them. Responses are shown in Table A.1.

Respondents were asked to enter additional data elements that they felt should be included for roadway segments (non-intersection), which resulted in 19 data elements. Respondents were also asked what additional intersection data elements should be included, which resulted in a list of 25 elements. A number of the data elements were already included in the list of roadway data elements. Several items were traffic operation data, such as annual average daily traffic. The roadway data elements suggested by survey respondents that were not already included were added to the list. Respondents were also asked for contact information and were included in a later survey to prioritize the data elements.

Once the survey was completed, the list of roadway data elements was finalized. The list was maintained in a spreadsheet. Roadway elements for all roadway segments were kept in one spreadsheet, and those specific to intersections were maintained in another. Information about other sources that had suggested that the data element was important was also recorded. For instance, one column was used to indicate whether the data element was listed in MMUCC, other columns were used for HSIS and MIRE, and another column indicated whether the data element was listed in a research question from SHRP 2 projects S01, S02, or S05.

A.3 Prioritization of Research Questions

The candidate list of roadway data elements was quite extensive, and, given limited resources in both S04A to acquire existing data sets and S04B to collect mobile data, it was necessary to prioritize roadway data elements. The team assessed priorities and created a prioritized list, which was used to guide mobile data collection. Elements ranked the highest were a top priority for mobile data collection if they could feasibly be collected and if the data element was expected to remain consistent throughout the data collection period. For example, edge drop-off, while a desired data element for run-off-road analysis, has a high temporal change rate and consequently did not make it to the final list of data elements collected with the mobile vans.

Considerations in prioritization of the data elements included the following:

- Stakeholder priorities;
- Importance to SHRP 2 analysis projects (S08);
- Focus on lane departure and intersection crashes;
- Importance to future safety research questions;
- Importance to future nonsafety research questions (e.g., asset management, travel demand modeling, transportation air quality analysis);
- Priority from MIRE;
- Importance from surveyed literature with focus on crash severity;
- Curve properties (e.g., radius);
- Resources to collect a data item in relationship to its importance;
- Whether the feature can be collected with few additional resources, even if it is lower ranked;
- Whether the feature will be available with reasonable accuracy from an existing database;
- Whether the feature could be extracted from forward NDS data acquisition system roadway video; and
- Team to review sample data set.

A.3.1 Literature Review

Data elements were prioritized using several sources of information. First, the priority assigned to each data element in MIRE was recorded. Next, a comprehensive literature review was conducted for lane departure and intersection crashes. These two crash types were selected because they were the focus of SHRP 2. The number of times a roadway data element was reported in the literature as having either a positive or negative correlation to crashes was reported.

A.3.2 Survey

Another survey was conducted to ask user groups about the data elements they felt were the most important. Originally, the team had planned a webinar where attendees could interactively respond to questions. However, the SHRP 2 webinar services could only post six interactive questions during the webinar. Since this was not sufficient to obtain feedback, the team used a hybrid webinar/survey approach. Attendees from the 2008, 2009, and 2010 SHRP 2 Safety Research Symposia were sent an email inviting them to the webinar/survey. In

addition to those individuals, the team also identified five human factors researchers who were familiar with the SHRP 2 NDS. Human factors researchers would have a different perspective on which roadway factors may present a safety risk than traditional roadway safety professionals. Human factors researchers had not been included in any of the groups surveyed to identify roadway data elements. Two state DOT traffic safety engineers were also invited to participate.

The webinar was hosted by SHRP 2 and held on September 30, 2010. Ninety-five sites registered for the webinar. Fifty-eight logged into the webinar, and 31 to 37 responded to the questions. The webinar consisted of the following:

- Introduction and summary of SHRP 2;
- General background on the S04 project;
- Description of data collection from state and local agencies;
- Method used to identify and prioritize roadway data elements; and
- Description of what was included in the survey.

Respondents were asked to respond to several questions during the webinar. First, they were asked about their level of expertise in using GIS for safety analyses. Of those who responded to this question (31), 26% considered themselves novice users, 29% indicated they were occasional users, and 19% and 10% were experienced or expert users, respectively (Figure A.1).

The second question asked respondents (37 answered) about their level of expertise in integrating disparate data sets, such as roadway inventory data and crash data. Figure A.2 shows that 30% felt that they were novice users, and 24% were occasional users; 19% indicated they were experienced users, and 14% indicated they were expert users.

The third question asked respondents how frequently they used federal roadway data, particularly for safety analyses. Out of the 31 responses, 42% indicated that they never or seldom use federal roadway data, as shown in Figure A.3. Another 23% indicated that they occasionally used the data, and 29% were frequent users.

Attendees were asked how regularly they used county or municipal roadway data, particularly with respect to safety analyses. Out of the 34 responses received, the majority, 65%, never or seldom use county or municipal data, while 21% indicated they occasionally use it and 6% indicated they use it frequently, as shown in Figure A.4.

The final in-webinar poll question asked attendees how frequently they used state roadway data, particularly with respect

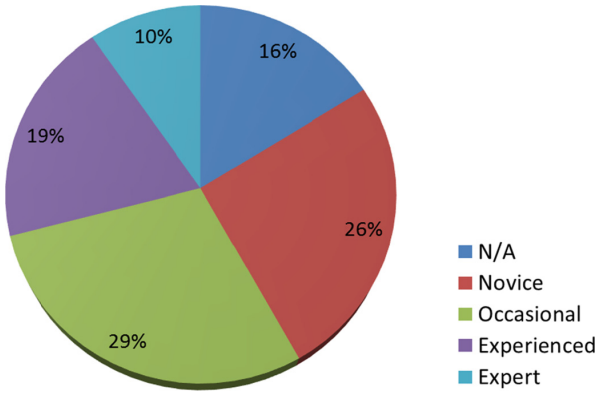


Figure A.1. Level of expertise using GIS for safety analyses.

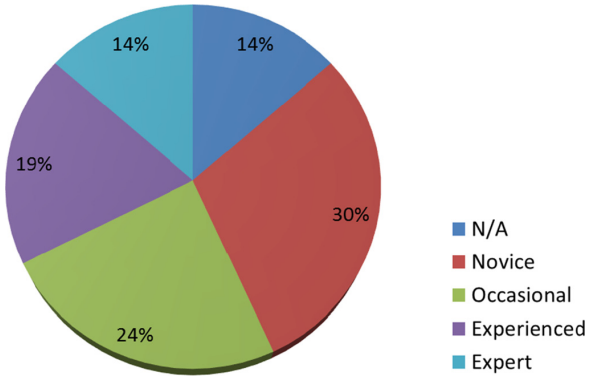


Figure A.2. Level of expertise in integrating disparate data sets.

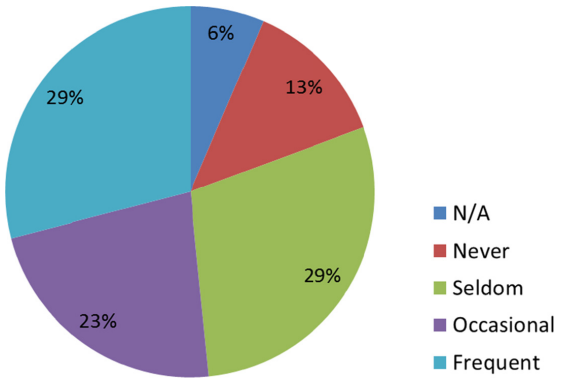


Figure A.3. Use of federal roadway data.

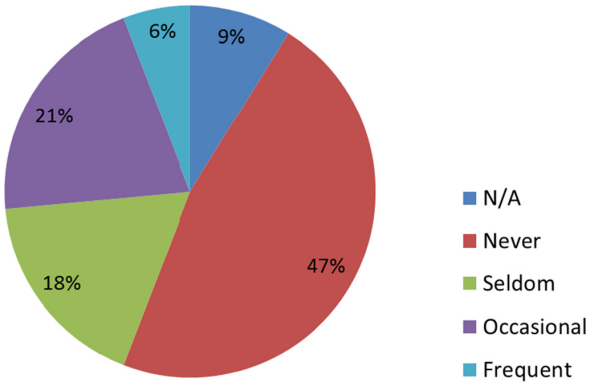


Figure A.4. Use of county or municipal data.

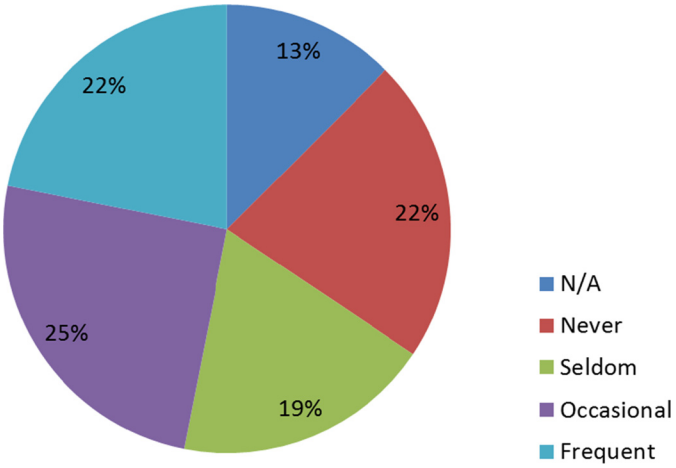


Figure A.5. Use of state data.

to safety analyses. Out of the 32 responses, 41% had never or seldom used state data, while 25% and 22% used it occasionally or frequently, respectively. Responses are shown in Figure A.5.

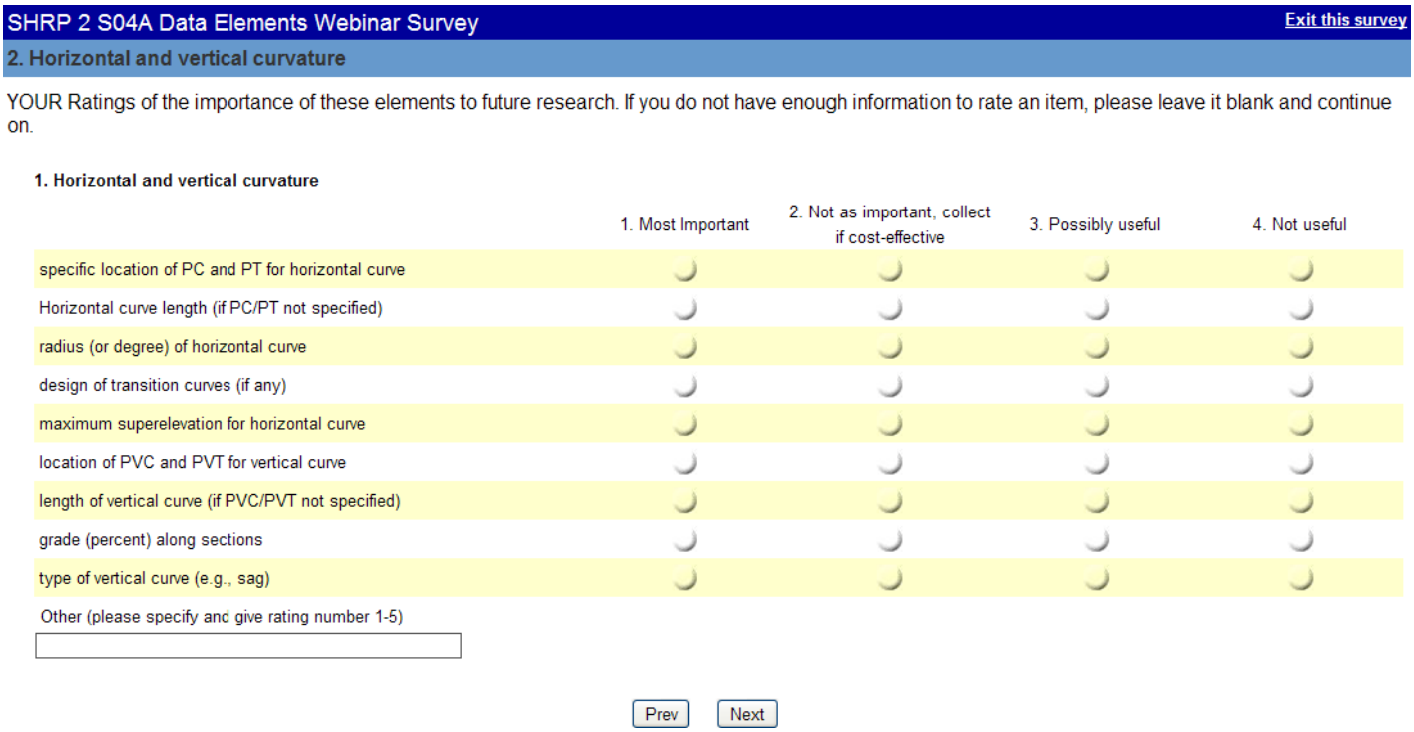
After initial information was provided about the S04A project and the method to identify data elements was presented, the S04A team reviewed the components of the online survey. Webinar attendees were then directed to the online survey, where they were able to indicate which data elements they thought were a priority. Respondents were to immediately fill out the survey, but a grace period of two weeks was provided.

The survey was conducted using Survey Monkey. In order to better display the information in the survey, roadway elements were divided into logical categories, and each question covered a category. For instance, the first category listed items included in horizontal and vertical curvature, as shown in Figure A.6. Features under that category (e.g., horizontal curve length, maximum superelevation) were listed individually, and respondents could select from the following:

- Most important;
- Not as important, collect if cost-effective;
- Possibly useful; and
- Not useful.

Since there was not a logical way to get respondents to prioritize the list, respondents could select a response as many times as they wished. For instance, a respondent could select "most important" for every data item. Respondents were asked to only indicate "most important" for a few top-priority items, but there was not a method to ensure that this happened. Categories included the following:

- Horizontal and vertical curvature;
- Cross section;
- Regulatory and warning signs;
- Pavement markings;
- Road surface condition;
- Countermeasures;
- Other, which included guide signs, service signs, and bridge features (location, type, bridge deck width);
- Roundabout characteristics that differ from regular intersections;



SHRP 2 S04A Data Elements Webinar Survey — Exit this survey

2. Horizontal and vertical curvature

YOUR Ratings of the importance of these elements to future research. If you do not have enough information to rate an item, please leave it blank and continue on.

1. Horizontal and vertical curvature

	1. Most Important	2. Not as important, collect if cost-effective	3. Possibly useful	4. Not useful
specific location of PC and PT for horizontal curve				
Horizontal curve length (if PC/PT not specified)				
radius (or degree) of horizontal curve				
design of transition curves (if any)				
maximum superelevation for horizontal curve				
location of PVC and PVT for vertical curve				
length of vertical curve (if PVC/PVT not specified)				
grade (percent) along sections				
type of vertical curve (e.g., sag)				

Other (please specify anc give rating number 1-5)

Prev Next

Figure A.6. Example webinar survey question.

- Intersection control; and
- Interchange ramp characteristics.

The next question asked respondents to rate the roadway types they felt data collection should focus on. For instance, is it more important to collect urban Interstates or rural minor arterials? This question helped prioritize data collection for the mobile data collection effort in S04B. An example of the question is provided in Figure A.7.

Only six people responded to the online prioritization survey. Of those who responded, 67% indicated that they have some experience with driver/user-focused traffic safety research, 50% indicated that they have some experience with vehicle-focused traffic safety research, and 100% indicated that they have some experience with vehicle-focused traffic safety research.

The list of roadway data elements was updated with a column that indicated whether any of the survey respondents had indicated the data element as being "most important" by one or more researchers.

A.3.3 Discussion with Human Factors Researchers

To get input and feedback from human factors researchers, a group was identified and targeted for the webinar/survey. However, a human factors conference was scheduled for the same time, so none were in attendance at the webinar or filled out the survey.

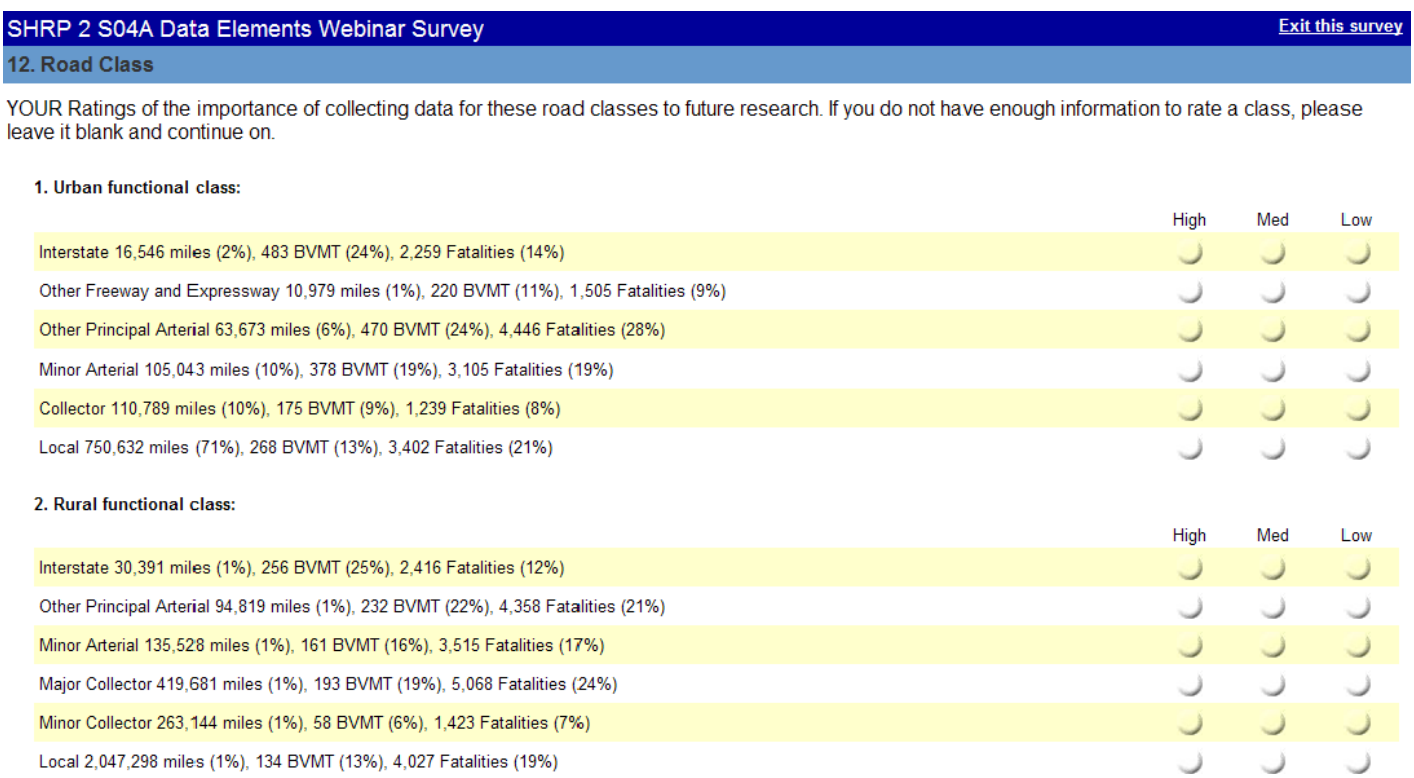
The S04A team contacted five human factors researchers who were familiar with the SHRP 2 Safety program and asked them individually for input. Their input was recorded in an additional column of the list of roadway data elements as being ranked "high importance" by one or more human factors researches.

A.3.4 Creation of Initial Prioritized List

Information from the previous steps was used to create an initial priority of data items. A point system was used to score all the roadway data items in the list. Points were assigned if the data element was the following:

- Included in the research questions from S01, S02, or S05;
- Included as a priority 1 in MIRE;
- Included as a data element in MMUCC;
- Included as a data element in HSIS;
- Identified in the literature review;
- Ranked "high importance" by one or more survey respondents; or
- Ranked "high importance" by one or more human factors researchers.

Points were added, and an initial list of priorities was developed. The initial ranked list with data elements having a sum of three or higher is shown in Table A.2 for tangent sections/


SHRP 2 S04A Data Elements Webinar Survey — Exit this survey

12. Road Class

YOUR Ratings of the importance of collecting data for these road classes to future research. If you do not have enough information to rate a class, please leave it blank and continue on.

1. Urban functional class:

	High	Med	Low
Interstate 16,546 miles (2%), 483 BVMT (24%), 2,259 Fatalities (14%)			
Other Freeway and Expressway 10,979 miles (1%), 220 BVMT (11%), 1,505 Fatalities (9%)			
Other Principal Arterial 63,673 miles (6%), 470 BVMT (24%), 4,446 Fatalities (28%)			
Minor Arterial 105,043 miles (10%), 378 BVMT (19%), 3,105 Fatalities (19%)			
Collector 110,789 miles (10%), 175 BVMT (9%), 1,239 Fatalities (8%)			
Local 750,632 miles (71%), 268 BVMT (13%), 3,402 Fatalities (21%)			

2. Rural functional class:

	High	Med	Low
Interstate 30,391 miles (1%), 256 BVMT (25%), 2,416 Fatalities (12%)			
Other Principal Arterial 94,819 miles (1%), 232 BVMT (22%), 4,358 Fatalities (21%)			
Minor Arterial 135,528 miles (1%), 161 BVMT (16%), 3,515 Fatalities (17%)			
Major Collector 419,681 miles (1%), 193 BVMT (19%), 5,068 Fatalities (24%)			
Minor Collector 263,144 miles (1%), 58 BVMT (6%), 1,423 Fatalities (7%)			
Local 2,047,298 miles (1%), 134 BVMT (13%), 4,027 Fatalities (19%)			

Figure A.7. Example questions about roadway types.

Table A.2. Roadway Tangent Data Elements Ranking Three or Higher

Data Element	Features	Sum
Access	Access control	3
	Driveway density	5
Road classification	Route/street name	3
	Functional class/type	4
Clear zone	Curb presence	3
	Type of objects within clear zone	4
Cross section	Type (i.e., regular, two-way left-turn lane [TWLTL], parking, acceleration, high-occupancy vehicle [HOV], reversible)	3
	Median width	3
	Number of lanes	4
	Median type	5
	Lane width	6
Horizontal curvature	Location, including PC and PT	3
	Tangent length between adjacent curves	3
	Direction of curve	3
	Horizontal curve deflection angle	3
	Length	4
	Presence and type of spirals	4
	Presence and amount of superelevation	4
	Radius or degree of curve	7
Illumination	Overhead lighting type	5
Other countermeasures	Type edgeline or shoulder rumble strips	3
Pavement markings	Centerline (i.e., dashed, solid)	3
	Edgeline	4
Regulatory signs	Pass/no pass zones	3
	School area	3
	Speed limit (location)	5
Road surface	Surface type (i.e., gravel, asphalt, portland cement concrete [PCC])	3
	Surface friction	3
Roadway defects	Surface irregularities	3
	Pavement edge drop-off	4
Shoulder	Right shoulder paved width	3
	Left shoulder type	3
	Left shoulder paved width	3
	Right shoulder type	5
	Right total shoulder width	6
Vertical curvature	Vertical curve length	4
	Grade (percent)	7
Warning signs	Horizontal alignment signs and location (i.e., chevron, curve advisory speed)	3

Table A.3. Roadway Intersection Data Elements Ranking Three or Higher

Data Element	Features	Sum
Cross section	Intersection/interchange type	5
	Number of lanes by approach	4
	Turn lanes (number, type)	4
	Median type	3
Pavement markings	Crosswalks	3
Intersection control	Type of intersection traffic control	5
	Presence of left-turn arrow (indication of left-turn phasing)	3
Illumination	Lighting type	4
Other	Sight distance	3

intersection approaches (38 elements out of a total of 153), and Table A.3 shows the list for data elements specific to intersections (nine elements out of a total of 113).

A.3.5 Develop Final List of Prioritized Data Elements

The initial prioritized listed was developed in the previous step. A final list, which was provided in the S04B proposal, was developed in this step. The final step was prioritized using several pieces of information. The assessment at this point was subjective.

