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Usage Guidelines of SHRP 2 Naturalistic Driving Study Data for Nevada

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Disclaimer

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USAGE GUIDELINES OF SHRP 2 NATURALISTIC DRIVING STUDY DATA FOR NEVADA

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1. EXECUTIVE SUMMARY

The second Strategic Highway Research Program (SHRP 2) has sponsored a naturalistic driving study (NDS) with its central goal of addressing driver performance and behavior in traffic safety. In this SHRP 2 NDS, participants were recruited from six sites across the United States, including Bloomington, Indiana; Central Pennsylvania; Tampa Bay, Florida; Buffalo, New York; Durham, North Carolina; and Seattle, Washington. Participants' driving behavior and surrounding conditions were recorded by the Data Acquisition System equipped on participants' vehicles. A total of 3,700 participant-years data was collected from the nearly 2,600 participants. NDS data is significant to safety analysis at the microscopic level. This data can provide insight on the influence and collision risk associated with roadway, environmental, vehicular, and human factors. The surrogate measures of crash or new crash events allow advanced traffic safety analysis and countermeasure development. With the concern of protecting the personal identification information (PII) of the study volunteers, the NDS data are not a public dataset that can be downloaded for free. Data users need to submit a data request with a clear description of when, where and what data is needed. Then the NDS data operator, the Virginia Tech Transportation Institute (VTTI), processes the data request for data preparation.

The SHRP 2 NDS data are considered to be better than other transportation datasets when taking into account the information details and data size. This dataset can be used to study traffic safety with consideration of drivers and their surroundings. State and local transportation agencies are encouraged to take advantage of the new available data for traffic safety, while most states do not have any similar data collected locally. Each area has its own characteristics that influence driver behavior and have an impact on traffic safety. When the local traffic issues need to be addressed by using the SHRP 2 NDS data, local agencies or researchers need to first select NDS data with the similar background conditions as the local area, then request and apply the data.

This project reviewed documentations and reports related to the SHRP 2 NDS data to summarize guidelines of selecting and requesting the dataset. Examples of applying NDS data for traffic safety and other applications were also provided to demonstrate how the NDS data can be used. The guidelines were also based on actual data request and applications of the project research team – the Center of Advanced Transportation Education and Research (CATER), University of Nevada Reno (UNR). The major innovation effort is development of a decision procedure, a decision matrix and ranking tables to compare selected attributes of the six NDS sites and a study region, which will lead to recommendation of the best-matching NDS site for the study area. Therefore, the appropriate NDS data can be selected and requested.

The site attributes of a local area or a study area have an impact on the local driving patterns and safety issues. The selected attributes for site comparison and selection are based on the site background data included in NDS site selection criteria. The site attribute selection also considered the data availability to researchers and engineers. The identified eight site attributes are listed as the following:

- Geographic characteristics
- Population

- Education attainment
- Household income
- Weather
- Traffic safety laws
- Median driver age
- Historical crash data

The first step of the procedure for NDS data selection is to collect traffic background data of the eight selected attributes. Then background data is analyzed for each of the NDS study sites and compare it to the study areas (Reno and Las Vegas as example areas in this project). From this, a rank of each selected attribute is determined for each NDS site by comparing the attribute difference between each NDS site and the study area. Ranks of the different attributes are then summarized into the decision matrix where each of the background attribute has a specific weight. Weight values were determined by a survey through the ITE web forum. Finally the best-matching NDS Site is identified based on the weighted sum of attribute ranks. Reno and Las Vegas in Nevada were selected as examples to apply the developed decision procedure and matrix. For the City of Reno, the most comparable site was identified to be Bloomington, IN, and the most comparable site of Las Vegas was determined to be Seattle, WA. The data analyzing process along with the decision matrix can be used for any study site in question as long the data can be compared and analyzed. The public data sources for obtaining the selected attribute data were also identified and included in this report.

It should be noted that the VTTI NDS data team may update the policy and data sharing agreement. The information presented in this report is for engineers and researchers to understand the general requirement and procedure. Data users need to contact VTTI for the latest requirement and procedure of NDS data request.

2. INTRODUCTION OF SHRP 2 NDS AND RID DATA

Traffic safety engineering relies on historical crash data for safety analysis and improvement. The crash data are used to study statistical relationship between crashes and contributing factors [1]. However, the crash reports are with limited amount and details, so not able to answer why and how such factors impact the performance of safety. As one example, it is known that driver behavior is a significant factor of highway crashes [2], but research to date mainly studied the driver behavior indirectly by very brief description in police crash reports. Thus new data collection studies and data sources need to be considered for detailed and direct data of different transportation factors, especially data about driver behavior. The new data with additional details will allow highway safety communities to better understand how different factors influencing driver behavior. The factors can be conditions of drivers, vehicles, roads and environment.

With the new available technologies and data collection methods, new transportation datasets have been collected in the last few years. These new datasets bring opportunities to improve traffic operation and highway safety. The Naturalistic Driving Study (NDS) [3] sponsored by the second Strategic Highway Research Program (SHRP 2) is one of these data collection studies. The SHRP 2 NDS was performed to collect detailed driver behavior data, as well as traffic condition and environmental conditions. A separate effort was conducted to collect roadway data on about 2,000 miles related to trip data collected by NDS. The road information data was named as Road Information Database (RID). The detailed and continuous information, including the videos of different directions, allow researchers to study transportation issues at the microscopic level.