A preliminary test run of the SHRP 2 data acquisition system (DAS) was evaluated to determine the roadway data elements that could feasibly be extracted in the event that they are not available in roadway data sets from SHRP 2 S04A or S04B. The team reviewed the list of roadway data elements and the DAS data set and commented on which roadway factors can be extracted from the DAS data set, which may be useful to S08 and other researchers. A summary is provided as Appendix C to the S01E report (Hallmark et al. 2011).

The types of crashes that each data element was likely to address were also determined. For instance, type of median is most related to cross-centerline crashes.

The team also determined whether it was feasible to collect the data element with mobile data collection. The cost for collection of each individual item was also considered.

Using the information about whether the data element could be obtained from the forward view of the DAS, consideration of type of crash addressed, and feasibility and cost were used to develop a final prioritized list, which was presented to SHRP 2.

The final list consisted of two tiers of critical items (Tier 1 and Tier 2), which were to be collected as part of the SHRP 2 mobile data collection project S04B. The two tiers of data are as follows:

- Tier 1
  - Horizontal curvature: Radius, length, PC, PT, and direction of curve (left or right based on driving direction).
  - Grade.
  - Cross slope/superelevation.
  - Lane information: Number, width, and type (e.g., through, turn, passing, acceleration, carpool).
  - Shoulder type/curb (and paved width, if it exists).
  - All MUTCD signs (location and message).
  - Intersection location.
- Tier 2
  - Intersections: Number of approaches and control (uncontrolled, all-way stop, two-way stop, yield, signalized, roundabout). Ramp termini are considered intersections.
  - Median presence: Type (depressed, raised, flush, barrier).
  - Rumble strip presence: Location (centerline, edgeline, shoulder).
  - Lighting presence.
  - Guardrail: Begin and end, type, and material.

A.4 References

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Council, F.M., D.L. Harkey, D.L. Carter, and B. White. 2007. *Model Minimum Inventory of Roadway Elements—MMIRE.* FHWA-HRT-07-046. Federal Highway Administration, Office of Safety Research and Development.

Hallmark, S., Y.-Y. Hsu, L. Boyle, A. Carriquiry, Y. Tian, A. Mudgal. 2011. *SHRP 2 Report S2-S01E-RW-1: Evaluation of Data Needs, Crash Surrogates, and Analysis Methods to Address Lane Departure Research Questions Using Naturalistic Driving Study Data.* Transportation Research Board of the National Academies, Washington, D.C.

MMUCC Guideline: Model Minimum Uniform Crash Criteria, 3rd ed. 2008.

Model Inventory of Roadway Elements (MIRE). http://www.mireinfo.org/about.html. Accessed June 2010.

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APPENDIX B

Technology Evaluation

The following information summarizes SHRP 2 S04A Task 3 activities, with the objective of further evaluating the capabilities of the mobile data collection vendors who participated in the SHRP 2 S03 Roadway Measurement System Evaluation (Rodeo) project. This was accomplished through documenting each vendor's ability to collect roadway geometric data and some selected inventory data features on two of the six Rodeo sites (6S and 7N). Task milestones included the following:

- May 12, 2010: Initial instructions and data format to vendors.
- May 24, 2010: Final instructions and data format to vendors.
- June 1, 2010: Deadline for vendor questions regarding data submittal.
- June 15, 2010: Final data submittal from vendors.
- July 27, 2010: Presentation of results to Expert Task Group (ETG).

B.1 Data Collection

Seven vendors participated by completing three data collection runs for each of the two roadway segments identified as 6S and 7N. The seven data features collected for each roadway segment included roadway section (location/length), horizontal curve, grade, cross slope, lane width, paved shoulder width, and regulatory signs.

B.2 Evaluation

B.2.1 Precision Versus Accuracy Evaluation

Each vendor submitted its data to the SHRP 2 S04A contractor for evaluation in terms of accuracy and precision (Figure B.1). A determination of both accuracy and precision was made.

For features involving location:

- *Precision* was evaluated through the following:
  - Determining the geometric mean for the three sets of coordinate pairs (projected) (i.e., average of X, average of Y).
  - Computing the Euclidian distance between each coordinate pair and the geometric mean coordinates.
- *Accuracy* was evaluated through the following:
  - Computing the Euclidian distance between each coordinate pair and the ground truth coordinate pair. Ground truth data sets were acquired from an independent surveyor for this project.

For features involving grade, cross slope, and width:

- *Precision* was evaluated through the following:
  - Computing the average value of three repetitions.
  - Computing the difference between each repetition and the average value.
- *Accuracy* was evaluated through the following:
  - Computing the difference between each repetition and the ground truth.

Figure B.2 presents how accuracy and precision were approached in the evaluation. Accuracy compares measurement to ground truth. Precision, however, focuses on repeatability, specifically the relationship among consecutive measurements by one vendor at the same location. High accuracy and precision are most desirable. Both aspects were critical to selecting the right vendor and technology for the project.

Figure B.3 gives an example of precision and accuracy results for one of the seven features, roadway section. Here the assessment for the location of the beginning and ending points of sections is given; a similar assessment was done for

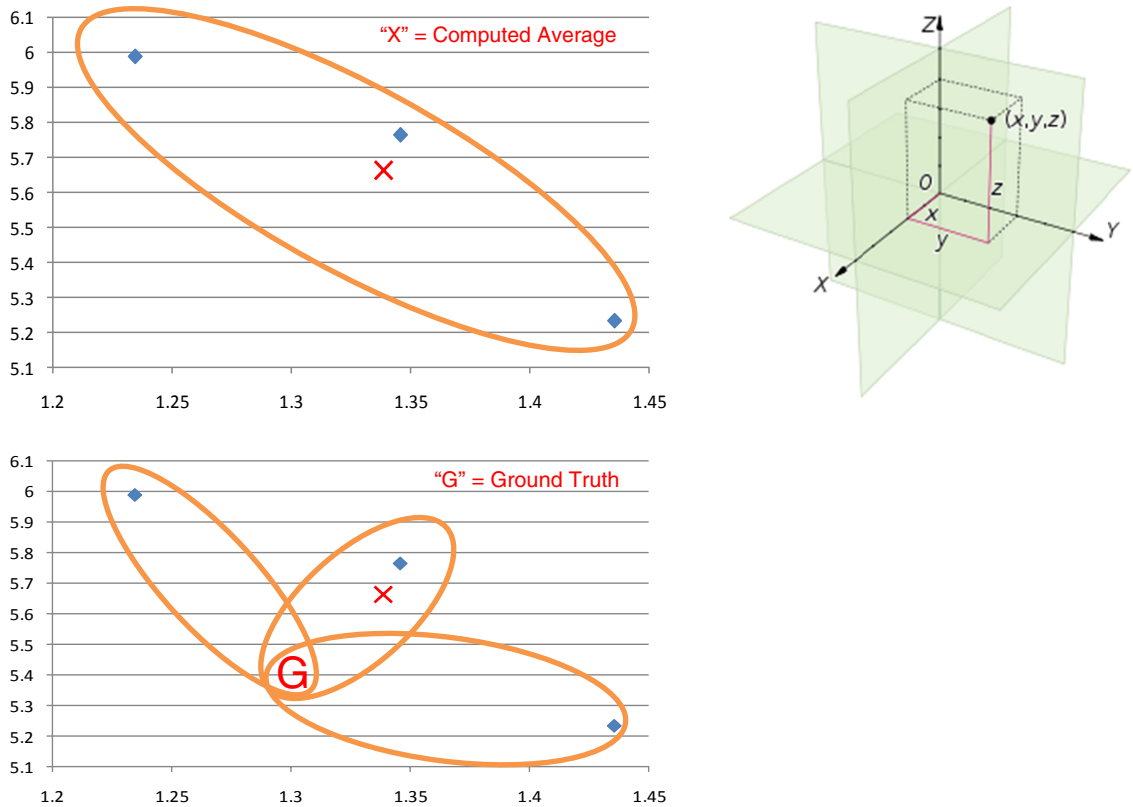
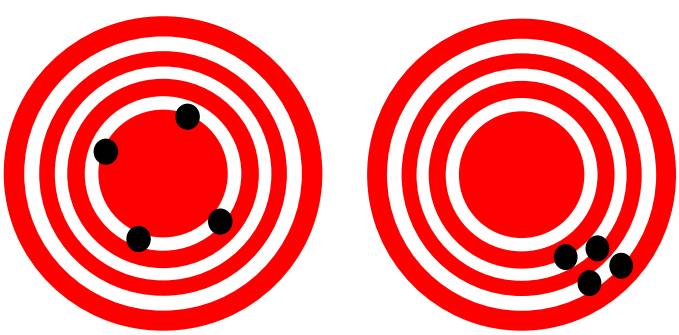


Figure B.1. Calculating precision and accuracy.

section length. The data in the figure shows the precision and accuracy of reporting the right begin and end location for each section. Vendors 1, 3, and 5 reported the most precise and accurate information.

Figure B.4 presents the results of horizontal curve assessment. Vendors were evaluated for locations of point of curvature (PC) and point of tangency (PT), curve radius, and curve length. The figure shows the difference between vendor data and the ground truth by showing the numbers of curves in each range (less than 3 ft, between 3 and 25 ft, between 25 and 50 ft, and more than 50 ft).



High accuracy, but low precision. High precision, but low accuracy.

Figure B.2. Accuracy versus precision.

B.2.2 Use of GIS for Evaluation

Previously collected surveyor data were provided to the research team for use in the vendor evaluation. These data were provided in multiple formats and coordinate systems. The coordinate system of each of the features was determined, and a single, common coordinate system was selected for evaluation purposes. Data sets, both computer-aided design (CAD) and tabular, were converted to ArcGIS format and projected onto the common coordinate system. Where necessary, appropriate attributes, such as sign type or curve radius, were added to the representative GIS-based features. Feature geometry (e.g., length and begin/end coordinates) was computed and added as attributes to each feature.

The survey-provided grade and cross-slope data had to be addressed in a different manner. Specifically, these data were provided in tabular format, with their locations conveyed using project stationing. Therefore, station-based linear referencing systems (LRS) were created for each project site

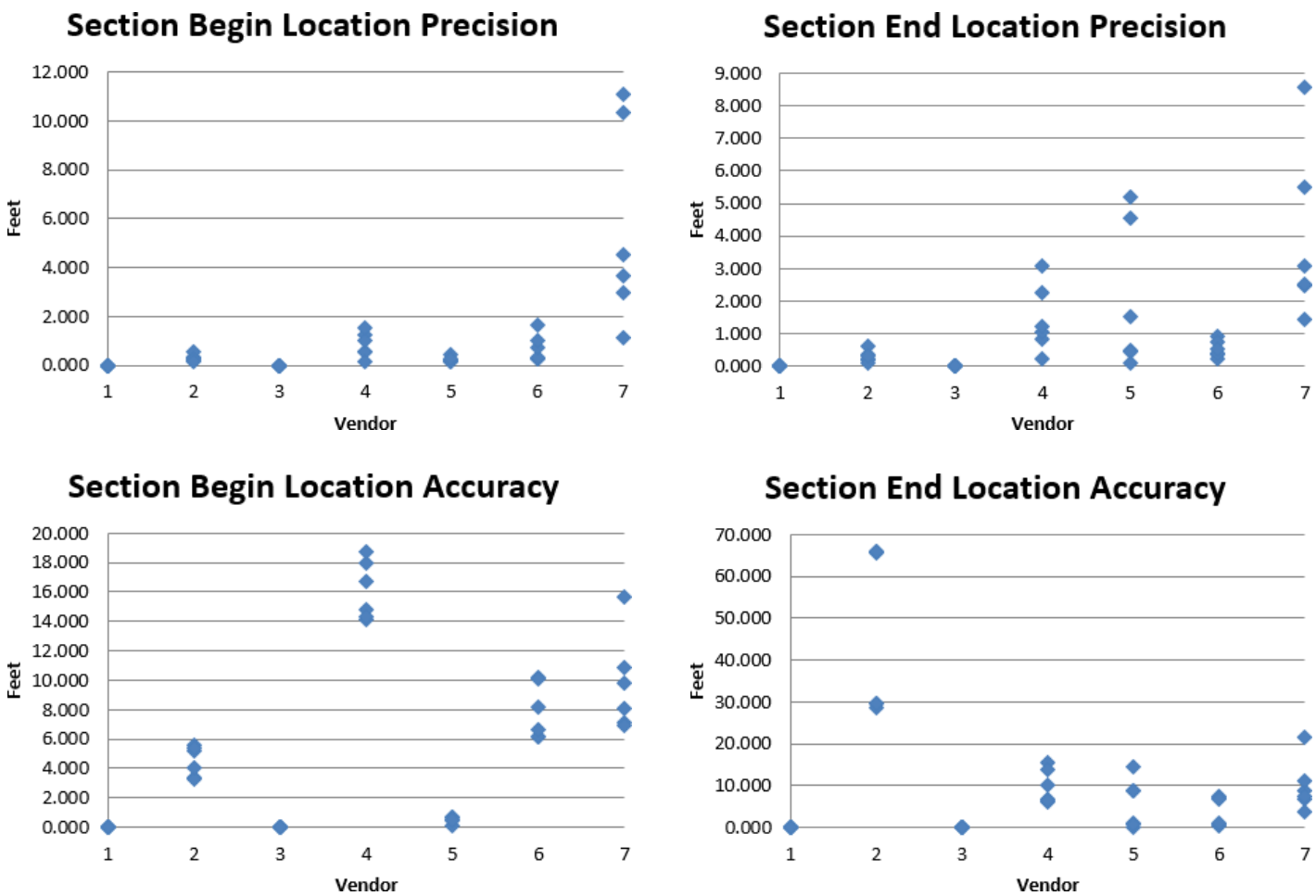


Figure B.3. Section begin and end points, accuracy and precision by vendor.

Curve Length Accuracy

Vendor	<=3'	3-25'	25-50'	>50'	Grand Total
1		8	1	3	12
2	3		3	6	12
3		4	1	4	9
4	3	9			12
5	3	9			12
6			3	9	12
7				12	12
Grand Total	9	30	8	34	81

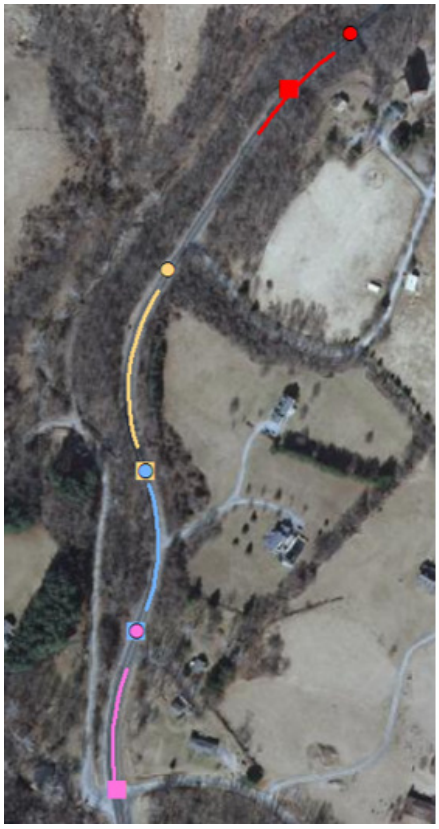
Curve PC, PT Accuracy

Vendor	<=3'	3-25'	25-50'	>50'	Grand Total
1		16	5	3	24
2		9	9	6	24
3		9	5	4	18
4		23	1		24
5	6	18			24
6		11	6	7	24
7			9	15	24
Grand Total	6	86	35	35	162

Curve Radius Accuracy

Vendor	<=3'	3-25'	25-50'	>50'	Grand Total
1		5	7		12
2		7	2	3	12
3	4	3	2		9
4	2	7	3		12
5	1	5	6		12
6				12	12
7				12	12
Grand Total	7	27	20	27	81

Figure B.4. Horizontal curve evaluation summary.



Vendor		Ground Truth	
Length_(ft)	Radius_(ft)	Length	Radius
218.342	762.323	292.150	889
561.241	659.623	429.300	491
434.013	676.997	337.990	553
431.942	841.255	326.880	679

Grade	
Vendor	Ground Truth
1.703	1.79
0.54	1.82
-0.194	-0.79
-0.702	-1.41

Figure B.5. Example comparison of vendor data with ground truth data.

(6S and 7N) in ArcGIS. A grade and cross-slope linear event table was created, and dynamic segmentation was used to create GIS-based features for each round. This process automatically associated the appropriate grade and cross-slope attributes with each feature.

Figure B.5 presents an example where curve length, curve radius, and segment grade from the vendor are compared to the ground truth data using centerline shape files.

B.3 Results

The vendor evaluation results were presented to the ETG at a meeting in Washington, D.C. The ETG members scored each vendor based on whether they were positive, neutral, or negative for each data element and on the importance level of that data element. Possible scores ranged from –18 (worst performance) to +18 (best performance). The ETG made the recommendation to prequalify three of the seven vendors based on the data presented, minimum accuracy requirements, and data item importance level. The S04A team, working with SHRP 2, conducted technical briefings with the disqualified vendors. Based on the evaluation, a minimum accuracy table (Table B.1) was developed and incorporated into the S04B request for proposals and qualifications (RFP&Q) that the three prequalified vendors were provided. Table B.2 presents the importance levels for each data element investigated in the vendor evaluation.

The evaluation results are summarized in Table B.3. Definitions for each performance category are provided.

Table B.1. Required Minimum Accuracies[a]

Data Element	Accuracy Requirement
Curvature length	50 ft
Curvature radius	50 ft
PC	25 ft
PT	25 ft
Grade (+ or –)	1.0%
Cross slope/superelevation	1.0%
Lane width	1 ft
Paved shoulder width	1 ft
Inventory features (signs) location	7 ft

[a] Initial minimum accuracy requirements that were changed.

Table B.2. Data Importance Levels

Data Element	Importance Level
Curvature length	High
Curvature radius	High
PC	High
PT	High
Grade (+ or –)	High
Lane width	Moderate
Paved shoulder width	Moderate
Inventory features (signs) location	Low
Sign type (correct MUTCD)	Low

Table B.3. Vendor Evaluation Results

Roadway Feature	Number of Vendors by Performance		
	Positive	Neutral	Negative
Curve: PC/PT location	2	3	2
Curve: Length	3	2	2
Curve: Radius	4	1	2
Roadway: Longitudinal grade	2	3	2
Roadway: Cross slope	0	5	2
Roadway: Lane width	6	1	0
Roadway: Paved shoulder width	5	1	1
Sign: Location	4	3	0
Sign: Message (MUTCD only)	3	3	1

Note:
Positive (score of 1): The majority of the data met the minimum accuracy requirement.
Neutral (score of 0): Roughly half of the data met the minimum accuracy requirement.
Negative (score of –1): The majority of the data did not meet the minimum accuracy requirement.

APPENDIX C

Database Design Specifications

This appendix documents the activities completed under SHRP 2 Project S04A for Task 5 (Database Design and Specification), which is aimed at developing the technical specifications and supporting management components for the SHRP 2 Roadway Information Database (RID). This task included developing data models to define the RID and to ensure its interoperability with the Naturalistic Driving Study (NDS) database.

This appendix provides the draft database design for the normalized RID, the S04A database, which is used for storing and maintaining the base data while maintaining data integrity.

C.1 Database Design and Specification

The objectives of Task 5 were to develop the technical specifications and supporting management components for the SHRP 2 RID, develop data models to define the RID, and to ensure its interoperability with the NDS database. Because the RID is the framework to which all other data in the SHRP 2 Safety program is attached, the ultimate success and usefulness of the SHRP 2 Safety program depends on establishing data specifications that provide some consistency across the six study area sites while recognizing and accounting for inherent differences among the data between, and even within, the NDS sites.

As such, the S04A database is designed to efficiently store all the data collected as part of the S04B project, along with additional data acquired from each of the six NDS sites. The design provides a high level of flexibility in the attributes that can be stored and in the method by which those attributes are located relative to the road network.

C.1.1 Assumptions

Because the base road networks for each of the six NDS sites were yet to be determined before development and because the list and sources of additional attributes were still being finalized, the following basic assumptions were made:

1. A standard road network framework would be established, either purchased or developed, for each of the six study area sites. This road network framework would be a topologically connected, geospatial database, and would use a standard link-node design to depict each road segment and intersection.
2. From this road network framework, a framework route system would be created where each route would be stored as a unique linear feature. Each route would be calibrated over its entire length (i.e., the start of the route has measure 0, the measures increase along the route, and the final measure is equal to the total length of the route).
3. Location events (i.e., signs, intersections, extents of lanes, horizontal curves) would be located using a route/measure linear referencing method (LRM).

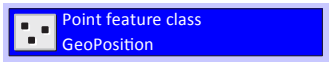
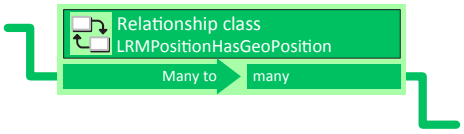
C.1.2 Design Concept

A spatially enabled database, or geodatabase, is a database designed to store, query, and manipulate geographic data, including points, lines, and polygons. Within the geodatabase are a number of classes that are used to store the attribute and spatial data, relationships between classes, and domains of valid attribute values. Table C.1 provides brief descriptions of the classes found in a typical geodatabase.

The design of the S04A database is a simplified version of the revised Unified Network-Transportation (UNETRANS) network data model proposed by Butler (2008). This data model offers several advantages:

- It allows route overlaps (i.e., when a single road segment has two or more route designations) to be handled by creating the framework routes independent of preexisting route designations. Alternative route designations (e.g.,

Table C.1. Geodatabase Classes

Class	Description
Table	The Table class is the basic data storage mechanism consisting of columns, referred to as fields, and an unordered collection of rows. All point and linear event data will be stored in tables.
Feature	The Feature class is similar to the Table class but it is spatially enabled, allowing it to store geometry. The spatial geometry field can be one of a number of different types, including points, lines, and polygons.  Examples of Feature classes include roads and routes.
Relationship	The Relationship class defines the links between fields in two Table/Feature classes. The Relationship can simply relate the two fields in a one-to-one or one-to-many cardinality, or it can be attributed to differentiate many-to-many cardinal relationships. 
Domain	The Domain classes provide valid values for the Table and Feature class fields. The Domain classes can be of two types: • Coded: The Domain defines the list of valid choices for the field. • Range: The valid values are defined using minimum and maximum values.

I-95, US-1) are then stored as linear events of the framework route.

- It allows geographic positions to be referenced against multiple routes, using different linear referencing methods.
- It provides flexibility by storing all simple route events within a single table. These simple route events, called aspects, normally only require a single attribute descriptor (e.g., functional class, pavement width, number of lanes).
- Complex route events (e.g., intersections, signs, alignments), called elements, that require multiple attribute descriptors, are stored in custom tables.
- It treats all route events, whether they are aspects or elements, in a similar manner.

Based on the requirements of the SHRP 2 NDS, the data contained within the S04A database was to be published into a denormalized data warehouse designed to improve data query and retrieval speeds at the cost of increased storage.

C.2 S04A Data Model

The following sections describe the draft S04A data model.

C.2.1 Road Network

All the event data within the RID is referenced against a route system, based on the defined RouteID field. This route system is built from the underlying links and nodes. This relationship is shown Figure C.1.

As stated in the assumptions, the RouteID is not be based on preexisting route designations (e.g., I-95, US-1), but uses an incrementing key.

C.2.2 LRM Locations

All positions used to locate point and linear events on the network are defined using an LRMPosition (see Figure C.2). For linear events, the FrMeasure, FrX, FrY, ToMeasure, ToX, and ToY are defined, while for point events only the FrMeasure, FrX, and FrY are required.

C.2.3 Alignments

The road alignment (i.e., horizontal and vertical curves) is defined using several related attributes and is stored separately as a linear event against the routes (see Figure C.3).

C.2.4 Aspects

Simple route events, called aspects, normally only require a single attribute descriptor (e.g., functional class, pavement width, rumble strip location). As such, they can be stored within the same table, Aspect, that provides the following (see Figure C.4):

- The spatial location for the route event;
- The type of the event (which infers the event value type); and
- The event value.

This structure is identical to the current data model developed by FHWA for submission of Highway Performance Monitoring System (HPMS) data.

The list of aspect route events to be stored within the Aspect table are defined within the AspectTypes Domain table (see Figure C.11).

Nodes

Simple feature class
nodes

Geometry *Point*
Contains M values *No*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
Shape	Geometry	Yes						Node point
NODEID	Long integer	Yes			0			Unique Identifier

Links

Simple feature class
links

Geometry *Polyline*
Contains M values *No*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
Shape	Geometry	Yes						Link polyline
LINKID	Double	Yes			0	0		Unique Identifier
FRNODEID	Double	Yes			0	0		From Node ID
TONODEID	Double	Yes			0	0		To Node ID
NAME	String	Yes					64	Road Name
DIR_TRAVEL	String	Yes					2	Travel Direction (F, T or B)
FUNC_CLASS	String	Yes					1	Functional Class
X	Double	Yes			0	0		X-coordinate of midpoint
Y	Double	Yes			0	0		Y-coordinate of midpoint
ROUTEBASE	String	Yes					64	Base Route Name
ROUTENAME	String	Yes					64	Route Name
ANGLE	Float	Yes			0	0		Angle of the link
PROUTEID	Double	Yes			0	0		Parent Route identifier
ROUTEID	Double	Yes			0	0		Route identifier
RAMP	String	Yes					2	Is this link a ramp?
Shape_Length	Double	Yes			0	0		GIS length of the link

Routes

Simple feature class
Routes

Geometry *Polyline*
Contains M values *Yes*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
Shape	Geometry	Yes						Route polyline
ROUTEID	Long integer	Yes			0			Unique identifier
PROUTEID	Long integer	Yes			0			Parent Route identifier
ROUTENAME	String	Yes					64	Route Name
ROUTEBASE	String	Yes					64	Base Route Name
LENGTH	Double	Yes			0	0		Length of the route
FRMEASURE	Double	Yes			0	0		From Measure
TOMEASURE	Double	Yes			0	0		To Measure
ONEWAY	Short integer	Yes			0			Is the route one-way?

Figure C.1. S04A road network data model.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Figure C.2. S04A LRMPosition table.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
Alignment

Alignment

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
AlignmentID	GUID	No			0	0	38	Unique identifier
LRMPositionID	GUID	No			0	0	38	Identifier for LRMPosition
Tangent	Short integer	No	0	TrueFalse	0			Tangent
Radius	Long integer	No			0			Curve radius
CurveDirectionID	Short integer	No		Direction	0			Curve direction
SuperElevation	Double	Yes			0	0		Super-elevation
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No		DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Figure C.3. S04A alignments data model.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
Aspect

Aspect

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
AspectID	GUID	No			0	0	38	Unique identifier
LRMPositionID	GUID	No			0	0	38	Identifier of the LRMPosition
AspectTypeID	Short integer	No		AspectTypes	0			Aspect Type ID
ValueNumeric	Double	No			0	0		Aspect numeric value
ValueText	String	No					32	Aspect text value
ValueDate	Date	No			0	0	8	Aspect date value
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1	DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Table
AspectType

Aspect Type

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
AspectTypeID	Short integer	No	-1		0			Unique identifier
Name	String	No					32	Name of the Aspect
FieldTypeID	Short integer	No	1	FieldTypes	0			Aspect data field type
GeometryTypeID	Short integer	No	1	GeometryTypeID	0			Aspect geometry type
DomainTypeID	Short integer	Yes		DomainTypes	0			Aspect domain
RangeMin	Double	Yes			0	0		Minimum range value
RangeMax	Double	Yes			0	0		Maximum range value
CodedValueTable	String	Yes					128	Coded Value Domain table name
UseOffset	Short integer	Yes		TrueFalse	0			Use LRM offset?

Figure C.4. S04A aspects data model.

C.2.5 Barriers

The barriers along the roads are defined using several related attributes and are stored as a linear event against the routes (see Figure C.5).

C.2.6 Intersections

Intersections are complex, as they need to be referenced against each route that intersects at the intersection. As such, the intersections are referenced as point events against each of the routes through the RouteIntersection table (see Figure C.6).

C.2.7 Lanes

Each segment of the road network can have multiple lanes of different types and widths. These lanes are linearly referenced against the routes as linear events (see Figure C.7).

C.2.8 Locations

Each section of the road network is reviewed to capture grade and cross slope. These locations are linearly referenced against the routes as linear events (see Figure C.8).

C.2.9 Shoulders

Each segment of the road network can have a defined shoulder of various types. These shoulders are linearly referenced against the route system as linear events. Additional fields in the LRMPosition table identify which side of the road the shoulder is located on, as seen in Figure C.9.

C.2.10 Signs

Each sign is associated with a sign assembly that is linearly referenced against the route system as a point event. A sign assembly can have multiple signs (see Figure C.10).

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
Barrier

Barrier

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
BarrierID		No			0	0	38	Unique Identifier
LRMPositionID		No			0	0	38	Identifier of the LRMPosition
BarrierTypeID	Short integer	No	-1	BarrierType	0			Barrier Type
StartTreatmentTypeID	Short integer	Yes	-1	BarrierTreatmentType	0			Treatment Type at the start of the Barrier
EndTreatmentTypeID	Short integer	Yes	-1	BarrierTreatmentType	0			Treatment Type at the end of the Barrier
PostMaterialID	Short integer	No		BarrierPostMaterial	0			Post Material
RubrailPresent	Short integer	Yes	-1	TrueFalse	0			Is a Rub Rail present?
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1	DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Figure C.5. S04A barriers data model.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
RouteIntersection

Route-Intersection

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
RouteIntersectionID	GUID	No			0	0	38	Unique identifier
IntersectionID	GUID	No			0	0	38	Identifier for Intersection
LRMPositionID	GUID	No			0	0	38	Identifier for LRMPosition
OBJECTID	Object ID							

Table
Intersection

Intersection

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
IntersectionID	GUID	No			0	0	38	Unique identifier
ControlTypeID	Short integer	No	-1	IntersectionControlType	0			Intersection Control Type
Approaches	Short integer	No	4	InterectionNumApproaches	0			Number of approaches to the Intersection
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1	DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Figure C.6. S04A intersections data model.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
Lane

Lanes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
LaneID	GUID	No			0	0	38	Unique identifier
LRMPositionID	GUID	No			0	0	38	Identifier for the LRMPosition
Width	Double	No			0	0		Lane width
ThroughLanes	Short integer	Yes	0		0			Number of Through Lanes
LeftTurnLanes	Short integer	Yes	0		0			Number of Left Turn Lanes
RightTurnLanes	Short integer	Yes	0		0			Number of Right Turn Lanes
CenterTurnLane	Short integer	No	0		0			Number of Center Turn Lanes
AccelerationLane	Short integer	No	0		0			Number of Acceleration Lanes
DecelerationLane	Short integer	No	0		0			Number of Deceleration Lanes
AccelDecelLane	Short integer	No	0		0			Number of Acceleration/Deceleration Lanes
BikeLane	Short integer	Yes			0			Number of Bike Lanes
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1	DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Figure C.7. S04A lanes data model.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
Location

Location

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
LocationID		No			0	0	38	Unique Identifier
LRMPositionID		No			0	0	38	Identifier of the LRMPosition
Grade	Double	Yes			0	0		Road grade
CrossSlope	Double	Yes			0	0		Road cross slope
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1		0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Figure C.8. S04A locations data model.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
Shoulder

Shoulder

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
ShoulderID	GUID	No			0	0	38	Unique identifier
LRMPositionID	GUID	No			0	0	38	Identifier of the LRMPosition
ShoulderTypeID	Short integer	No	-1	ShoulderType	0			Shoulder Type
Width	Double	No			0	0		Shoulder Width
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1	DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Figure C.9. S04A shoulders data model.

C.2.11 Domains

The domains within the RID define the valid values for a subset of the fields within the S04A data model and are used for efficiency, as they allow numeric IDs to be stored within the tables rather than repeated strings.

The domains fall into two categories:

1. Fixed domains: The values within the domain do not change between RID databases.
2. Dynamic domains: The values within the domain are dynamically populated based on the loaded data.

C.2.11.1 Fixed Domains

Fixed domains are shown in Figure C.11.

C.2.11.2 Dynamic Domains

The codes listed within these domains are dynamically inserted by scanning the S04B databases to determine unique values for the associated fields. Dynamic domains are shown in Figure C.12.

C.3 S04B Databases

The SHRP 2 S04B Mobile Data Collection project is focused on the deployment of a roadway measurement system to collect, at highway speed, roadway-feature data on selected roads within the study sites. The data includes the following:

- Tier 1
  - Horizontal curvature: Radius, length, point of curvature (PC), point of tangency (PT), and direction of curve (left or right based on driving direction).
  - Grade.
  - Cross slope/superelevation.
  - Lane: Number, width, and type (e.g., through, turn, passing, acceleration, carpool).
  - Shoulder type/curb (and paved width if it exists).
  - Sign location.
  - MUTCD signs.

Table
LRMPosition

LRM Positions on Routes

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
PositionID	GUID	No			0	0	38	Unique identifier
RouteID	Long integer	No			0			Route identifier
FrMeasure	Double	No			0	0		From measure
ToMeasure	Double	No			0	0		To measure
SideOfRoad	String	No		SideCode			1	Side of Road
OffsetReferent	Short integer	No	0	Referents	0			Lateral Offset Referent
OffsetDir	Short integer	No	0		0			Offset direction
OffsetDistance	Double	No	0		0	0		Offset distance
Length	Double	Yes	0		0	0		Polyline length
FrX	Double	Yes			0	0		Point or start of polyline x-coordinate
FrY	Double	Yes			0	0		Point or start of polyline y-coordinate
ToX	Double	Yes			0	0		End of polyline x-coordinate
ToY	Double	Yes			0	0		End of polyline y-coordinate
LocationMethod	Short integer	Yes		LocationMethod	0			Data location method

Table
SignAssembly

Sign Assembly

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
SignAssemblyID	GUID	No			0	0	38	Unique identifier
LRMPositionID	GUID	No			0	0	38	Identifier of the LRMPosition
NumSigns	Short integer	No	1		0			Number of Signs on the Assembly
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1	DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Table
Sign

Sign

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length	
OBJECTID	Object ID							
SignID	GUID	No			0	0	38	Unique Identifier
SignAssemID	GUID	No			0	0	38	Identifier for Sign Assembly
MUTCDCodeID	Short integer	No		SignMUTCDCode	0			MUTCD Code
MUTCDNameID	Short integer	No		SignMUTCDName	0			MUTCD Name
MUTCDCategoryID	Short integer	No		SignMUTCDCategory	0			MUTCD Category
Message	String	No					32	Message on the Sign
Comment	String	Yes					255	Comment
SourceID	String	Yes					32	Source of the data
DataSourceID	Short integer	No	-1	DataSource	0			ID of the source record
DataDate	Date	Yes			0	0	8	Date of the source record

Figure C.10. S04A signs data model.

Coded value domain
AspectTypes

Description *Name*
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Code	Description
1	Route Name
2	AADT
3	Functional Class
4	Lighting
5	Median Strip
6	Rumble Strip
7	IRI
8	Speed Limit

Coded value domain
Datums

Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
1	State Plane
2	WGS 84
0	Unknown

Coded value domain
Direction

Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
-1	Left
0	None
1	Right

Coded value domain
DomainTypes

Description *Domain Types*
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Code	Description
0	None
1	Range
2	Coded Value

Coded value domain
GeometryTypeID

Description
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Code	Description
1	Point
2	Polyline

Range domain
InterectionNumApproaches

Description
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Minimum value	Maximum value
0	10

Coded value domain
LocationMethod

Description *Method used for*
Field type *locating the polyline*
Split policy *Short integer*
Merge policy *Default value*

Code	Description
1	End points on same route
2	End point on adjacent routes
3	Shortest path
-1	Original and Conflated polyline length differ by more than 20%
-2	End point(s) failed to snap to network within tolerance
-3	Failed to find shortest path between end points

Coded value domain
OffsetDirections

Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
0	None
1	In
2	Out
3	North
4	East
5	South
6	West
7	Toward
8	Away From

Figure C.11. Fixed S04A domains. (Continued on next page.)

Coded value domain
FieldTypes
Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
1	Short Integer
2	Integer
3	Long Integer
5	String
6	Float
7	Double
8	ObjectID
9	DateTime
10	GUID
11	XML
12	Blob

Coded value domain
Referents
Description
Field type *Short integer*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
0	None
1	Edge of Pavement
2	Face of Curb
3	Back of Curb
4	Back of Sidewalk
5	Edge of Right of Way
6	Centerline of Road
7	Centerline of Ditch

Coded value domain
SideCode
Description
Field type *String*
Split policy *Duplicate*
Merge policy *Default value*

Code	Description
L	Left Side Only
R	Right Side Only
B	Both Sides & Street
S	Street Only
N	Both Sides & Not Street
U	Unknown
C	Center

Coded value domain
TrueFalse
Description
Field type *Short integer*
Split policy *Default value*
Merge policy *Default value*

Code	Description
-1	True
0	False
1	True

Figure C.11. Fixed S04A domains. (Continued from previous page.)

  - Barriers and guardrail.
  - Intersection location.
- Tier 2
  - Intersections: Number of approaches, and control (uncontrolled, all-way stop, two-way stop, yield, signalized, roundabout). Ramp termini are considered intersections.
  - Median presence: Type (depressed, raised, flush, barrier).
  - Rumble strip presence: Location (centerline, edgeline, shoulder).
  - Lighting presence.

These data are provided as a Microsoft Access database in a standard format and are processed directly from this database.

C.3.1 ETL Routine

Extract-transform-load (ETL) routines developed as part of this task are used to load the collected data from the Microsoft Access databases into the RID. These ETL routines include the following:

- Spatial locations are referenced against the underlying route system and references loaded into the LRMPosition table.
- The alignment, intersection, lane, sign, and shoulder events are loaded into the appropriate custom Element route event tables.
- The remaining collected data (i.e., median type, grade, lighting, rumble strip location) are loaded into the Aspect route event table.

C.4 Hardware and Software

The physical assembly of the new server infrastructure is complete. Some electrical system upgrades were needed to accommodate the universal power supply (UPS) unit.

Coded value domain
BarrierPostMaterial

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
ShoulderType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
BarrierTreatmentType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
SignMUTCDCategory

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
BarrierType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
SignMUTCDCode

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
IntersectionControlType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
SignMUTCDName

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Coded value domain
MedianType

Description	*BarrierTreatmentType*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
-1	Unknown

Figure C.12. Dynamic S04A domains.

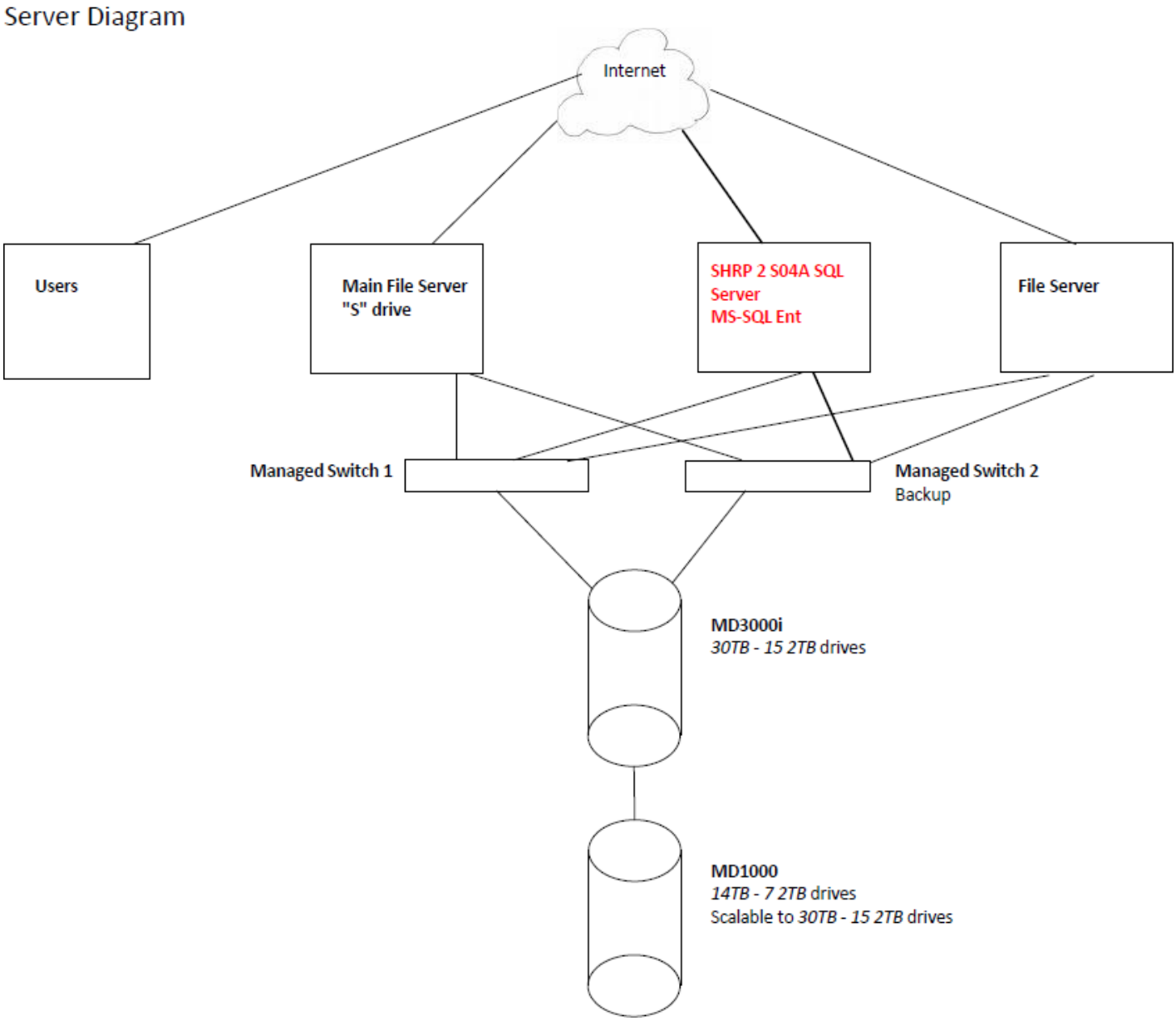


Figure C.13. SHRP 2 SQL server.

With the system physically in place and all power upgrades completed, the SHRP 2 S04A SQL server setup was completed and is fully functional. The storage array system setup and implementation was completed in January 2011. Figure C.13 shows the server diagram.

C.5 Reference

Butler, J.A. 2008. *Designing Geodatabases for Transportation.* Esri Press, Redlands, Calif.

APPENDIX D

Supplemental Data

D.1 Introduction

The SHRP 2 Safety and Reliability focus areas had data of common interest to both programs that were not addressed in either of the focus areas' projects. SHRP 2 initiated a Phase 1 Supplemental Naturalistic Driving Study (NDS) Site Data Feasibility project (S32) to determine the availability and feasibility of acquiring these supplemental data in each of the six SHRP 2 NDS sites. The supplemental NDS site data project was divided into two phases: Phase 1 (feasibility study) and Phase 2 (acquisition and integration into the SHRP 2 RID). Phase 1, which is covered in this appendix, identified the availability and cost of acquiring and integrating supplemental data into the RID. During Phase 2, the project team acquired the supplemental data and integrated them into the RID. See Figure D.12 for the final list of supplemental data items that were acquired for each of the six NDS study sites and included in the RID.

D.2 Objectives

The following objectives were completed to support this effort:

1. Determine the availability and feasibility of acquiring a list of supplemental data items specific to both SHRP 2 Safety and Reliability focus areas, in each of the six SHRP 2 naturalistic driving sites. The list of data items included but were not limited to the following: incident information; five-year crash history; traffic data; traffic control information; weather information; work zone information; safety improvements; special event information; and information that would allow for before-after evaluations of new safety programs, initiatives, and laws that were introduced or changed during the period of the SHRP 2 study in each NDS site.
2. Recommend to SHRP 2 the most efficient method to acquire, store, deliver, and manage these data to support analyses.

D.3 Findings

This section provides a summary of the work activities and findings to accomplish the objectives of Phase 1.

D.3.1 Supplemental Data Items

This effort identified a broad range of potential supplemental data items to facilitate input from the SHRP 2 staff and research designees. Figure D.1 shows the initial list of supplemental data items.

This list was further populated through a variety of efforts and sources, including the following:

- Exploring websites of potential public sources of data, including state departments of transportation (DOTs), metropolitan planning organizations (MPOs)/regional planning associations (RPAs), cities, counties, and safety groups.
- Identifying relevant private data sources, such as weather and real-time traffic/travel information.
- Reviewing safety and reliability literature, research efforts, and recommendations.
- Reviewing previous work and recommendations from SHRP 2 projects Development of Analysis Methods (S01, four projects), Development of the NDS Analysis Workplan (S02), and the NDS Study Design (S05). This effort included a review of the numerous research questions generated by these projects.
- Conducting limited discussions with agency staff in the six NDS sites.

These actions resulted in a more comprehensive list of data items, as shown in Figure D.2, which includes group labels of safety, common (items of interest to both the Safety and Reliability programs), reliability, and policy. Policy data items are not roadway specific but rather give a picture of the individual

	Data Item
SAFETY AND COMMON DATA ITEMS	**Crash**
	Aerial Imagery
	Work Zone
	Weather
	Traffic Information
	AADT
	Truck Traffic
	Peak Hourly Volume
	Design Hourly Volume
	Level of Service
	Safety Campaigns Information
	Special Enforcement
	Click-it-or-ticket
	Sobriety
	Other
	Overall Traffic Control Strategy
	Truck traffic operations
	Corridor management
	Signalized intersection timings
	Signal operation
	Variable message signs
	Reversible lanes/Dynamic lanes
	Changes in the infrastructure condition
	Changes in operations
	Red Light Running Cameras
	Speed Enforcement Cameras
	Flashing Left Turn Arrow
RELIABILITY ITEMS	**Special Events**
	Timed and major events
	Sanctioned by an official entity
	Incidents
	Disabled vehicles
	Cargo spills
	Train stall
	Coordinated with incident mgmt
	Travel Time Reliability

Figure D.1. Initial list of supplemental data items.

state's policy toward issues such as seat-belt laws and cell phone and texting laws.

D.3.2 Expert Feedback and Refinement

The list of supplemental data items was presented to both a safety and a reliability group for refinement and prioritization. This was accomplished through two webinars.

D.3.2.1 Feedback (Webinars)

Two webinars, on July 29 and August 9, 2011, were organized for safety and reliability participants, respectively. Each group was presented with the comprehensive list of supplemental data items and asked to provide input on the following:

- The completeness and categories used for the list (any missing data items not included).
- The interest level and specific information desired by item. For example, work zone by roadway is important, but participants expressed a desire to seek out the physical limits of the work zone area, the impact to travel and primary work activity/duration, and frequency by location.

Based on the input received, a revised list of supplemental data items was prepared. In an effort to provide group members with an opportunity to share their thoughts, this revised list was resubmitted to the groups in the form of an online survey.

D.3.2.2 Feedback (Survey)

An online survey was prepared that included 32 supplemental data items that were categorized under four topics (safety, reliability, common, and policy). The survey was completed by 14 safety and reliability researchers/experts.

Respondents were asked to indicate the significance (low, medium, high) of each data item in terms of supporting research in their area of expertise, and a text box was provided for respondents to share their reasoning for each ranking decision (see Figure D.3).

The first question asked participants to identify themselves as either a safety or a reliability expert or an expert in both areas. Among 14 responders, 11 identified themselves as safety experts, only one as a reliability expert, and two as experts in both safety and reliability focus areas. The expertise classification was then used to cross-tabulate the survey responses.

The survey findings were as follows. Items that were ranked as high, medium, and low by the majority of the responders (>50%) were grouped as Tier 1, Tier 2, and Tier 3 items, respectively (see Figure D.4). In addition to overall importance ranking, a ranking by expertise was also considered in tier assignment, because the majority of respondents were safety experts. In some cases, a high ranking from the reliability experts was prioritized even if an item's overall ranking was low. See highlights in Figure D.4.

The survey analysis was followed up with an item-by-item discussion, which resulted in final tier assignments (1, 2, and 3, with 1 being the highest priority) for each supplemental data item. The resulting tier assignments by data item are shown in Table D.1. The number next to each data item refers to the survey question for easy tracking to the results.

(text continues on page 80)

	Data Item
SAFETY AND COMMON DATA ITEMS	**Crash**
	Aerial Imagery
	Work Zone
	Locations and begin/end
	Time Period
	Impact/activity, traffic control
	Weather
	Roadway Level
	Local Area
	Statewide
	511
	Incidents/Closures
	Weather/Alerts
	Winter Weather Operations and Advisories
	Special Events
	Bridge and Tunnel Status
	Construction
	Cameras
	Travel Speeds (e.g. >50mph, 30-49mph, <30mph)
	Traffic Information
	Volume - Automatic Traffic Recording
	Volume - Annual or regular occurring counts
	Volume - Special counts
	Truck Traffic
	Peak Hourly Volume
	Design Hourly Volume
	Level of Service
	Safety Campaigns Information
	Special Enforcement
	Click-it-or-ticket
	Sobriety
	Other*
	Overall Traffic Control Strategy
	Truck traffic operations
	Corridor management
	Signalized intersection timings
	Signal operation
	Variable message signs
	Reversible lanes/Dynamic lanes
	Changes in the infrastructure condition
	Changes in operations

Data Item
Pavement Markings
Retroreflectivity
Installation date
Type and Width
Maintenance Activities (repainting)
Signs
Condition
Retroreflectivity
Select Inventory: Stop, Chevron, Slippery/Wet
Maintenance Activities
Lighting
Inventory (locations)
Glare and Illumination levels
Pedestrian Crossings
Pedestrian Volume
Special Crossing Treatments and Locations
Roadway
Rumble Strips (locations)
Edge drop off maintenance
Clear zone or fixed object setback
Sight Distance
Vertical Curvature
Friction
Roughness
Changes to Adjacent Land Uses
Weigh Station Activity
Operations
No Passing Zones (locations, limits)
School Speed Zones (speed, locations, limits, times)
Rural Community Speed Transition Zones
On-Street Bike Lanes (locations)
ITS Assets
Cameras / Video (locations, data)
Red Light Running Cameras (location/approach)
Speed Enforcement Cameras (location/approach)

Figure D.2. Comprehensive list of supplemental data items before prioritization and acquisition.
(Continued on next page.)

	Data Item
Reliability	**Recurring Congestion**
	Locations where traffic demand exceeds capacity
	Nonrecurring Congestion
	Incident data by location
	Disabled vehicles
	Cargo spills
	Train stall
	Coordinated through an incident mgmt system
	Work zones frequency by location
	Weather data by impacts to travel time and location
	Daily/Seasonal Traffic Variations that impact travel
	Inadequate base capacity locations
	Special Events
	Timed and major events
	Sanctioned by an official entity
	Emergencies (unplanned)
	Independent Travel Time Reliability Business Processes
	Monitoring weather station data
	Coordinating traffic signals
	Dispatching DOT maintenance support
	Implementing a work zone
	Integrated Travel Time Reliability Business Processes
	Traveler information during emergencies
	Implementing active traffic management
	Multi-agency incident management program
	Integrated Corridor Management Strategies
	Integrated Area Work Zone Coordination Strategies
	Roadway Capacity Improvements
	Major roadway capacity improvement actions
	Major operational capacity enhancements
	Variation in Structured Data (history/data formats)
	Data storage, archiving, format, visualization, usage
	Volume (ATR, radar, Select counts, other)
	Occupancy
	Speed
	Incidents and Events
	Acquire Archival Travel Time Raw Data (among 6 sites)
	Site, Length, Lanes, Spacing, Travel Times, Dates
	Analysis Tools
	Predictive models

Figure D.2. Comprehensive list of supplemental data items before prioritization and acquisition. (Continued from previous page and continued on next page.)

	Data Item
POLICY ITEMS	**Aggressive Driving and Speeding**
	Laws Countermeasure
	Speed Limits
	Enforcement Countermeasure
	Automated enforcement
	Distracted Driving and Drowsy Driving
	Laws and Enforcement
	GDL requirements for beginning drivers
	Cell phone and text messaging laws
	Two-wheeled Motorcycle Safety
	Motorcycle Helmets Countermeasure
	State motorcycle helmet use laws
	Young Drivers
	Graduated Driver Licensing Countermeasures
	Graduated driver licensing (GDL)
	Learner's permit length, supervised hours
	Intermediate - nighttime restrictions
	Intermediate - passenger restrictions
	Older Drivers
	Licensing Countermeasures
	License screening and testing
	Pedestrians
	All Pedestrians Countermeasure
	Reduce and enforce speed limits
	Targeted enforcement
	Bicycles
	Children Countermeasure
	Bicycle helmet laws for children
	All Bicyclists Countermeasure
	Active lighting and rider conspicuity
	Alcohol-Impaired and Drugged Drivers
	Deterrence:Laws Countermeasures
	Administrative licence revocation or suspension
	Open Containers
	Deterrence: Enforcement Countermeasures
	Sobriety Checkpoints
	Saturation Patrols
	Preliminary Breath Test Devices
	Deterrence: DWI Offender Countermeasures
	Alcohol problem assessment, treatment
	Alcohol interlocks

Data Item
Prevention, Intervention, Comm and Outreach
Alcohol screening and brief intervention
Mass-media campaigns
Underage Drinking and Alcohol-Impaired Driving
Minimum drinking age 21 laws
Seat Belt Use
Seat Belt Use Law Enforcement Countermeasure
State primary enforcement belt use laws
Seat Belt Law Enforcement Countermeasure
Short-term high-visibility belt law enforcement
Communications and Outreach Countermeasure
Communications and outreach supporting enforcement
Seat Belt Use - Pre-Teen and Teenage Occupants
Restraint Use Laws Countermeasure
Coverage by restraint use law: seating position, vehicles, ages
Seat Belt Use - Children in Child Restraints and Booster
Child Restraint/Booster Seat Use Laws Countermeasure
Enactment of child restraint use laws
Coverage: seating position, vehicles, ages
Child Restraint/Booster Seat Use Law Enforcement Countermeasure
Short-term high visibility-child restraint/booster law enforcement
Communications and Outreach Countermeasure
Communications and outreach supporting enforcement

Figure D.2. Comprehensive list of supplemental data items before prioritization and acquisition. (Continued from previous page.)

SHRP 2 S04A Supplemental Data Items Survey

Exit this survey

Safety Data Items

Please indicate the significance each data item has in terms of supporting research in your area of expertise. **Please include a justification in the provided textbox for each data item importance level**

***3. Crash**
Crash data including 5 years before and during the two-year SHRP2 NDS study
Rating:

Low Medium High

Reasoning and Comments

***4. Traffic Counts**
Permanent and seasonal count data such as automatic traffic recording, annual or regular occurring counts, special counts, truck traffic, peak hour volumes
Rating:

Low Medium High

Reasoning and Comments

***5. Pedestrian Crossings**
Data including location, volume, and traffic control devices, special countermeasures
Rating:

Low Medium High

Reasoning and Comments

Figure D.3. Screenshot from the online survey.

#	Data Items	Tier 1	Tier 2	Tier 3		Safety	Reliability	Safety and Reliability	Response Percent		Reliability Response %
10	Recurring Congestion		X		Low	2	0	0	15.4%		0.00%
					Medium	4	0	2	46.2%		66.67%
					High	4	1	0	38.5%		33.33%
11	Nonrecurring Congestion Data	X			Low	0	0	0	0.0%		0.00%
					Medium	8	0	1	69.2%		33.33%
					High	2	1	1	30.8%	*	66.67%
12	Travel Time Reliability Business Process			X	Low	6	0	1	53.8%		33.33%
					Medium	2	1	1	30.8%		66.67%
					High	2	0	0	15.4%		0.00%
13	Travel Time Data	X			Low	6	0	0	46.2%		0.00%
					Medium	2	0	1	23.1%		33.33%
					High	2	1	1	30.8%	*	66.67%
14	Travel Demand Management		X		Low	8	0	1	69.2%		33.33%
					Medium	1	1	1	23.1%		66.67%
					High	1	0	0	7.7%		0.00%
15	Public Transportation		X		Low	8	1	0	69.2%		33.33%
					Medium	2	0	2	30.8%		66.67%
					High	0	0	0	0.0%		0.00%
16	Analysis Tools Used			x	Low	7	1	1	69.2%		66.67%
					Medium	2	0	0	15.4%		0.00%
					High	1	0	1	15.4%		33.33%

Figure D.4. Ranking of reliability data items.

(continued from page 75)

D.3.2.3 Prioritized Approach

On the basis of time and resources available to accomplish this effort, a prioritized approach was established, which included the following:

- First choice was to obtain or identify sources of information, with the second choice being data. For example, if an agency had average daily traffic (ADT) information in GIS files (a format that allows for easy integration into the RID), this was preferred, versus obtaining all the agency's raw data.
- DOT and Tier 1 information was the focus. This follows the fact that DOTs own most of the Tier 1 data items. The critical question was whether the information is archived with easy access. If, within these discussions, a local agency was identified as having data items of interest, the team would target these entities for follow-up discussions.

D.3.2.4 Consistency

To ensure consistency, completeness, and efficiency during the information gathering process, the research team addressed the following:

- *Data definitions.* Based on the input from previous tasks, a data definn table was used to clarify questions and to share with agency staff (see Table D.2).
- *Informational paragraph.* An email template (text) was prepared for each site for new contacts who may not be aware of the SHRP 2 NDS effort. This included program background

Table D.1. Tier Classification of the Initial Data Items

			Tier		
			1	2	3
Safety	3	Crash data	X		
	4	Traffic counts	X		
	5	Pedestrian crossings			X
	6	Work zone data	X		
	7	Weather data	X		
	8	511 information		X	
	9	Operational countermeasures	X		
Reliability	10	Recurring congestion		X	
	11	Nonrecurring congestion data	X		
	12	Travel time reliability business process			X
	13	Travel time data	X		
	14	Travel demand management		X	
	15	Public transportation		X	
	16	Analysis tools used			X
Common	17	Aerial imagery	X		
	18	Change in adjacent land use			X
	19	Speed limit data	X		
	20	Level of service		X	
	21	Variable message signs		X	
	22	Reversible dynamic lanes			X
	23	Changes to existing infrastructure condition	X		
	24	Roadway capacity improvements	X		
	25	Innovative treatments data	X		
Policy	26	Safety campaign information	X		
	27	Speed limit laws	X		
	28	Cell phone and text messaging laws	X		
	29	Automated enforcement for aggressive driving and speeding	X		
	30	Graduated driver licensing		X	
	31	State motorcycle helmet use laws		X	
	32	License screening and testing			X
	33	Targeted enforcement for pedestrian crossings		X	
	34	Laws and enforcement for alcohol-impaired and drugged drivers	X		
	35	Laws and enforcement for seat-belt use		X	

Table D.2. Original Data Item Definitions

Tier					
1	2	3	Category	Item	Description
X			Safety	Crash data	Crash data, including 5 years before and during the 2-year SHRP 2 NDS.
X			Safety	Traffic counts	Data, including ADT, truck traffic, and any other seasonal or special count data, if available. Do they archive continuous counts, seasonal counts, special counts, PHV, LOS?
X			Safety	Work zone data	Data, including location, limits, time period, and, if available, the impact to travel (lane closure, lane narrowing, lower speed limit). First priority: Location, limits, time period.
X			Safety	Weather data	Atmospheric data, including air temperature, dew point, relative humidity, average wind speed, wind gust, wind direction, precipitation, and roadway data, such as surface and subsurface temperature by sensor location.
X			Safety	Automated enforcement	Data, including the location and dates of operation for either red light running or automated speed enforcement devices.
X			Reliability	Nonrecurring congestion	Location, area of influence, time and source of congestion. Do they keep track of incidents such as disabled vehicles, cargo spills, train stalls? Is this coordinated through an incident management system? Do they keep track of special events, such as timed/major events, sanctioned events?
X			Reliability	Travel time data	Travel time data by site and including corridor, number of lanes, intersection spacing, and date.
X			Common item	Aerial imagery	Document the available aerial imagery by study site, type of imagery, resolution. Example: Digital orthophotography SID images, topographic maps.
X			Common item	Speed limit data	Data, including speed limit by location, posted, advisory, special restrictions, changes during the SHRP 2 NDS period.
X			Common item	Changes to existing infrastructure condition	Data documenting changes to infrastructure condition, such as overlays or replacements that improve condition without adding capacity or changing geometry.
X			Common item	Roadway capacity improvements	Data documenting major operational and capacity enhancements, such as additional lanes, intersection treatments, traffic control, traffic signalization, reversible lanes, designated lanes, roundabouts.
X			Common item	Innovative treatments	Data documenting targeted safety enhancements, such as curve treatments, shoulders, rumble strips during the NDS study.
X			Policy	Safety campaigns information	Sobriety checkpoints, distracted driving, share the road awareness, seat belt, targeted enforcement veh/ped.
X			Policy	Speed limit laws	Any increase or decrease to the maximum statutory speed limit over the two-year duration on state roads.
X			Policy	Cell phone and text messaging laws	Laws that prohibit hand-held cell phone use and/or texting while driving.
X			Policy	State laws regarding automated enforcement	Laws that enable or prohibit the use of automated speed enforcement, red light running cameras, or other devices.
X			Policy	Laws for alcohol-impaired and drugged drivers	Laws enacted that prohibit driving while impaired, publicizing and enforcing those laws, and punishing the offenders.
	X		Safety	511 information	Data, including incidents/closures; weather/alerts; winter weather operations and advisories; special events; bridge and tunnel status; construction; travel speeds (e.g., <30 mph, 30–49 mph, >50 mph).
	X		Reliability	Recurring congestion	For roadway segments, this includes free flow and actual speeds by time of day and location. For intersections, data identifying locations where traffic demand exceeds capacity by location, area of influence, duration, and time.

(continued on next page)

Table D.2. Original Data Item Definitions (continued)

Tier					
1	2	3	Category	Item	Description
	X		Reliability	Travel demand management	Information specific to efforts to reduce travel demand, such as share a ride, park and ride, zip cars, incentives, HOV lanes. Information specific to community public transportation modes, use, coverage.
	X		Reliability	Public transportation	Information specific to community public transportation modes, use, coverage.
	X		Common item	Level of service	Data, including level of service by times of day for intersections and road segments.
	X		Common item	Variable message signs	Descriptive data, including locations, devices, and operations (messages, duration, frequency).
	X		Policy	State law regarding graduated driver licensing (GDL)	Laws specific to GDL (nighttime hours, number of passengers, cell phones, learner's permit, seat-belt use, etc.).
	X		Policy	State motorcycle helmet use laws	Laws covering helmet use for both driver and rider and, if there are any differences, by specified ages.
	X		Policy	Laws for seat-belt use	Primary enforcement belt use laws permit seat-belt use law violators to be stopped and cited independently of any other traffic behavior. Secondary enforcement laws allow violators to be cited only after they first have been stopped for some other traffic violation.
		X	Safety	Pedestrian crossings	Data, including locations where special countermeasures are implemented and a description of the countermeasures.
		X	Reliability	Travel time reliability business process	Coordinating traffic signals (locations and frequency), using weather station data to dispatch maintenance support, standardized process for implementing work zone, providing traveler information during emergencies, implementing active traffic management, implementing a multiagency incident management program, and integrated corridor management.
		X	Reliability	Analysis tools used	Document agency actions based on use of predictive models, software tools to manage travel time reliability during the NDS period.
		X	Common item	Change to adjacent land use	Data that documents the changes in land use over time by corridor and study area (e.g., agricultural to commercial land use) over the two-year NDS period.
		X	Common item	Reversible dynamic lanes	Descriptive data including locations, operations, directions, restrictions.
		X	Policy	State procedures on driver's license screening and testing	Administered driver's license screening and testing to evaluate drivers' abilities and skills. Process of driver referral, screening, assessment, counseling, and licensing action.

information/links and served to orient the audience on the supplemental data request.

- *Working documents.* A working document for each NDS site was prepared based on the tiered listing. These documents were continuously updated with notes from email messages, phone conversations, and web searches.
- *Findings template.* A template was developed for use in populating the results from each site based on the information within each working document. Table D.3 shows an example of the template and specific details, whether for DOT or other agencies, including the following:
  - Archived: Are the supplemental data items archived (yes, no, limited)?
  - Format: In what format are the data collected, maintained, and stored (data are maintained in a wide variety of formats and media such as GIS, XML, PDF, and CSV)?
  - Accessibility: What options are available to access the data/information (online, by request, through an approval process, etc.)?
  - Cost: What is the cost to get data from a private source or a public agency?
  - Restrictions: Are there any special restrictions to accessing and/or acquiring the data/informational item (agreement, needs to be established, not sure, etc.)?
  - Comment: A comment field was provided for the team to note any specific details about the data or information received.

The above information was used to estimate associated costs for each data item in terms of a relative cost to acquire and integrate the information into the SHRP 2 RID. A three-point cost scale was used (low, medium, and high), given the granularity

Table D.3. State Informational Detail and Cost Template (Example Only)

		DOT						
		Information Details					Costs	
Tier	Item	Archived	Format	Accessibility	Restrictions	Comment	Acquire	Integrate
1	Crash data	Yes	GIS	Online	Agreement	Descriptive	Low	Low
1	Traffic	No	XML	Request	Under review	Information	Medium	Medium
1	Work zone	Limited	Limited	Other	TBD	About data	High	High

of the information. In general, the measure of expense and effort to obtain the data item was categorized as follows:

- Low: No cost for the data and minimal effort required to acquire and integrate.
- Medium: Moderate to high cost for the data and/or the same for the effort to acquire and integrate.
- High: High cost for either the data or the effort needed to support analysis, acquisition, or integration.

D.3.2.5 Summary of Findings

Figure D.5 provides a qualitative cost summary by data item in terms of the cost (low, medium, high) to acquire and integrate the data into the SHRP 2 RID. As shown, there are some blanks for various items, because the assessments are based on discussions about the available data with different agencies, as opposed to acquiring the actual data, and because not enough information was available to determine a cost category. The information in Figure D.5 was used as input for data acquisition. The findings for each site are shown in Figure D.6 (New York), Figure D.7 (Florida), Figure D.8 (Pennsylvania), Figure D.9 (Indiana), Figure D.10 (North Carolina), and Figure D.11 (Washington). The finalized list of supplemental data that were acquired for each of the six NDS study states and integrated into the RID is shown in Figure D.12.

		NY	FL	PA	IN	NC	WA	NY	FL	PA	IN	NC	WA
Tier	Item	Acquire	Acquire	Acquire	Acquire	Acquire	Acquire	Integrate	Integrate	Integrate	Integrate	Integrate	Integrate
1	Aerial Imagery	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
1	Speed Limit Data	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
1	Changes to existing infrastructure condition	Medium	Medium	Medium	Medium	Medium	Medium	High	High	High	High	High	High
1	Roadway Capacity Improvements	Medium	Medium	Medium	Medium	Medium	Medium	High	High	High	High	High	High
1	Innovative Treatments		Medium			Low			High			High	
2	Level of Service	Low				Medium		High				Medium	
2	Variable Message Signs	Low						High					
3	Change to Adjacent Land Use					Medium						High	
3	Reversible Dynamic Lanes												
1	Speed Limit Laws	Low	Low	Low	Low	Low	Low	NA	NA	NA	NA	NA	NA
1	Cell phone and text messaging laws	Low	Low	Low	Low	Low	Low	NA	NA	NA	NA	NA	NA
1	State laws regarding automated enforcement	Low	Low	Low	Low	Low	Low	NA	NA	NA	NA	NA	NA
1	Laws for Alcohol-Impaired and Drugged Drivers	Low	Low	Low	Low	Low	Low	NA	NA	NA	NA	NA	NA
1	Safety Campaigns Information	High	High	High	High	High	High	High	High	High	High	High	High
2	State law regarding graduated driver licensing (GDL)	Low	Low	Low	Low	Low	NA	NA	NA	NA	NA	NA	NA
2	State motor cycle helmet use laws	Low	Low	Low	Low	Low	NA	NA	NA	NA	NA	NA	NA
2	Laws for Seat Belt Use	Low	Low	Low	Low	Low	NA	NA	NA	NA	NA	NA	NA
3	State procedures regarding driver's license screening a												
1	Nonrecurring Congestion	Low	High	Low		Low	High	Medium	High	Medium	0	Medium	High
1	Travel Time Data			Low		Low	Medium			Low		Low	High
2	Recurring Congestion					Medium						Medium	
2	Travel Demand Management												
2	Public Transportation					High						High	
3	Travel Time Reliability Business Process												
3	Analysis Tools Used	Low				Medium		Low				Low	
1	Crash Data	Low	Low	Low	Low	Low	Low	Low	Low	Low	Medium	Low	Low
1	Information - AADT	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
1	Work Zone	Low	Medium	Medium	Medium	Low	Medium	Medium	Medium	Medium	High	Medium	High
1	Winter Road Conditions (DOT)	Low		Low	Low	Low	High	Low		Low	Low	Low	High
1	Local Climatological Data (LCD) NOAA	Low	Low	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium
1	Data - Continuous Counts (ATR)	High	Low		Medium	Medium	Low	High	Low		High	Medium	Low
1	Data -Short Duration Counts	High	Low		Medium	Medium	Low	High	Low		High	Medium	Low
1	Cooperative Observer/Other Sources	Low	Low	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium
1	Automated Enforcement	High	High	Low			High	Medium	Medium	Medium			High
1	Traffic												
1	Other					Medium	Medium					High	High
1	Weather												
1	Roadway Level (RWIS) DOT				Medium		High				High		High
1	Hourly Precipitation Data NOAA	Medium	Medium	Medium	Medium	Medium	Medium	High	High	High	High	High	High
1	Storm Event Data (by County) NOAA	Medium	Medium	Medium	Medium	Medium	Medium	High	High	High	High	High	High
2	511 Information	Medium	Medium	Low	Medium	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium
3	Pedestrian Crossings					Low						Low	

Figure D.5. Qualitative cost summary (all sites).

#	Item	Priority	Category	Data Description	Integration	Data Frequency
1	Crash Data	1	Common	2006-2013 data delivered in access from NYDOT	Convert to GIS using Lat/Long, conflate to network	Yearly
2	Traffic Information - AADT		Safety	2011-2013 data in excel from NY DOT	Joined to GIS, conflate to network	Yearly
3	Aerial Imagery		Common	2011 NAIP aerial imagery by county in 1 meter resolution	None	Single Year
4	Speed Limit Data		Safety	2011 speed limit data from FLDOT	Conflate to network	Single Year
5	Speed Limit Laws		Policy	Documented laws from 2011-2013	None	Yearly
6	Cell phone and text messaging laws		Policy	Documented laws from 2011-2013	None	Yearly
7	Automated enforcement laws		Policy	Documented laws from 2011-2013	None	Yearly
8	Alcohol-Impaired and Drugged Drivers laws		Policy	Documented laws from 2011-2013	None	Yearly
9	Graduated driver licensing (GDL) laws		Policy	Documented laws from 2011-2013	None	Yearly
10	State motor cycle helmet use laws		Policy	Documented laws from 2011-2013	None	Yearly
11	Seat Belt Use laws		Policy	Documented laws from 2011-2013	None	Yearly
12	Local Climatological Data (LCD) NOAA		Common	Monthly Quality Controlled Local Climatological (QCLCD) Data from 2011-2013 for 3 stations around NDS study site	Access Database by Station	Monthly
13	Cooperative Weather Observer/Other Sources		Common	Monthly Global Historical Climatology Network (GHCN) data from 2011-2013. Includes 14 COOP stations, 68 CoCoRaHS stations, and 14 ASOS stations. Also have severe weather events for surrounding counties of NDS study site.	Access Database by Station	Monthly
14	Winter Road Conditions (DOT)	2	Common	2011-2013 511 data including weather events from NYDOT and NITTEC	Convert to GIS using Lat/Long, conflate to network	NA
15	Work Zone		Common	2011-2013 511 data including work zones impacting roadway from NYDOT and NITTEC	Convert to GIS using Lat/Long, conflate to network	Yearly
16	511 Information		Common	2011-2013 511 data from NYDOT and NITTEC	Convert to GIS using Lat/Long, conflate to network	Yearly
17	Traffic Data - Continuous Counts (ATR)		Safety	2011-2013 ATR data from NY DOT	Join data to shapefile, conflate to network	Yearly
18	Traffic Data -Short Duration Counts		Safety	2011-2013 short duration count data from NY DOT	Join data to shapefile, conflate to network	Yearly
19	Changes to existing infrastructure condition		Safety	Changes to Roadway Data	Conflate to network	Yearly
20	Roadway Capacity Improvements		Common	Roadway Improvement Data	Conflate to network	Yearly

Figure D.6. Summary for New York.

#	Item	Priority	Category	Data Description	Integration	Data Frequency
1	Crash Data	1	Common	2006-2013 Shapefile from FLDOT	Conflate to network	Yearly
2	Traffic Information - AADT		Safety	2011-2013 Shapefile from FLDOT	Conflate to network	Yearly
3	Aerial Imagery		Common	2009-2013 FLDOT aerial imagery by county in 1 foot resolution 2013 NAIP aerial imagery by county in 1 meter resolution	None	Single Year
4	Speed Limit Data		Safety	2013 speed limit data from FLDOT	Conflate to network	Single Year
5	Speed Limit Laws		Policy	Documented laws from 2011-2013	None	Yearly
6	Cell phone and text messaging laws		Policy	Documented laws from 2011-2013	None	Yearly
7	Automated enforcement laws		Policy	Documented laws from 2011-2013	None	Yearly
8	Alcohol-Impaired and Drugged Drivers laws		Policy	Documented laws from 2011-2013	None	Yearly
9	Graduated driver licensing (GDL) laws		Policy	Documented laws from 2011-2013	None	Yearly
10	State motor cycle helmet use laws		Policy	Documented laws from 2011-2013	None	Yearly
11	Seat Belt Use laws		Policy	Documented laws from 2011-2013	None	Yearly
12	Local Climatological Data (LCD) NOAA		Common	Monthly Quality Controlled Local Climatological (QCLCD) Data from 2011-2013 for 7 stations around NDS study site	Access Database by Station	Monthly
13	Cooperative Weather Observer/Other Sources		Common	Monthly Global Historical Climatology Network (GHCN) data from 2011-2013. Includes 3 COOP stations, 120 CoCoRaHS stations, and 12 ASOS stations. Also have severe weather events for surrounding counties of NDS study site.	Access Database by Station	Monthly
14	Winter Road Conditions (DOT)	2	Common	Not Applicable	None	NA
15	Work Zone		Common	2011-2013 511 data including work zones impacting roadway	TBD	Yearly
16	511 Information		Common	2011-2013 511 data including work zones impacting roadway	TBD	Yearly
17	Traffic Data - Continuous Counts (ATR)		Safety	2011-2013 ATR shapefile data from FLDOT	Conflate to network	Yearly
18	Traffic Data -Short Duration Counts		Safety	2011-2013 short duraction shapefile data from FLDOT	Conflate to network	Yearly
19	Changes to existing infrastructure condition		Safety	Kml data from FLDOT of projects completed within 2011-2013	Convert to GIS then conflate	Yearly
20	Roadway Capacity Improvements		Common	Kml data from FLDOT of projects completed within 2011-2013	Convert to GIS then conflate	Yearly

Figure D.7. Summary for Florida.

#	Item	Priority	Category	Data Description	Integration	Data Frequency
1	Crash Data	1	Common	2006-2013 data delivered in access from PA DOT	Convert to GIS using Lat/Long, conflate to network	Yearly
2	Traffic Information - AADT		Safety	2011-2013 Shapefile from PA DOT	Conflate to network	Yearly
3	Aerial Imagery		Common	2013 NAIP aerial imagery by county in 1 meter resolution	None	Single Year
4	Speed Limit Data		Safety	2013 speed limit data from FLDOT	Conflate to network	Single Year
5	Speed Limit Laws		Policy	Documented laws from 2011-2013	None	Yearly
6	Cell phone and text messaging laws		Policy	Documented laws from 2011-2013	None	Yearly
7	Automated enforcement laws		Policy	Documented laws from 2011-2013	None	Yearly
8	Alcohol-Impaired and Drugged Drivers laws		Policy	Documented laws from 2011-2013	None	Yearly
9	Graduated driver licensing (GDL) laws		Policy	Documented laws from 2011-2013	None	Yearly
10	State motor cycle helmet use laws		Policy	Documented laws from 2011-2013	None	Yearly
11	Seat Belt Use laws		Policy	Documented laws from 2011-2013	None	Yearly
12	Local Climatological Data (LCD) NOAA		Common	Monthly Quality Controlled Local Climatological (QCLCD) Data from 2011-2013 for 1 stations around NDS study site	Access Database by Station	Monthly
13	Cooperative Weather Observer/Other Sources		Common	Monthly Global Historical Climatology Network (GHCN) data from 2011-2013. Includes 8 COOP stations, 10 CoCoRaHS stations, and 0 ASOS stations. Also have severe weather events for surrounding counties of NDS study site.	Access Database by Station	Monthly
14	Winter Road Conditions (DOT)	2	Common	2011-2013 511 data including weather events from PA DOT	Convert to GIS using Lat/Long, conflate to network	NA
15	Work Zone		Common	2011-2013 511 data including work zones from PA DOT	Convert to GIS using Lat/Long, conflate to network	Yearly
16	511 Information		Common	2011-2013 511 data from PA DOT	Convert to GIS using Lat/Long, conflate to network	Yearly
17	Traffic Data - Continuous Counts (ATR)		Safety	2011-2013 ATR data from PA DOT	Reduce data, convert to GIS, conflate to network	Yearly
18	Traffic Data -Short Duration Counts		Safety	2011-2013 short duration count data from PA DOT	Conflate to network	Yearly
19	Changes to existing infrastructure condition		Safety	2011-2013 projects in shapefile from PA DOT	Conflate to network	Yearly
20	Roadway Capacity Improvements		Common	2011-2013 projects in shapefile from PA DOT	Conflate to network	Yearly

Figure D.8. Summary for Pennsylvania.

#	Item	Priority	Category	Data Description	Integration	Data Frequency
1	Crash Data	1	Common	2006-2013 data delivered as a .DAT file from INDOT	Extract data, convert to GIS , conflate to network	Yearly
2	Traffic Information - AADT		Safety	2011-2013 Shapefile from FLDOT	Conflate to network	Yearly
3	Aerial Imagery		Common	2012 Indiana University GIS aerial imagery by county in 1 meter resolution	None	Single Year
4	Speed Limit Data		Safety	2011 speed limit data from FLDOT	Conflate to network	Single Year
5	Speed Limit Laws		Policy	Documented laws from 2011-2013	None	Yearly
6	Cell phone and text messaging laws		Policy	Documented laws from 2011-2013	None	Yearly
7	Automated enforcement laws		Policy	Documented laws from 2011-2013	None	Yearly
8	Alcohol-Impaired and Drugged Drivers laws		Policy	Documented laws from 2011-2013	None	Yearly
9	Graduated driver licensing (GDL) laws		Policy	Documented laws from 2011-2013	None	Yearly
10	State motor cycle helmet use laws		Policy	Documented laws from 2011-2013	None	Yearly
11	Seat Belt Use laws		Policy	Documented laws from 2011-2013	None	Yearly
12	Local Climatological Data (LCD) NOAA		Common	Monthly Quality Controlled Local Climatological (QCLCD) Data from 2011-2013 for 5 stations around NDS study site	Access Database by Station	Monthly
13	Cooperative Weather Observer/Other Sources		Common	Monthly Global Historical Climatology Network (GHCN) data from 2011-2013. Includes 16 COOP stations, 81 CoCoRaHS stations, and 3 ASOS stations. Also have severe weather events for surrounding counties of NDS study site.	Access Database by Station	Monthly
14	Winter Road Conditions (DOT)	2	Common	2011-2013 511 data from CARS Program	TBD	NA
15	Work Zone		Common	2011-2013 511 data from CARS Program including work zone impact	TBD	Yearly
16	511 Information		Common	2011-2013 511 data from CARS Program	TBD	Yearly
17	Traffic Data - Continuous Counts (ATR)		Safety	2011-2013 ATR data from INDOT	Conflate to network	Yearly
18	Traffic Data -Short Duration Counts		Safety	2011-2013 short duraction count data from INDOT	Conflate to network	Yearly
19	Changes to existing infrastructure condition		Safety	TBD	TBD	Yearly
20	Roadway Capacity Improvements		Common	TBD	TBD	Yearly

Figure D.9. Summary for Indiana.

#	Item	Priority	Category	Data Description	Integration	Data Frequency
1	Crash Data	1	Common	2006-2013 delivered as excel from HSIS	Convert to GIS using LRS, conflate to network	Yearly
2	Traffic Information - AADT		Safety	2011-2013 Shapefile from NC DOT	Conflate to network	Yearly
3	Aerial Imagery		Common	2012 NAIP aerial imagery by county in 1 meter resolution	None	Single Year
4	Speed Limit Data		Safety	2011 speed limit data from FLDOT	Conflate to network	Single Year
5	Speed Limit Laws		Policy	Documented laws from 2011-2013	None	Yearly
6	Cell phone and text messaging laws		Policy	Documented laws from 2011-2013	None	Yearly
7	Automated enforcement laws		Policy	Documented laws from 2011-2013	None	Yearly
8	Alcohol-Impaired and Drugged Drivers laws		Policy	Documented laws from 2011-2013	None	Yearly
9	Graduated driver licensing (GDL) laws		Policy	Documented laws from 2011-2013	None	Yearly
10	State motor cycle helmet use laws		Policy	Documented laws from 2011-2013	None	Yearly
11	Seat Belt Use laws		Policy	Documented laws from 2011-2013	None	Yearly
12	Local Climatological Data (LCD) NOAA		Common	Monthly Quality Controlled Local Climatological (QCLCD) Data from 2011-2013 for 6 stations around NDS study site	Access Database by Station	Monthly
13	Cooperative Weather Observer/Other Sources		Common	Monthly Global Historical Climatology Network (GHCN) data from 2011-2013. Includes 18 COOP stations, 129 CoCoRaHS stations, and 2 ASOS stations. Also have severe weather events for surrounding counties of NDS study site.	Access Database by Station	Monthly
14	Winter Road Conditions (DOT)	2	Common	2011-2013 Traffic Incident Management System data from NC DOT in shapefile with weather events	Conflate to network	NA
15	Work Zone		Common	2011-2013 Traffic Incident Management System data from NC DOT in shapefile with work zone impacts	Conflate to network	Yearly
16	511 Information		Common	2011-2013 Traffic Incident Management System data from NC DOT in shapefile	Conflate to network	Yearly
17	Traffic Data - Continuous Counts (ATR)		Safety	2011-2013 ATR data from NC DOT	Convert to GIS, conflate to network	Yearly
18	Traffic Data -Short Duration Counts		Safety	2011-2013 short duration count data from NC DOT	Conflate to network	Yearly
19	Changes to existing infrastructure condition		Safety	TBD	TBD	Yearly
20	Roadway Capacity Improvements		Common	TBD	TBD	Yearly

Figure D.10. Summary for North Carolina.

#	Item	Priority	Category	Data Description	Integration	Data Frequency
1	Crash Data	1	Common	2006-2013 data in excel from WA DOT	Convert to GIS using LRS, conflate to network	Yearly
2	Traffic Information - AADT		Safety	2011-2013 Shapefile from WA DOT	Conflate to network	Yearly
3	Aerial Imagery		Common	2011 NAIP aerial imagery by county in 1 meter resolution	None	Single Year
4	Speed Limit Data		Safety	2011 speed limit data from WA DOT	Conflate to network	Single Year
5	Speed Limit Laws		Policy	Documented laws from 2011-2013	None	Yearly
6	Cell phone and text messaging laws		Policy	Documented laws from 2011-2013	None	Yearly
7	Automated enforcement laws		Policy	Documented laws from 2011-2013	None	Yearly
8	Alcohol-Impaired and Drugged Drivers laws		Policy	Documented laws from 2011-2013	None	Yearly
9	Graduated driver licensing (GDL) laws		Policy	Documented laws from 2011-2013	None	Yearly
10	State motor cycle helmet use laws		Policy	Documented laws from 2011-2013	None	Yearly
11	Seat Belt Use laws		Policy	Documented laws from 2011-2013	None	Yearly
12	Local Climatological Data (LCD) NOAA		Common	Monthly Quality Controlled Local Climatological (QCLCD) Data from 2011-2013 for 7 stations around NDS study site	Access Database by Station	Monthly
13	Cooperative Weather Observer/Other Sources		Common	Monthly Global Historical Climatology Network (GHCN) data from 2011-2013. Includes 22 COOP stations, 123 CoCoRaHS stations, and 5 ASOS stations. Also have severe weather events for surrounding counties of NDS study site.	Access Database by Station	Monthly
14	Winter Road Conditions (DOT)	2	Common	2011-2013 511 data including weather events from WA DOT	Data feed to GIS, conflate to network	NA
15	Work Zone		Common	2011-2013 511 data including work zones from WA DOT	Data feed to GIS, conflate to network	Yearly
16	511 Information		Common	2011-2013 511 data from WA DOT	Data feed to GIS, conflate to network	Yearly
17	Traffic Data - Continuous Counts (ATR)		Safety	2011-2013 ATR data in shapefile from WA DOT	Conflate to network	Yearly
18	Traffic Data -Short Duration Counts		Safety	2011-2013 short duration count data in shapefile from WA DOT	Conflate to network	Yearly
19	Changes to existing infrastructure condition		Safety	2011-2013 projects completed from WA DOT	Convert to GIS using Lat/Long, conflate to network	Yearly
20	Roadway Capacity Improvements		Common	2011-2013 projects completed from WA DOT	Convert to GIS using Lat/Long, conflate to network	Yearly

Figure D.11. Summary for Washington.

#	Item	Priority	Category	Description	Data Type	Data Frequency	Time Period of Interest
1	Crash Data	1	Common	State's official crash file.	GIS State/County	Yearly	2006-2013
2	Traffic Information - AADT		Safety	Computed AADT by site or segment.	GIS Statewide	Yearly	2011-2013
3	Aerial Imagery		Common	Aerial imagery at 1 meter resolution which can be associated with Geographic Information Systems (GIS).	1 Meter Resoultion Image County Based	Single Year	Between 2011-2013
4	Speed Limit Data		Safety	Posted speed limit by location, and if available advisory and special restrictions along with changes during the SHRP2 NDS period	GIS Statewide	Single Year	Between 2011-2013
5	Speed Limit Laws		Policy	Any increase or decrease to the maximum statutory speed limit over the two-year duration on state roads.	State Summary Document	Yearly	2011-2013
6	Cell phone and text messaging laws		Policy	Laws which prohibit hand-held cell phone use and/or texting while driving.	State Summary Document	Yearly	2011-2013
7	Automated enforcement laws		Policy	Laws which enable or prohibit the use of automated speed enforcement, red light running cameras, or other devices.	State Summary Document	Yearly	2011-2013
8	Alcohol-Impaired and Drugged Drivers laws		Policy	Laws enacted that prohibit driving while impaired, publicizing and enforcing those laws, and punishing the offenders.	State Summary Document	Yearly	2011-2013
9	Graduated driver licensing (GDL) laws		Policy	Laws specific to GDL (nighttime hours, number of passengers, cell phones, learners permit, seat-belt use, etc).	State Summary Document	Yearly	2011-2013
10	State motor cycle helmet use laws		Policy	Laws covering helmet use for both driver and rider and if there are any differences by specified ages.	State Summary Document	Yearly	2011-2013
11	Seat Belt Use laws		Policy	Primary enforcement belt use laws permit seat belt use law violators to be stopped and cited independently of any other traffic behavior. Secondary enforcement laws allow violators to be cited only after they first have been stopped for some other traffic violation.	State Summary Document	Yearly	2011-2013
12	Local Climatological Data (LCD) NOAA		Common	A monthly NOAA summary from major airport weather stations that includes a daily account of temperature extremes, degree days, precipitation and winds. Also included are the hourly precipitation and abbreviated 3-hourly weather observations.	Access Database by Station	Monthly	2011-2013
13	Cooperative Weather Observer/Other Sources		Common	Hourly precipitation amounts obtained from recording rain gages located at National Weather Service, FAA, and cooperative observer stations which includes inches to tenths at local standard time; includes maximum precipitation for nine time periods for some stations; these data are final quality controlled copy and have a 4 to 6 month time lag. National Climactic Data Center Storm Event data which includes storm events by county including tornadoes, thunderstorm winds, and hail. Clarus data where available. Weather Underground (personal weather station information) data if available including (daily high/low/avg; Temp(F), Dew Point(F), Humidity(%), Sea Level Pressure (in), Visibility (mi), Wind (mph), Precip (in).	Access Database by Station	Monthly	2011-2013
14	Winter Road Conditions (DOT)	2	Common	Winter Travel Advisory by road segment and time. When available this will include roadway and segment limits; Roadway Status (clear, wet, snow, ice, severe, closed); Pavement Condition; Weather Condition; and date/time of last update	GIS Statewide	Yearly	2011-2013
15	Work Zone		Common	Data including location, limits, time period, and if available the impact to travel (minimal, moderate, severe).	GIS Statewide	Yearly	2011-2013
16	511 Information		Common	Includes Incidents/closures; Weather/Alerts; Winter Weather Operations and Advisories; Special Events; Bridge and Tunnel Status; Construction; Travel Speeds (e.g. <30mph, 30-49mph, >50mph) where available.	GIS Statewide	Yearly	2011-2013
17	Traffic Data-Continuous Counts (ATR)		Safety	Continuous count data from permanent equipment which operates 365 days a year.	GIS Statewide	Yearly	2011-2013
18	Traffic Data-Short Duration Counts		Safety	Short count data from portable equipment which typically operates from 2 days to 7 days. These counts usually vary in frequency per location from every year to up to 5 years in between counts.	GIS Statewide	Yearly	2011-2013
19	Changes to existing infrastructure condition		Safety	Data documenting changes to infrastructure condition such as overlays or replacements that improve condition without adding capacity or changing geometry.	GIS Statewide	Yearly	2011-2013
20	Roadway Capacity Improvements		Common	Data documenting major operational and capacity enhancements such as additional lanes, intersection treatments, traffic control, traffic signalization, reversible lanes, designated lanes, roundabouts, etc.	GIS Statewide	Yearly	2011-2013

Figure D.12. Final list of supplemental data acquired.

APPENDIX E

Quality Assurance Process

The quality assurance process was a continuous task to ensure that quality data were collected by the mobile data vendor. Random sites, control sites, and a curve analysis were used to evaluate the accuracy of the data. This appendix provides, as an example, an overview of the postprocessing of the quality assurance plan for one of the NDS sites (Pennsylvania) and for one of the data collection years (2013). Similar processes were used on all the data collected by the mobile data collection vendor.

From a geographic information system (GIS) perspective, all roadway features are represented with individual GIS data layers. The resulting data set is essentially a set of overlaid data layers. Figure E.1 presents a roadway segment with SHRP 2 Roadway Information Database (RID) roadway features. While some roadway features are point features, such as signs and intersections, some are longitudinal (segment) features, such as shoulders and lanes. Random site data points collected by the team are points with all available roadway data attributes at that location. For example, data collection at point A in the figure would provide lane (type and width), shoulder (type and width), grade, cross slope, rumble strip, and lighting data. These data would then be linked to the GIS data layers from S04B vendor data during postprocessing.

Before each site visit, a field preparation procedure was followed in-house by the project team. The procedure consisted of preparation of maps (GIS maps for the data collection device and hard copies for the team), data collection equipment, and initial routing. Initial routing helped the team broadly identify areas to cover each day and the most efficient route.

After site visits, collected data were submitted to the analysis team, and postprocessing began. Typically, 130 to 200 data points were collected at the site visits. Through a custom-made ArcGIS toolbox and scripts (Figure E.2), random data site points were matched to RID roadway-feature data layers. One roadway feature per layer was assigned to a random point, except for rumble strips and lighting since they are linear segment and not point data. These two layers assigned two features if present on both sides of the roadway. The ArcGIS toolbox also had an ambiguity and review feature, which notified the team during the accuracy analysis to investigate the roadway feature further. Ambiguity occurred when the random point was at the intersection of two lines, and the additional review occurred when the user was unsure about which feature to select. These data sets were then processed to create comparison data sets for each roadway feature.

The roadway features and comparison criteria were as follows:

- Intersections (location, type, number of approaches, control type);
- Signs (MUTCD code, speed limit value, image);
- Highway lighting (presence);
- Lanes (type, width);
- Medians (presence, type);
- Shoulders (type, width);
- Rumble strips (presence, type);
- Location (grade and cross-slope values); and
- Barriers (barrier type, start/end treatment type, post material, rub rail).

Accuracy requirements for length and location of features are presented in Table E.1.

For each roadway feature, charts presenting whether the vendor data were correct in attribute match (e.g., lane type) and met accuracy requirements (e.g., location of a vendor speed sign in allowable distance from the site data point) were prepared (Figure E.3 to Figure E.15). For identified problems, data collection video log files were reviewed. After this refinement, results were communicated to the S04B team. Described below are the steps for the roadway features' quality assurance for the random and control sites. The control site charts have multiple comparisons to the mobile data, which accounts for the separate trips through the control site by different units.

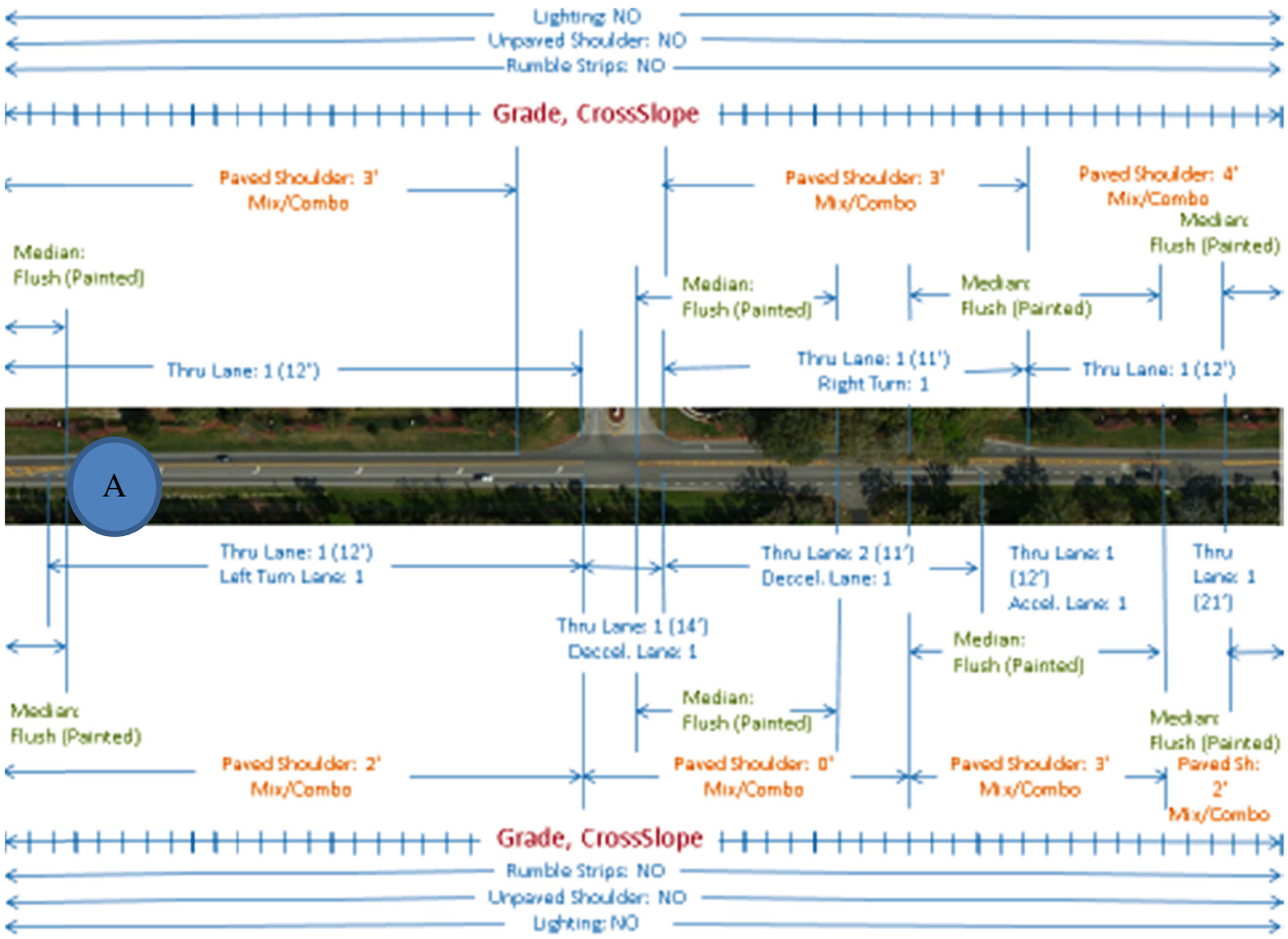


Figure E.1. S04B roadway features on a road segment.

The first step in the process was to verify coverage of all random site points. Location data were present every 21 ft and were located on every data collection route. All points were verified to have location data, even when no grade or cross-slope data were collected. The grade and cross slope were then compared to the location data to determine the differences between the random site data collected and the mobile data. These can be seen in Figure E.3 through Figure E.5.

Intersections were then checked for accuracy requirements. The intersection is represented as a point and should be located along the side of the road in "direction 5" (i.e., the primary or cardinal direction of travel). It was first verified that all intersections were identified as part of the mobile data collection.

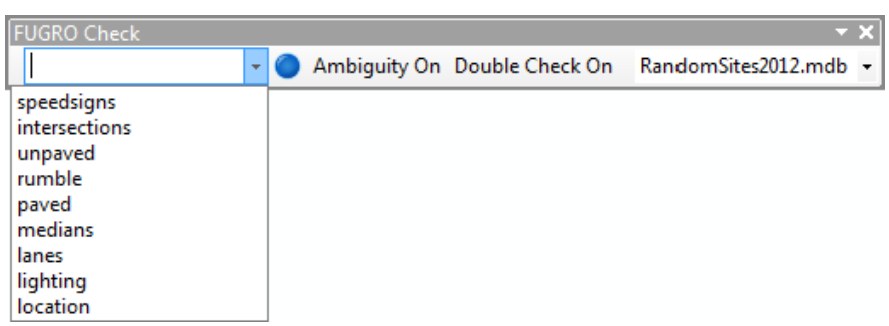


Figure E.2. GIS module to link data.

Table E.1. S04B Data Accuracy Requirements

Data Element	Accuracy Requirement
Curvature radius	100 ft (curves less than 1,500 ft radius) 250 ft (curves between 1,500 ft and 6,000 ft radius) Within 13% (curves over 6,000 ft radius)
Curvature length	100 ft (curves less than 1,500 ft radius) 200 ft (curves above 1,500 ft radius)
PC	50 ft
PT	50 ft
Grade (+ or –)	1.0%
Cross slope/superelevation	1.0%
Lane width	1 ft
Paved shoulder width	1 ft
Inventory features (signs) location	7 ft

The intersection point from the mobile data had to be within 150 ft of the random/control site point. The final check was whether the number of approaches was correct, as well as the control type (Figure E.6).

The other point features from the mobile data collection were signs. The signs were separated into speed signs and all other signs, because each possesses different attributes. The presence of all signs within the mobile data were verified, as well as whether the signs were within 7 ft of the random/control site point. Speed signs were evaluated for the accuracy of the speed limit text and the classification of regulatory and advisory sign types (Figure E.7). The MUTCD code and sign text of the remaining signs were evaluated for accuracy (Figure E.8).

As discussed in Chapter 6, when running the script to join the reference field data collected and the mobile data, only one roadway feature from each layer was associated to a random/control point. The exceptions were highway lighting and rumble strip data. If present, these features had segments selected on both sides of the roadway for comparison. Highway lighting was represented on both sides of the roadway, if present, and the indication was confirmed (Figure E.9). Rumble strips on both sides of the lane were classified as a set. The presence of rumble strips was also confirmed (Figure E.10).

The linear features, medians, guardrail, and lanes were all checked individually to verify correct classification (Figure E.11 through Figure E.13). Medians were first evaluated for presence. Of the medians that were present, the type of median was evaluated for accuracy. Guardrails were also evaluated for the accuracy of the start and end treatments, the type of guardrail, whether a rub rail was present, and the post material. The lanes data were first evaluated for the accuracy of the width. The widths were assessed based on the required 1 ft accuracy. The number of lanes was then compared, as well as the classification of the lane types.

Shoulders were separated into paved and unpaved shoulders (Figure E.14 and Figure E.15). Both shoulder types were evaluated together as part of the quality assurance process. The indication of paved or unpaved shoulder was first verified for accuracy. The type of shoulder for both the unpaved and paved

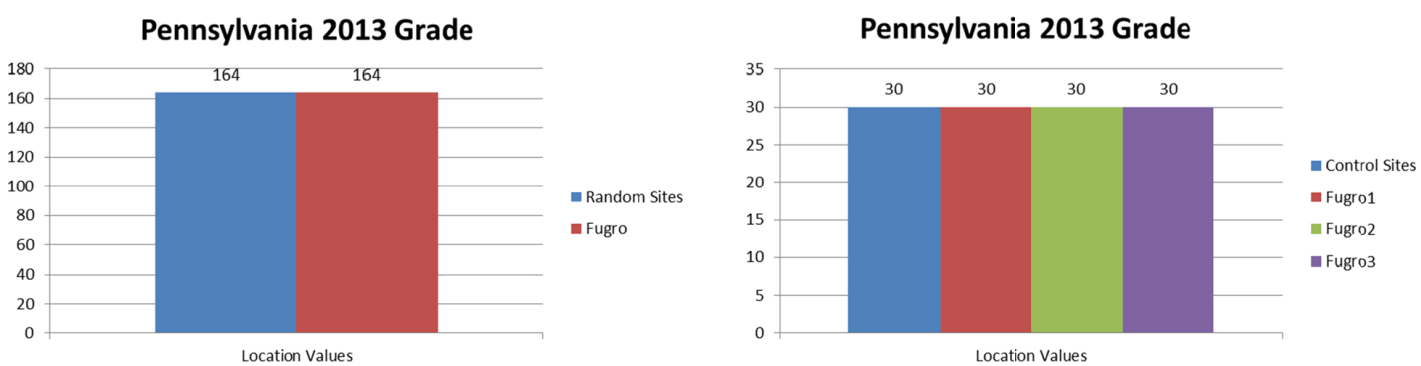


Figure E.3. Pennsylvania 2013 grade random and control site chart (location).

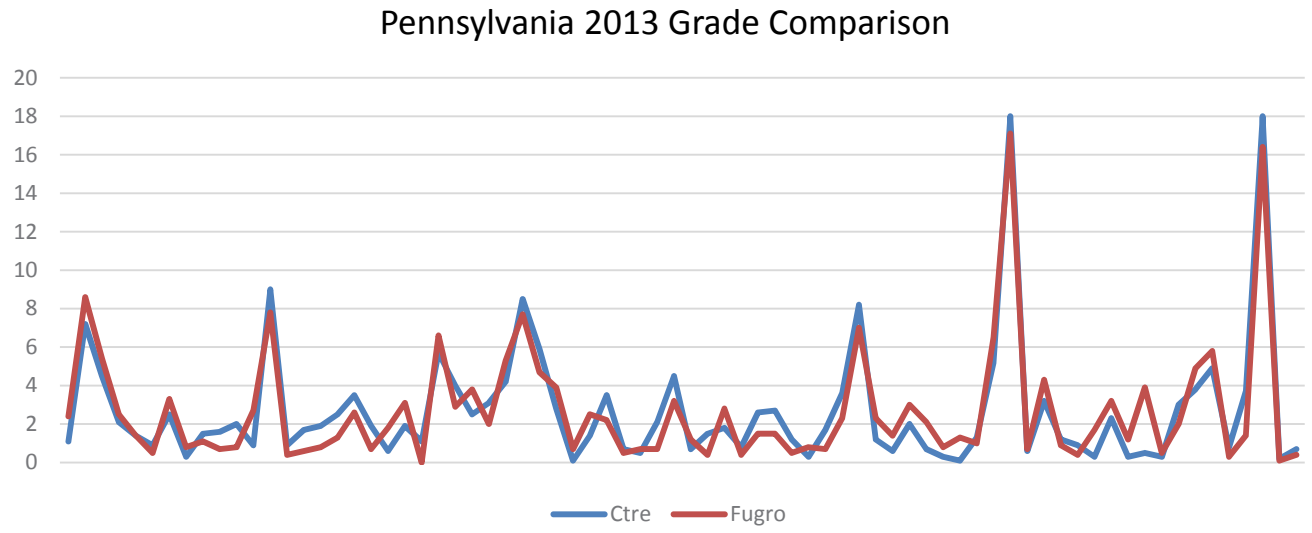


Figure E.4. Pennsylvania 2013 random site grade comparison.

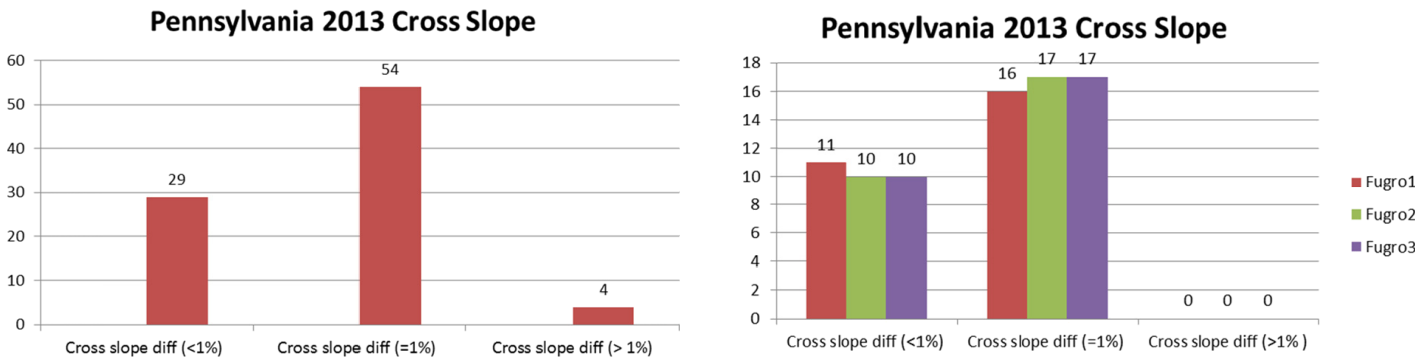


Figure E.5. Pennsylvania 2013 cross slope random and control site charts.

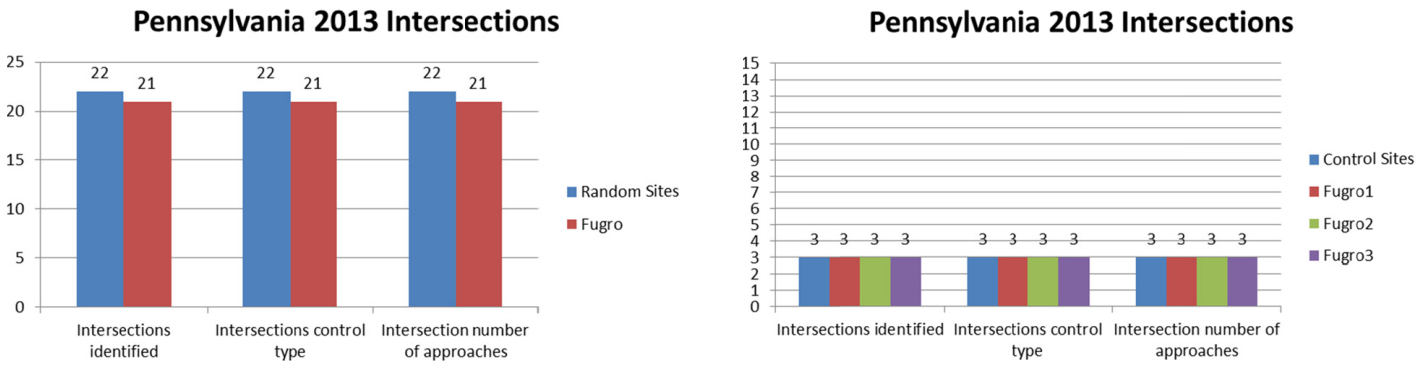


Figure E.6. Pennsylvania 2013 intersection random and control site charts.

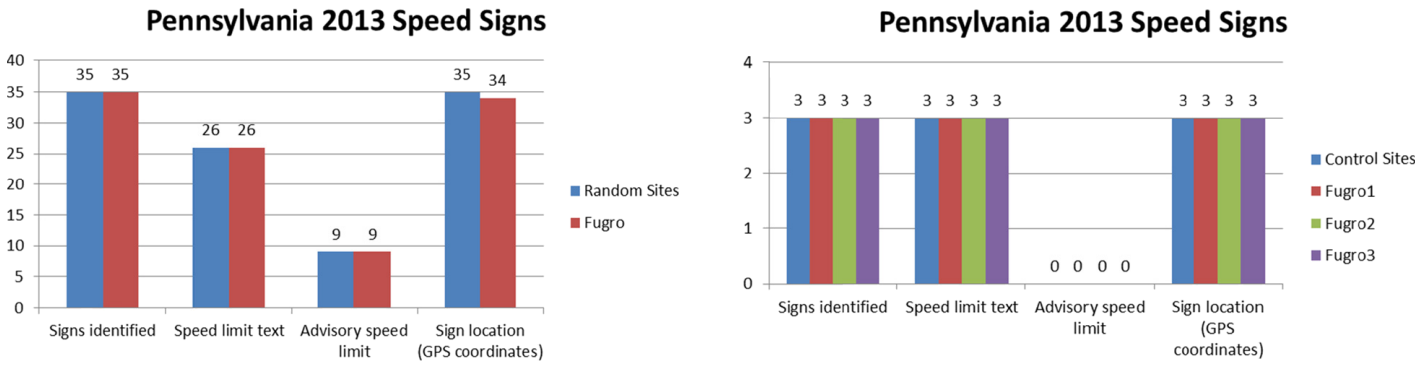


Figure E.7. Pennsylvania 2013 speed signs random and control site charts.

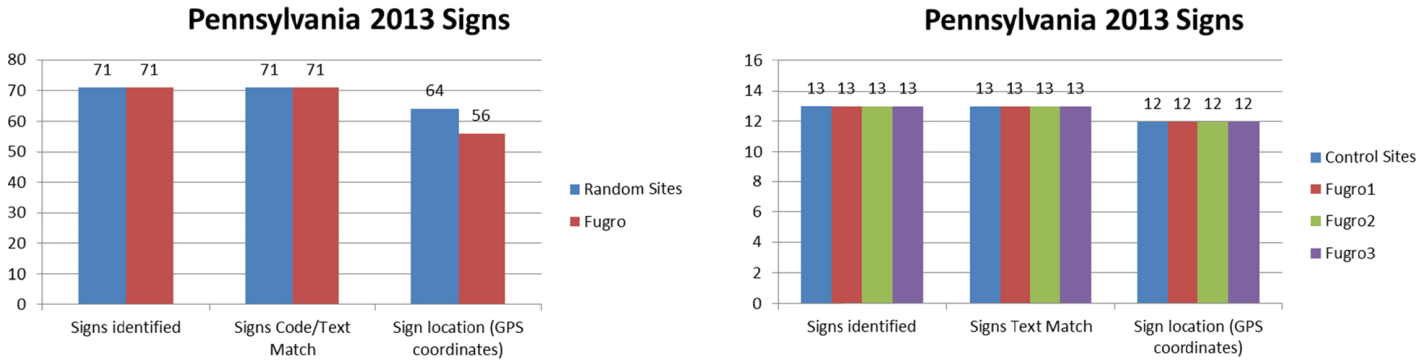


Figure E.8. Pennsylvania 2013 signs random and control site charts.

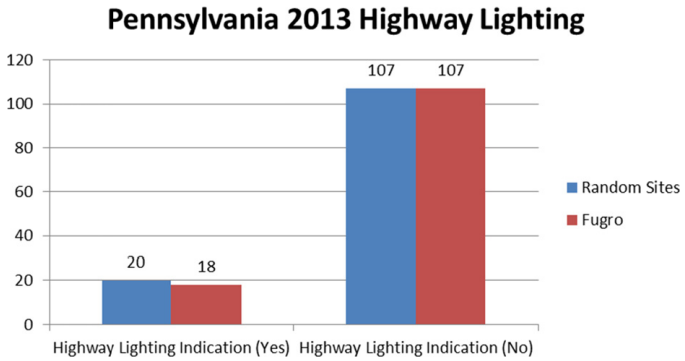


Figure E.9. Pennsylvania 2013 highway lighting random site chart.

shoulders was then checked. The paved shoulders required an additional step to evaluate the width. No widths were collected as part of the unpaved shoulder data.

For the control sites, mobile-collected curve point of curvature (PC), point of tangency (PT), radius, and length were compared to the corresponding department of transportation–provided alignment attributes. Random curve evaluation required a separate process, because these data could not be accurately found in the field data set. The process used GPS traces from the mobile data collection to measure the radius of curves. By selecting points within a curve, the length of curve and the chord of the curve were calculated. Using these values, the curve radius could accurately be calculated and compared to the mobile vendor radius values.

The GPS trace points were provided at 21 ft intervals along the roadways collected. The research team plotted these points in Esri ArcGIS, along with select points within random curves across the entire network (Figure E.16). An equal proportion of curves in the ranges of less than 1,500 ft, 1,500 ft to 6,000 ft, and greater than 6,000 ft were selected. Because the radius of the curve was not known when selecting the curve, multiple iterations were completed until the desired number of curves was found in each range.

Once the points were selected, a polyline was created by joining the GPS traces of the curve. From this polyline, the length of curve and chord of the curve were determined. The radius of the curve was derived from these values and spatially joined to the respective mobile data curve. Figures E.17 to E.19 show the results after the comparison of the radii were completed. Any curves that were identified as problems were further evaluated for discrepancies.

This concluded the quality assurance process. Any confirmed errors were reported in detail and provided to the contractor to address the issues with the data. Any identified problem was remediated through correction in post-processing of the data or, in rare occasions, re-collection of the data. The majority of the corrections took place during the pilot phase of the data collection.

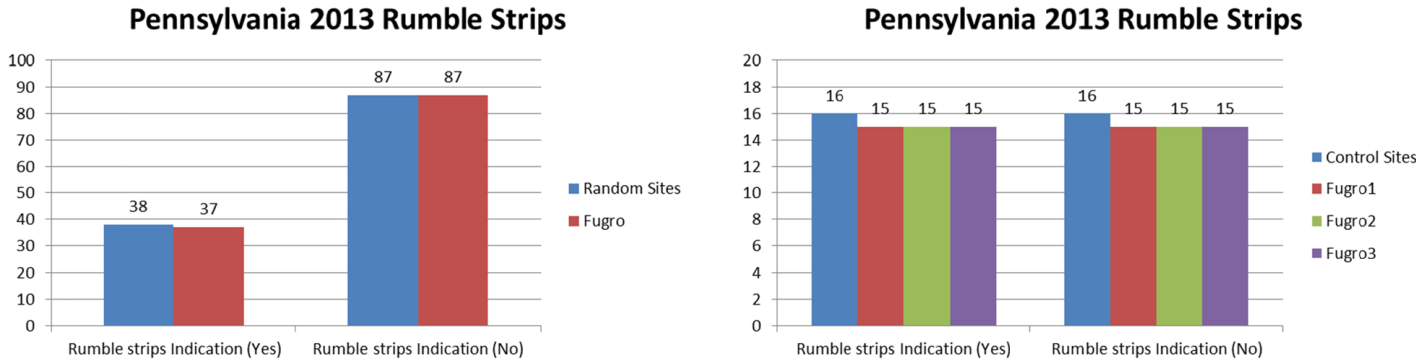


Figure E.10. Pennsylvania 2013 rumble strips random and control site charts.

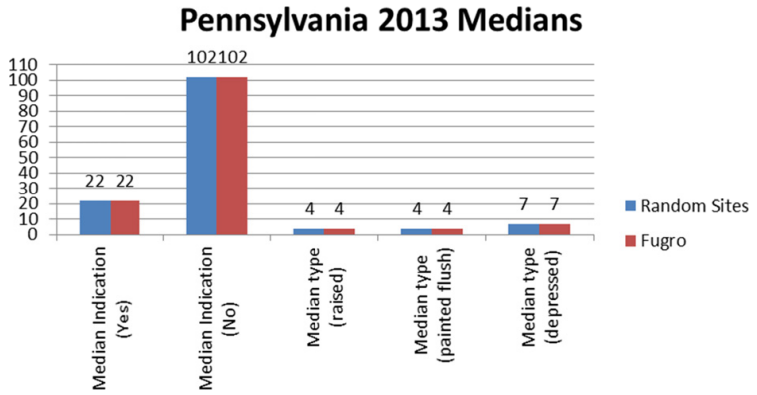


Figure E.11. Pennsylvania 2013 medians random site chart.

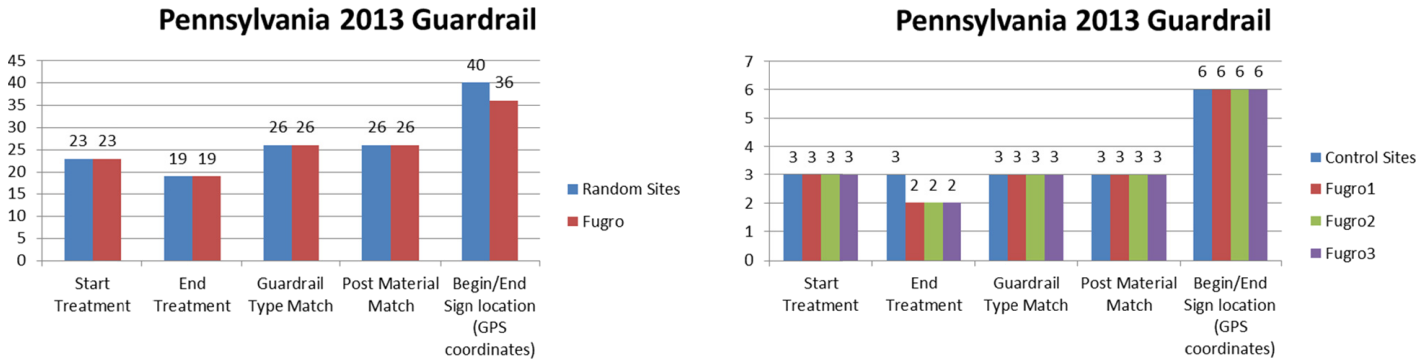


Figure E.12. Pennsylvania 2013 guardrail random and control site charts.

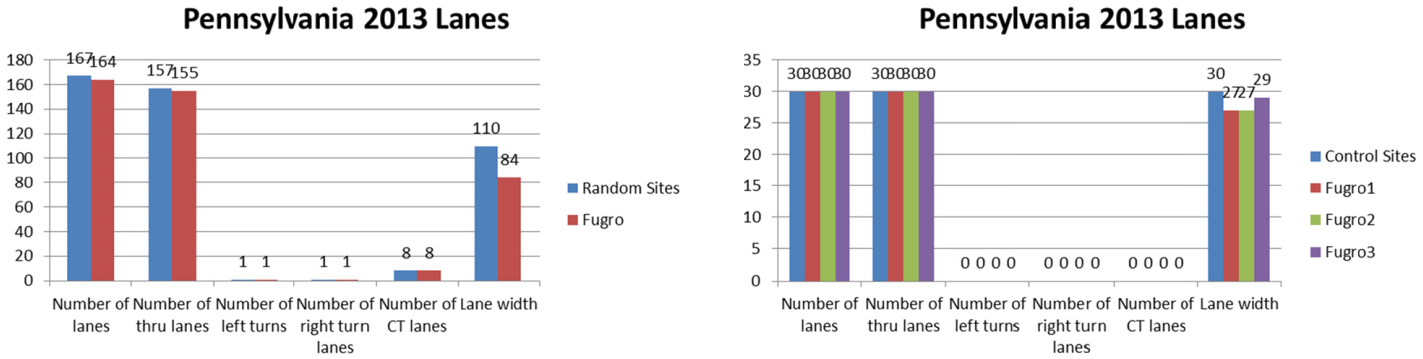


Figure E.13. Pennsylvania 2013 lanes random and control site charts.

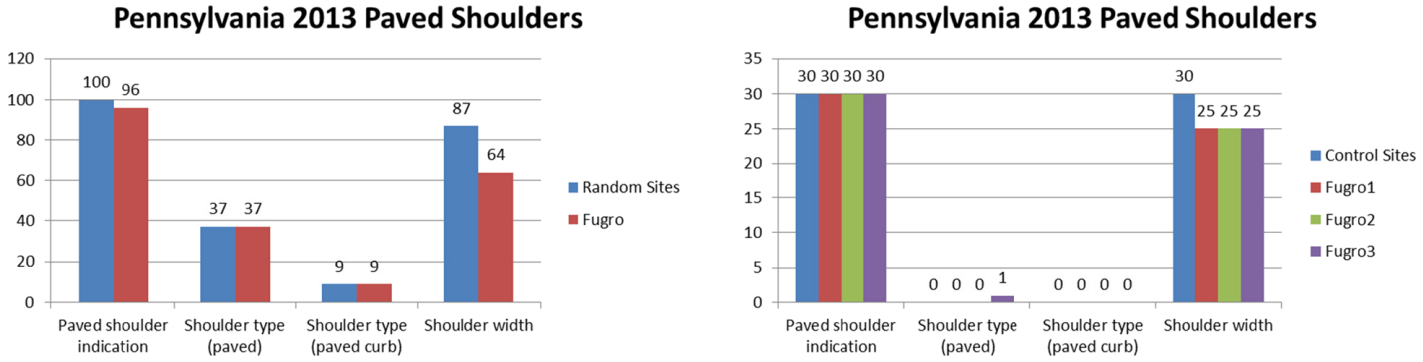


Figure E.14. Pennsylvania 2013 paved shoulder random and control site charts.

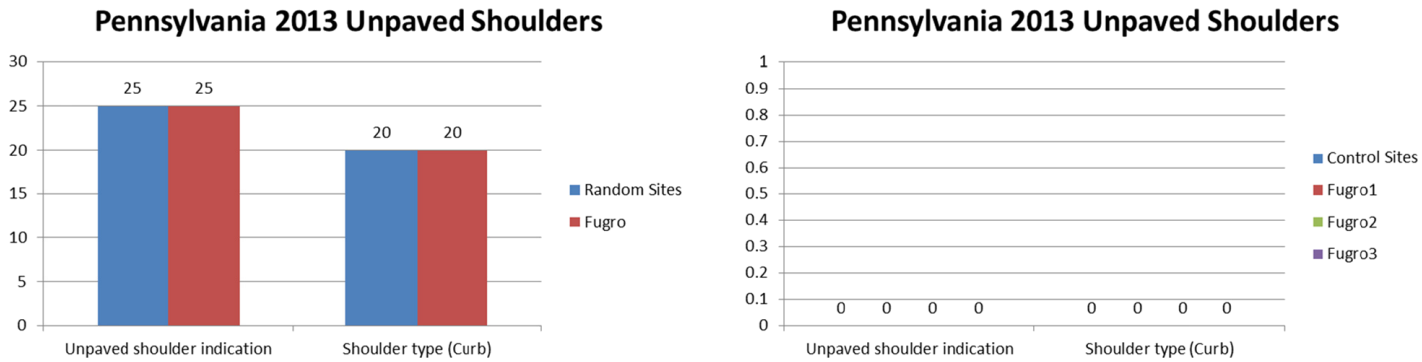


Figure E.15. Pennsylvania 2013 unpaved shoulder random and control site charts.

Figure E.16. Selection of GPS traces for curve.

CTRE.Radius <= 1500 ft.

For 2 of 63 observations (3%) |CTRE.Radius-Fugro.Radius|>100 ft.

<=1500	63	
ABS DIFF <=100 FT	61	96.8%
ABS DIFF >100 FT	2	3.2%

FKEY_1	ROUTE	DIRECTION	FUGRO RADIUS	CURVE2	CTRE RADIUS	DIFFERENCE IN RADIUS (C-F)
21175	US 30	6	1079	6123	972.900286	106
10402	US 30	5	1120	5123	1014.70728	105

Figure E.17. Pennsylvania 2013 radius range of less than 1,500 ft.

1500 ft. < CTRE.Radius < 6000 ft.

For 8 of 181 (4%) observations |CTRE.Radius-Fugro.Radius|>250 ft.

1500<CR<6000	181	
ABS DIFF <=250 FT	173	95.6%
ABS DIFF >250 FT	8	4.4%

FKEY_1	ROUTE	DIRECTION	FUGRO RADIUS	CURVE2	CTRE RADIUS	DIFFERENCE IN RADIUS (C-F)
14018	I 80	6	5768	6014	4538	1230
17911	PA 550	6	2843	6044	1934	909
11211	US 522	5	2873	5052	2506	367
9460	US 22	5	3858	5042	4189	331
2837	I 83	5	6117	5082	5822	295
10239	US 220	5	2270	5025	2538	268
20826	US 220	6	2325	6025	2588	263
13556	I 180	6	5794	6145	5534	260

Figure E.18. Pennsylvania 2013 radius range of 1,500 ft to 6,000 ft.

CTRE.Radius > 6000 ft.

For 8 of 69 curves (12%), the absolute difference between the radii is greater than 13% of CTRE.Radius

FKEY_1	ROUTE	DIRECTION	FUGRO RADIUS	CURVE2	CTRE RADIUS	DIFFERENCE IN RADIUS (C-F)	13%(CTRE.R)	>6000 FT PROBLEM?
2890	I 99	5	23302	5111	13638	9664	1773	Problem
13857	I 80	6	11680	6144	15340	3660	1994	Problem
2492	I 80	5	6065	5144	9606	3541	1249	Problem
2000	I 70	5	11610	5127	14201	2591	1846	Problem
21042	US 220	6	12781	6156	15215	2434	1978	Problem
9962	US 220	5	11761	5105	10130	1631	1317	Problem
21025	US 220	6	8775	6147	7481	1294	973	Problem
21110	US 220	6	7321	6101	8593	1272	1117	Problem

Figure E.19. Pennsylvania 2013 radius range of greater than 6,000 ft.

APPENDIX F

Roadway Information Database Operating Procedures

The Roadway Information Database (RID) was built on an underlying, route-measure-based linear referencing system (LRS). Other roadway features, such as those identified in S04B, have been conflated to this LRS and are represented as individual features within an Esri ArcGIS geodatabase. Each feature also possesses corresponding LRS-based route and measure values. Therefore, the RID supports both attribute- and spatial-based queries, as well as dynamic segmentation. Dynamic segmentation may be used to overlay multiple, independently maintained, and disparate data sets to identify locations satisfying specific conditions. Below is a step-by-step example of how the process can be used to answer a research question.

The research objective for this example is to identify rural, two-lane horizontal curves in North Carolina with shoulder widths less than 6 ft. (This was completed before the final miles in North Carolina were collected in 2013.)

F.1 Step 1: Identify Data Needed

Identify the data sets necessary to satisfy the objective. The following are the required data sets and corresponding sources:

- Two-lane roads: S04B Lane data.
- Shoulder width: S04B Shoulder data.
- Horizontal curves: S04B Alignment data.
- Rural areas: U.S. Census urban area boundaries data.

F.2 Step 2: Select Two-Lane Highways

The S04B lane data provide the number of lanes and lane types for all roadways collected in both directions. This step uses an attribute-based query to select only two-lane roads.

1. Import S04B Lanes data.
2. Open the selection tool Select By Attributes.
3. Use the query shown in Figure F.1, which uses the ThroughLanes, LeftTurnLanes, and RightTurnLanes attributes from the S04B Lanes data.
4. Right-click on the S04B Lanes layer, select Data, select Export Data . . .
5. Export the selected lanes as TwoLaneHighway.shp (Figure F.2). This shapefile is used in Step 6.

Because the S04B data are collected in both directions, a value of one for ThroughLanes would select any two-lane roadways. The LeftTurnLanes and RightTurnLanes attributes were used to remove any locations with turn lanes.

F.3 Step 3: Select Shoulders Less Than 6 ft

The S04B Shoulder data provide shoulder type and width for all roadways collected. This step uses an attribute-based query to select shoulders that have a width less than 6 ft.

1. Import S04B Shoulder data.
2. Open the selection tool Select By Attributes.
3. Use the query shown in Figure F.3, which uses the Width attribute to select shoulders that are less than 6 ft.
4. After the selection, right-click on the S04B Shoulder layer, select Data, select Export Data . . .
5. Export the selected shoulders as ShoulderLessThanSix.shp (Figure F.4). This database file is used in Step 7.

The S04B Shoulder data provide the shoulder width as part of the Width attribute. A “less than” query was used because the research objective is to find all shoulders less than 6 ft.

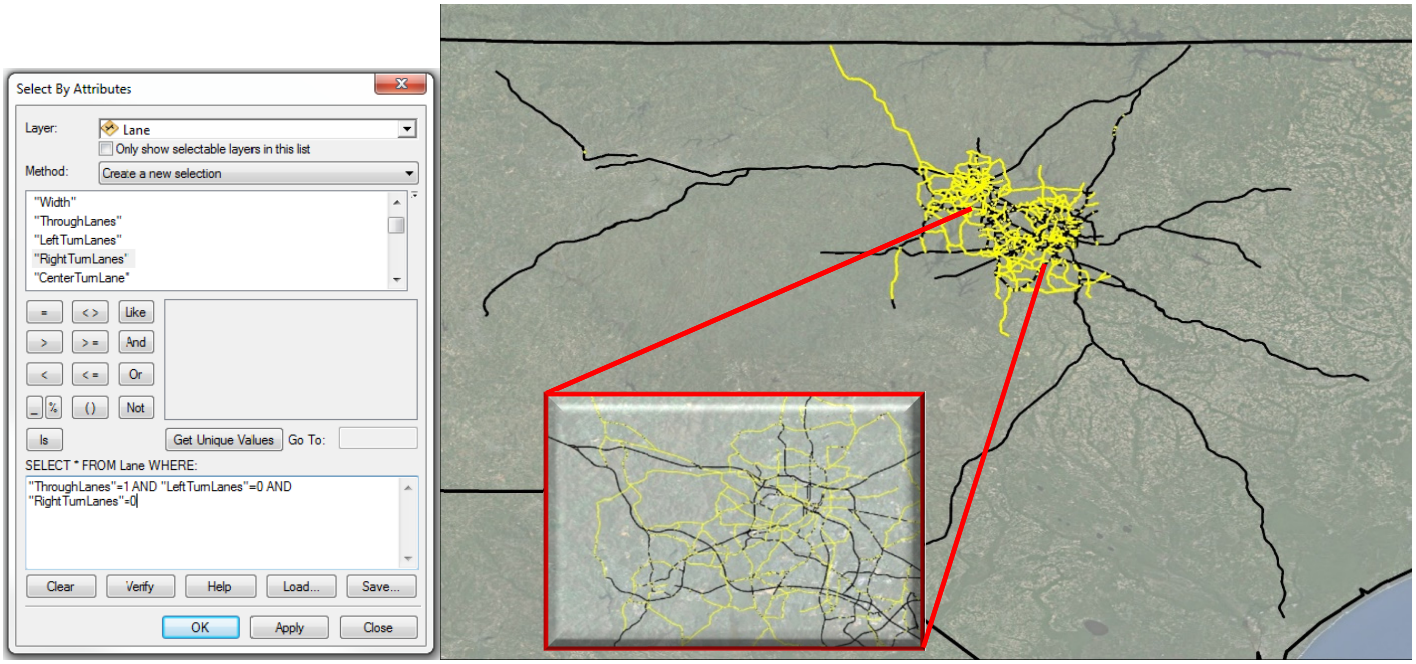


Figure F.1. Query to select two-lane highways.

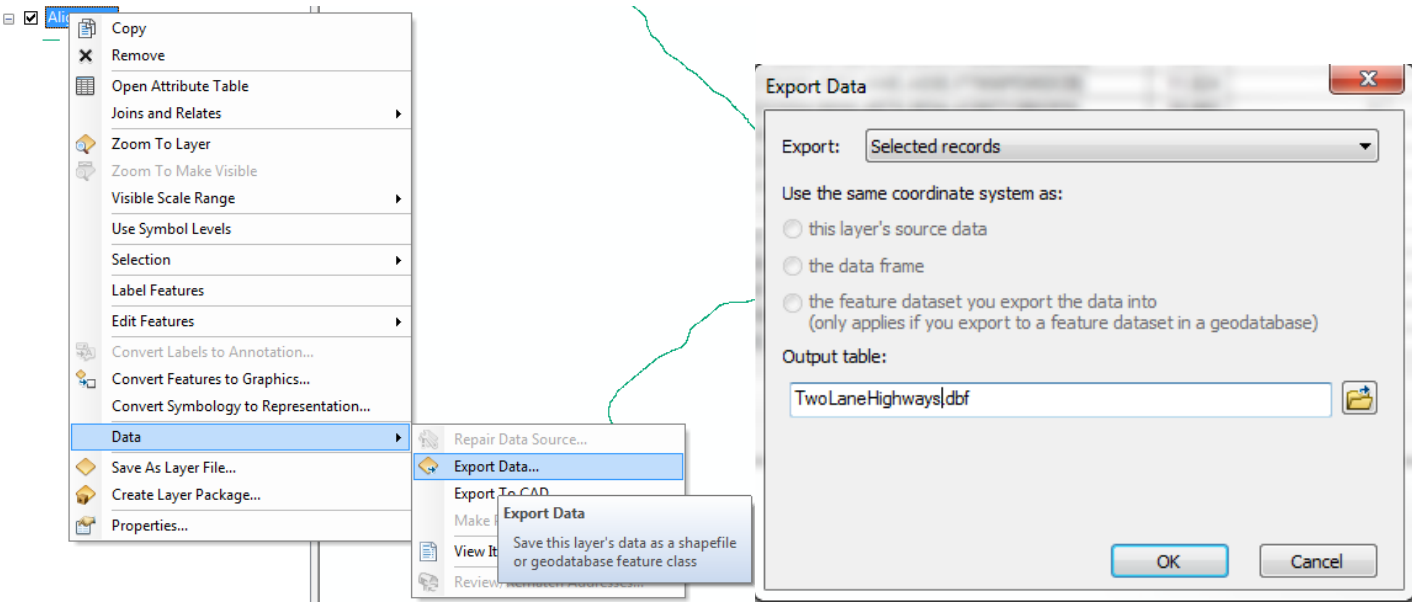


Figure F.2. Export selected two-lane highways.

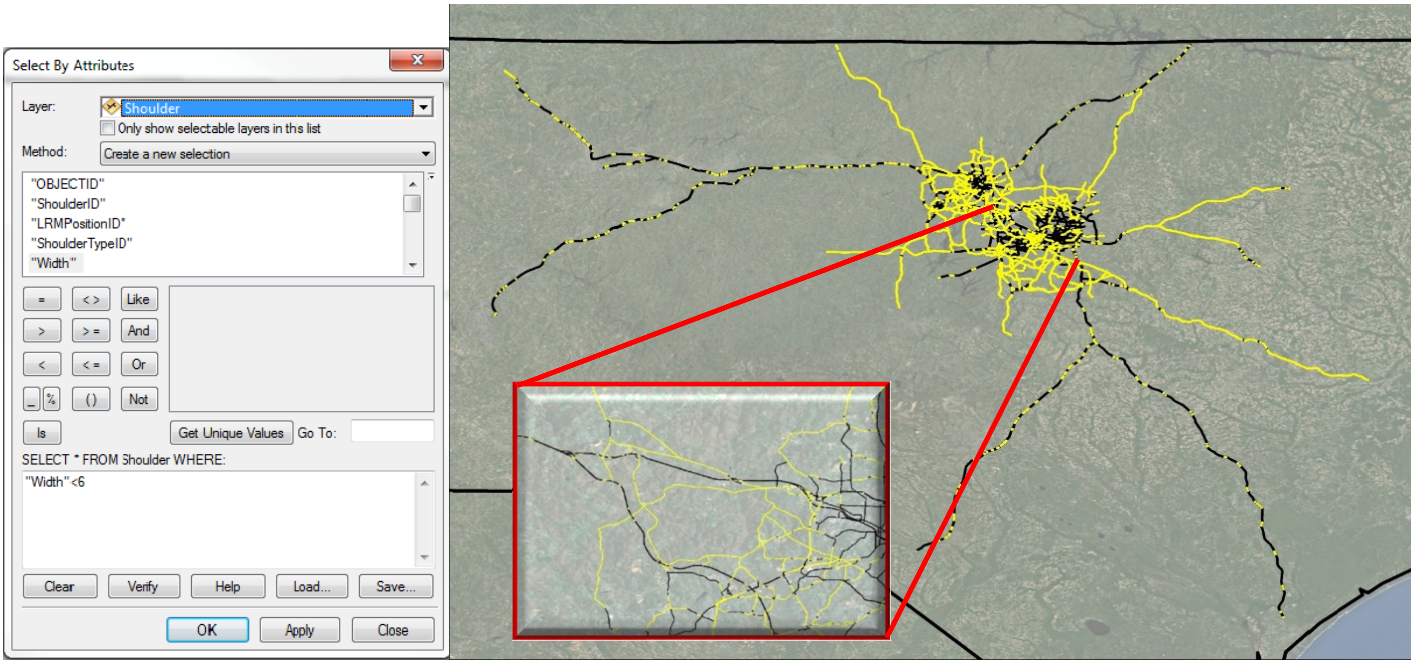


Figure F.3. Query to select shoulders less than 6 ft.

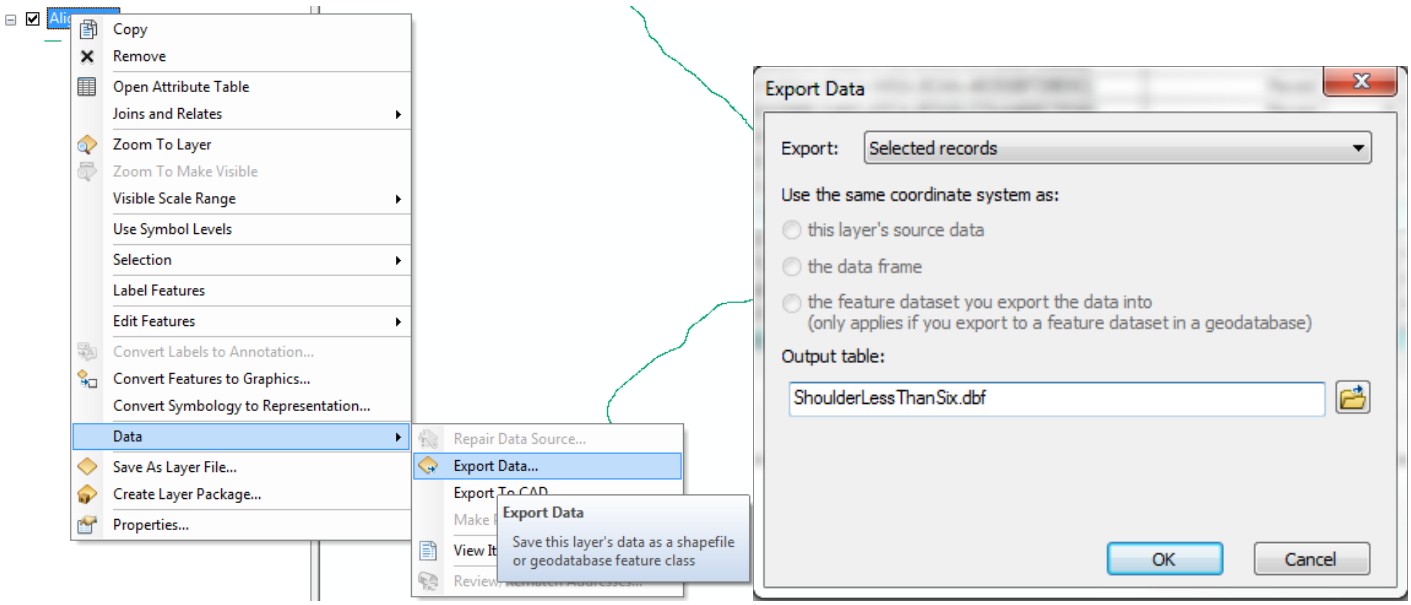


Figure F.4. Export shoulder less than 6 ft.

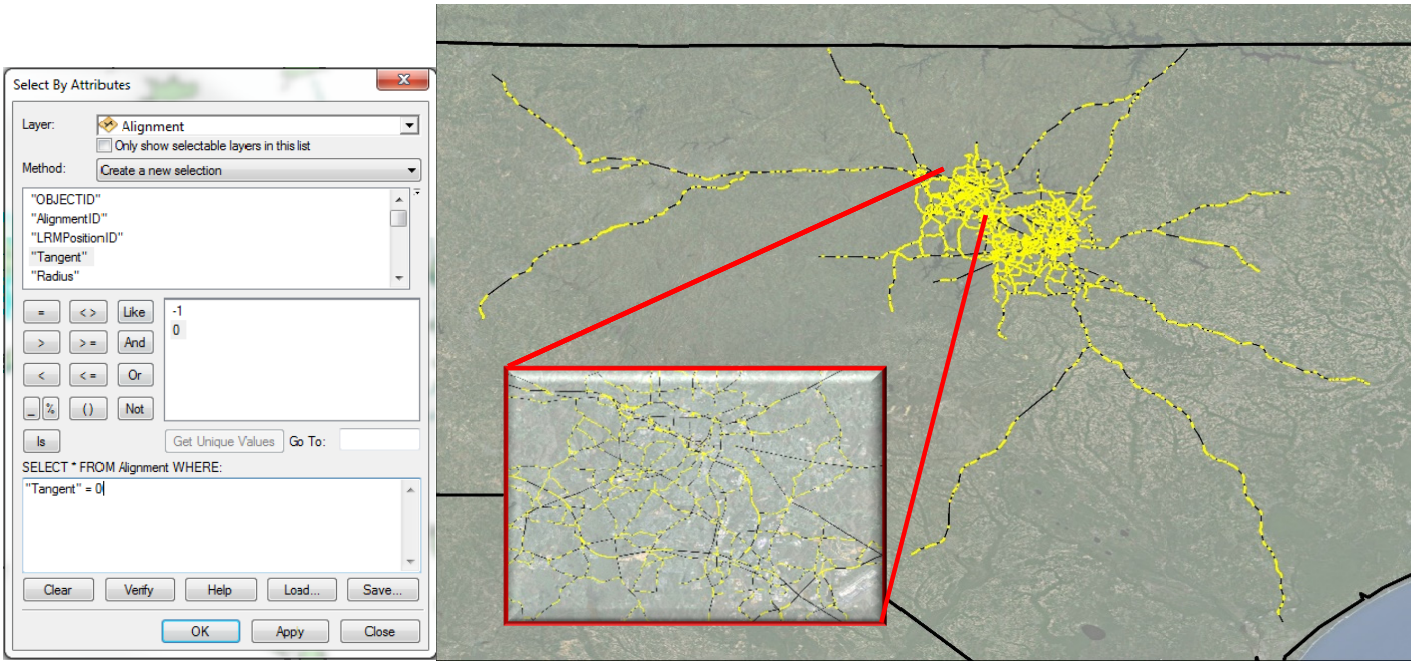


Figure F.5. Query to select curves.

F.4 Step 4: Select Curves

The S04B Alignment data define whether a roadway is a tangent or curve, along with the radius of the curve. This step again uses an attribute-based query to select the curve from the S04B Alignment data.

1. Import S04B Alignment data.
2. Open the selection tool Select By Attributes.
3. Use the query shown in Figure F.5, which uses the Tangent attribute to select only the curves.
4. Right-click on the S04B Alignment layer, select Data, select Export Data . . .
5. Export the selected curves as Curves.shp (Figure F.6). This shapefile is used in Step 5.

The S04B Alignment database uses the Tangent attribute to distinguish between tangents and curves. A value of zero for

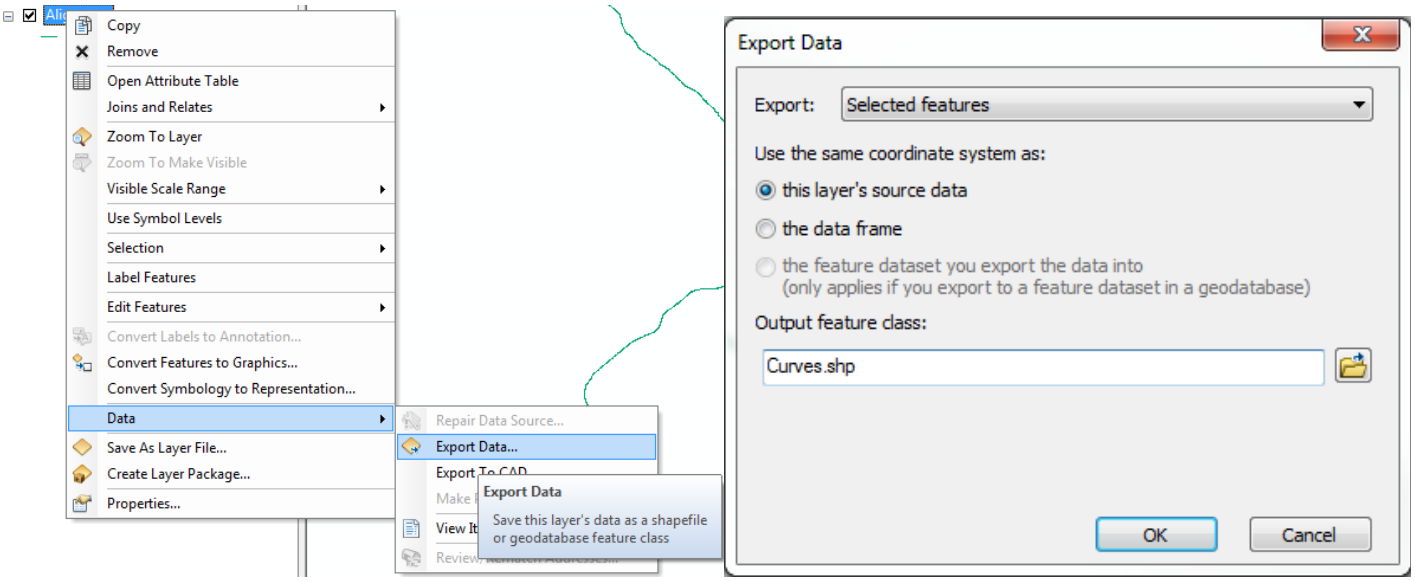


Figure F.6. Export selected curves.

this attribute is used to identify curves. The curves are reduced further in Step 5.

F.5 Step 5: Select Rural Curves

This step uses the Curves.shp created in Step 4 and the Urban Boundary from the census data to select curves located in rural areas. A spatial selection is used to select all curves within the urban boundaries.

1. Import Urban Boundary from census data and Curves.shp from Step 4.
2. Open the selection tool Select By Location.
3. Use the settings shown in Figure F.7 to use the spatial selection. This selects all the curves within the urban boundaries.
4. Because all rural curves are desired, the selection must be reversed. Right-click on the Curves layer and select Open Attributes Table.
5. Select Switch Selection ( ), which switches the selection from urban curves to rural curves.
6. The selected curves can now be exported. Right-click on the Curves.shp, select Data, select Export Data . . .
7. Export the selected rural curves as RuralCurves.shp (Figure F.8). This shapefile is used in Step 6.

F.6 Step 6: Dynamic Segmentation of Rural Curves and Two-Lane Highways

The first dynamic segmentation is completed using the Rural Curves.shp from Step 5 and the TwoLaneHighway.shp from Step 2. This step selects any locations where both attributes are present.

1. Import TwoLaneHighway.shp from Step 2 and RuralCurves .shp from Step 5.
2. Under the Linear Referencing Tools, select Locate Features Along Routes (Figure F.9).
3. To perform dynamic segmentation, use the RouteID, FrMeasure, and ToMeasure attributes from each database file, as shown in Figure F.10.
   These are part of the linear referencing system and are used to select rural curves and two-lane highways that are at the same location on the network.
4. For the Output Event Table, name the table RuralTwoLane Curve. The table created from this will be a database file that can be plotted using the linear referencing system.
5. To plot the RuralTwoLaneCurve event table created, the S04B Routes data needs to be imported.
6. Right-click on the RuralTwoLaneCurve event table and select Display Route Events . . .

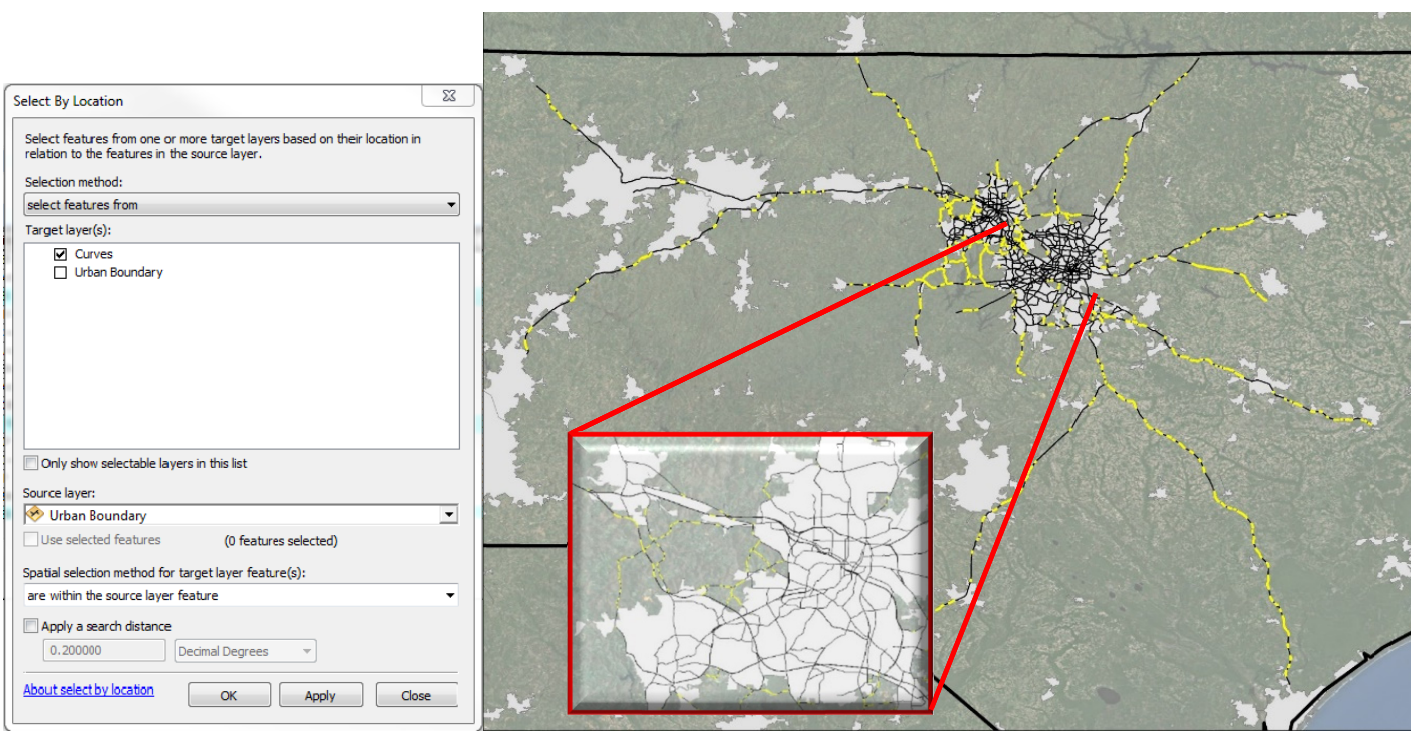


Figure F.7. Query to select rural curves.

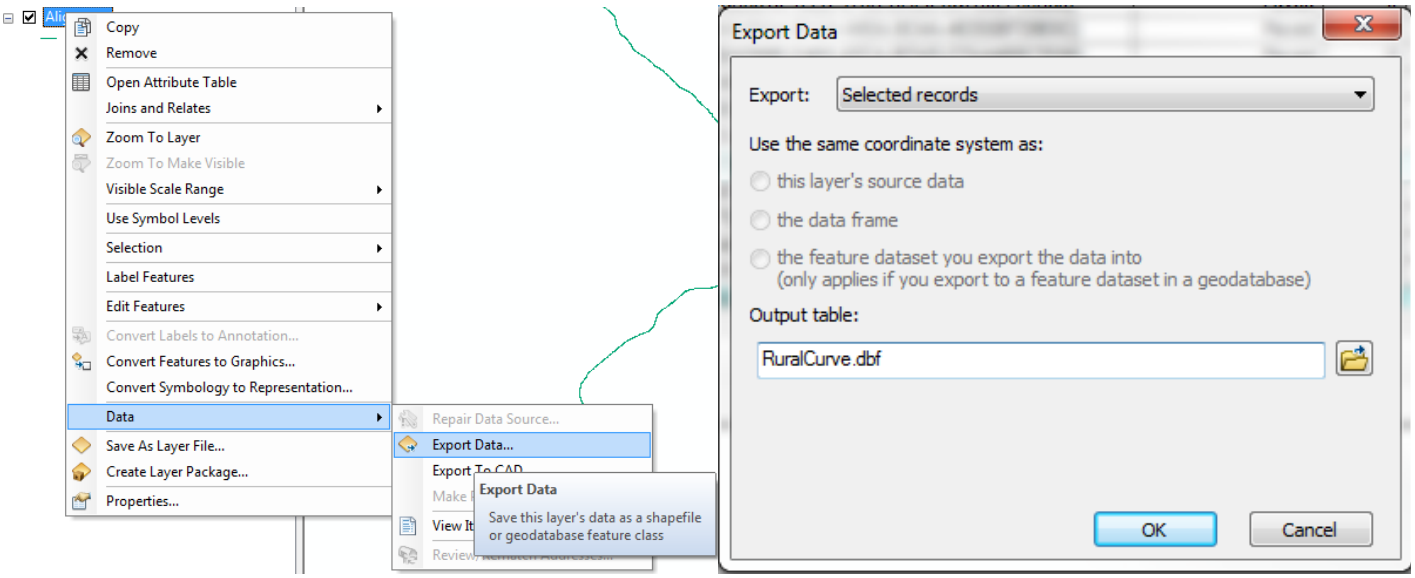


Figure F.8. Export rural curves.

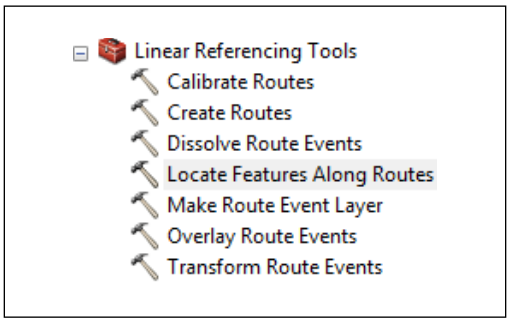


Figure F.9. Dynamic segmentation tool.

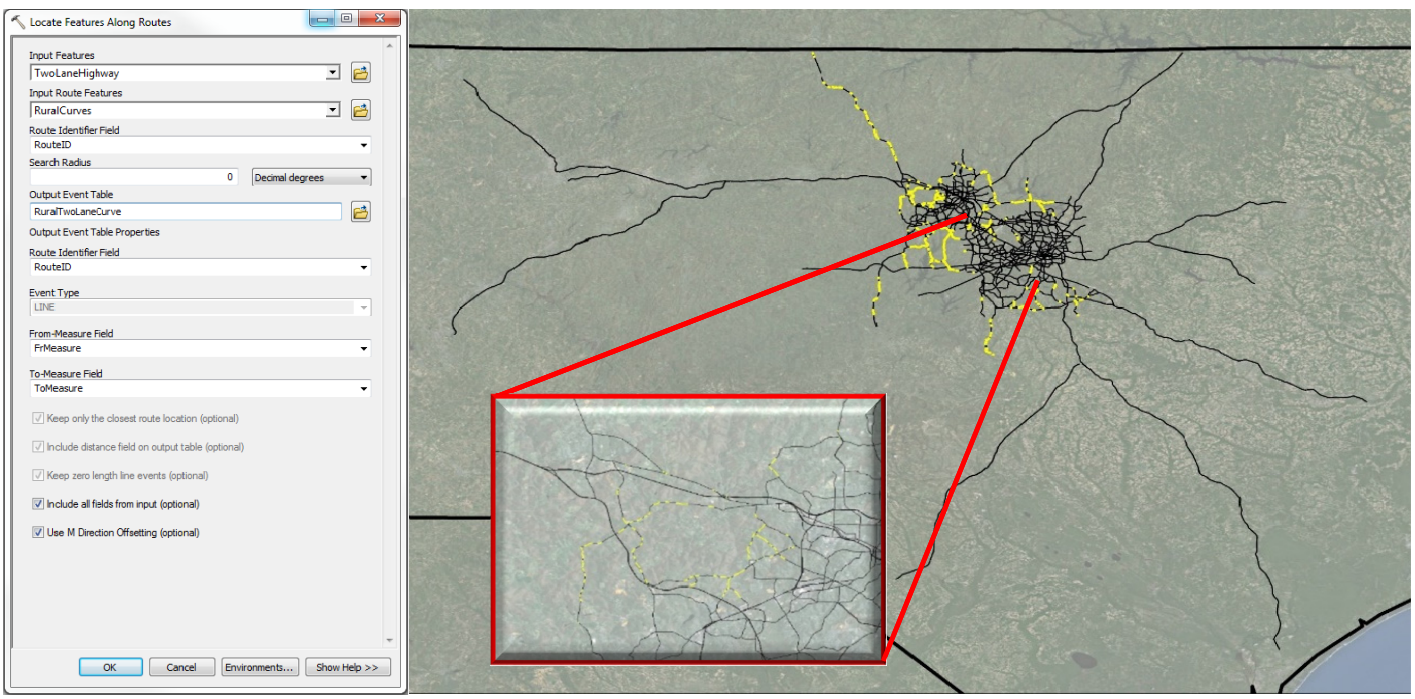


Figure F.10. Dynamic segmentation of rural curves and two-lane highways.

7. Use the selections shown in Figure F.11, which create a RuralTwoLaneCurve Events layer.
8. Right-click on the RuralTwoLaneCurve Events, select Data, select Export Data . . .
9. Export the selected rural two-lane curves as RuralTwoLane Curve.shp. This shapefile is used in Step 7.

The RuralTwoLaneCurve.shp now shows all locations where the rural curves and two-lane highway are both present. This shapefile now contains all data from both layers and can be used again for dynamic segmentation.

F.7 Step 7: Dynamic Segmentation of Rural Two-Lane Curves and Shoulders with Width Less Than 6 ft

The second dynamic segmentation uses the RuralTwoLane Curve.shp from the first dynamic segmentation in Step 6 and ShoulderLessThanSix.shp from Step 3. The same process is followed as in Step 6.

1. Import RuralTwoLaneCurve.shp from Step 6 and Shoulder LessThanSix.shp from Step 3.
2. Under the Linear Referencing Tools, select Locate Features Along Routes (Figure F.9).
3. To perform dynamic segmentation, use the RouteID, FrMeasure, and ToMeasure attributes from each database file, as shown in Figure F.12.
4. For the Output Event Table, name the table FinalCurve.
5. To plot the FinalCurve event table created, the S04B Routes data needs to be imported.
6. Right-click on the FinalCurve event table and select Display Route Events . . .
7. Use the selections shown in Figure F.11, which will create a FinalCurve Events layer.

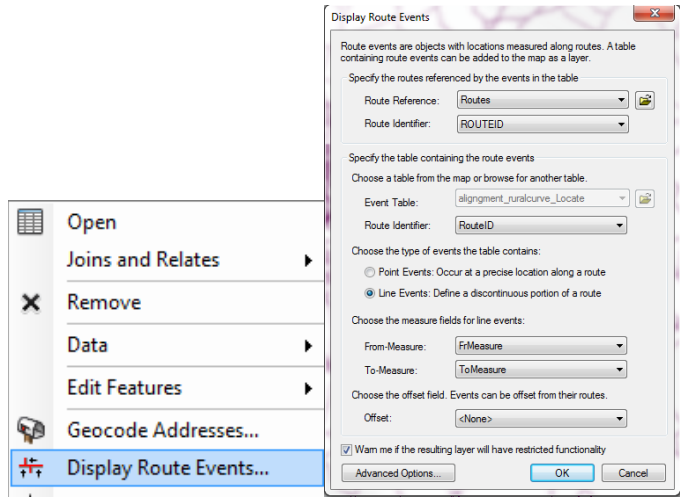


Figure F.11. Display route events.

8. Right-click on the FinalCurve Events, select Data, select Export Data . . .
9. Export the selected rural two-lane curves with shoulders less than 6 ft as FinalCurve.shp.

Exported is a layer with the final list of curves that are located in a rural area, on a two-lane highway, and with a shoulder less than 6 ft. All the attribute data from the S04B Lanes, S04B Alignment, and S04B Shoulders have been retained and included in the final layer.

These steps resulted in three reductions of the curves using three S04B data elements (Figure F.13). North Carolina originally had 8,414 curves as part of the mobile data collection, which was reduced to 854 curves of interest. The result is a layer with all locations that are on a curve, on a two-lane highway, have a shoulder less than 6 ft, and are in a rural area in North Carolina. Multiple other data elements can be used to refine the results further. Other attributes can also be used to narrow/broaden results for each data element.

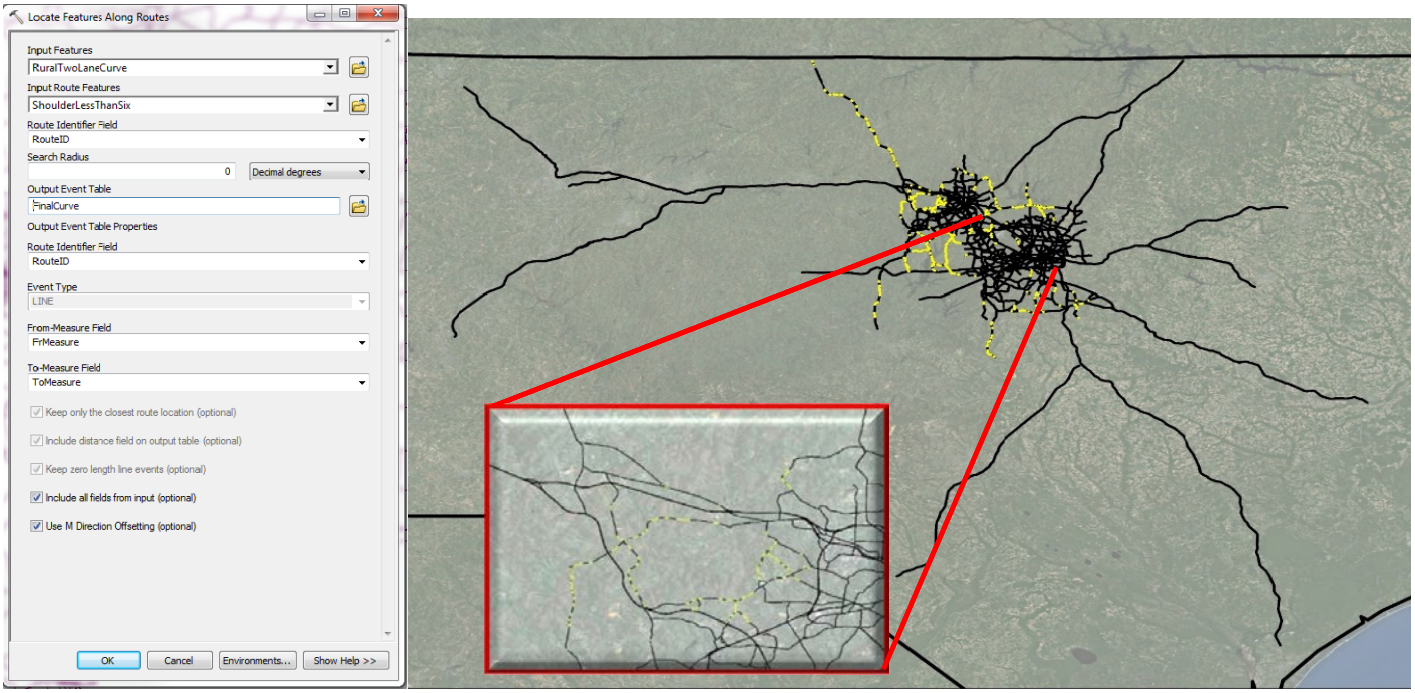


Figure F.12. Dynamic segmentation of rural curves on two-lane highways and less than 6 ft shoulder.

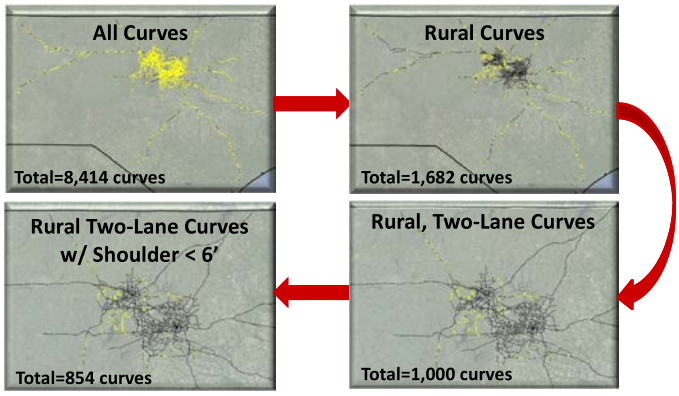


Figure F.13. Dynamic segmentation curve reduction.

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*Membership as of July 2014.

Related SHRP 2 Research

Design of the In-Vehicle Driving Behavior and Crash Risk Study (S05)

Naturalistic Driving Study: Technical Coordination and Quality Control (S06)

Naturalistic Driving Study: Collecting Data on Cell Phone Use (S06)

Naturalistic Driving Study: Field Data Collection (S07)

Analysis of Naturalistic Driving Study Data: Safer Glances, Driver Inattention, and Crash Risk (S08A)

Analysis of Naturalistic Driving Study Data: Offset Left-Turn Lanes (S08B)

Analysis of Naturalistic Driving Study Data: Roadway Departures on Rural Two-Lane Curves (S08D)

Naturalistic Driving Study: Descriptive Comparison of the Study Sample with National Data (S31)

Naturalistic Driving Study: Alcohol Sensor Performance (S31)

Naturalistic Driving Study: Linking the Study Data to the Roadway Information Database (S31)