The SHRP 2 NDS serves the goal of the SHRP 2 Safety Research Plan that is to address the role of driver performance and behavior in traffic safety [4]. The SHRP 2 NDS was designed to investigate driving behavior under real-world conditions. Volunteers were recruited to have their cars equipped with the NDS data acquisition systems (DASs) including cameras, radar, and other sensors to capture data during their usual driving tasks. [5][6] Table 1 presents the summary of DAS sensors. The NDS data collection sites included Bloomington, Indiana; Central Pennsylvania; Tampa Bay, Florida; Buffalo, New York; Durham, North Carolina; and Seattle, Washington. More details about the six data collection sites are shown in Table 2. By the end of the study, a total of 4,368 participant-years data were collected from 3,542 drivers. The final SHRP 2 NDS database is about 2 petabytes (2,000 terabytes), including 5.5 M trip files and 32.5 M vehicle miles. [7] 1,600 crashes and 2,900 near-crashes have been recorded. NDS data is critical to safety analysis at the microscopic level. This data can provide insight on the influences and collision risk associated with roadway, environmental, vehicular, and human factors on driver behavior and performance. The data will help to accurately study a driver's behavior before a crash or near-crash events, which could not be learned from after-the-fact crash investigations. When crash data have been widely used, the surrogate measures of collisions (crashes or near-crashes) recorded in NDS data can be taken into consideration for safety analysis. The near-crash events could not be found in any accident reports, but are able to provide as significant information as crash records for safety improvement. Trip data not related to crash or near-crash events can also be used to analyze the drivers' observation behavior and influencing factors. Two key advantages are offered by the SHRP 2 NDS as claimed by Kenneth L. Campbell [7]: "*(a) detailed and accurate precrash information, including objective information about driving behavior, and (b) exposure* *information, including the frequency of behavior in normal driving, as well as the larger context of contributing factors.*" Summary of NDS and RID data is presented in Table 3.

Table 1. Summary of Instrumentation in DAS

Instrumentation	Notes
Four video cameras	2 outward (1 color, 2 wide angle view) and 2 inward-viewing black & white video
Still image camera	Periodic image to detect number of people in vehicle
Accelerometers (3 Axis)	Lateral, longitudinal, and vertical vehicle accelerations
Rate Sensors (3 axis)	Lateral (turning), longitudinal and lateral (roll) rate
GPS (with antenna)	Latitude, longitude, elevation, time, velocity
Forward radar (on front bumper) & radar interface box (RIB)	X, Y positions & X, Y velocities of objects in front of vehicle
Cell phone (with antenna)	Automatic crash notification; vehicle location notification, health checks, remote upgrades
Illuminance sensor	Level of luminance outside vehicle (day/night indicator)
Infrared illuminator	To enable viewing of driver's face at night by camera
Passive alcohol sensor	Intended to detect nominal amounts of alcohol in cabin air. NOT driver specific. May also detect alcohol from topical sources (hand sanitizer, etc.).
Incident push button	Audio recorded only if button pushed
Turn signals (other lights?)	State of turn signal (on/off) recorded
Vehicle network data (cabling to connect DAS with OBD)	Accelerator, brake pedal activation, automatic braking system (ABS), gear position, steering wheel angle, speed, horn, seat belt information, airbag deployment and other data

Table 2. Areas and Unique Features of the Six NDS Sites

Study Center Area Name (State)	Recruiting Area Defined	Counties Within Study Center Recruiting Area (Major and Minor Contributors)	Unique Features Within Area	Nominal Number of DAS Units
Bloomington (Indiana)	39 zip codes inprimary area; 25 zip codes in secondary area[a] (64 total)	*Major/Primary (11):* Brown, Dubois, Greene, Johnson, Lawrence, Martin, Monroe, Morgan, Orange, Owen, Putnam *Minor/Secondary (6):* Marion, Bartholomew, Clay, Davies, Jackson, Shelby (8% of participants from secondary)	• Large parts of the Hoosier NationalForest and the Deam Wilderness area • Naval Surface Warfare Center Crane located in Martin County • Camp Atterbury located in BartholomewCounty • Primary area mostly rural, agricultural; secondary area more urban	150
Buffalo (New York)	1 county	*Major/Primary:* Erie *Minor/Secondary:* Niagara (4% of participants) and Cattaraugus (0.2% of participants)	• One international border crossing withinprimary study center area C Peace Bridge, Buffalo, NY • Additional features just outside primaryarea C Three additional U.S./Canada bridge crossings (Niagara County) C Niagara Falls Air Force Base	450

Durham (North Carolina)	39 zip codes	*Major/Primary:* Chatham, Wake, Orange, and Durham *Minor/Secondary:* Granville, Johnston, andHartnett (less	• Durham is in North Carolina's central piedmont, a geographic region lying nearly equal distance between themountains	300
Seattle (Washington)	3 counties	*Major/Primary:* Snohomish, King, and Pierce	• Two military bases within primary studycenter area: C Joint Base Lewis-McChord (south ofTacoma in Pierce County) C Puget Sound Naval Complex in Everett, Snohomish County • Additional features just outside primary area: C Whidbey Island Naval Air Station, northwest of Snohomish County C Several U.S./Canada border crossings (e.g., Vancouver, B.C.) within a few hours' drive north of primary driving area	420[b]
State College (Pennsylvania)	10 counties	*Major/Primary:* Blair, Cambria, Centre,Clearfield, Clinton, Huntingdon, Juniata, Mifflin, Snyder, Union	• Although mostly rural, area featuresinclude rugged mountainous environ-ments as well as sweeping, rollingvalleys.	150
Tampa (Florida)	2 counties	*Major/Primary:* Hillsborough and Pasco *Minor/Secondary:* Pinellas	• MacDill is an active U.S. Air Force base located in Tampa, Florida.	450

[a] In Bloomington, 39 of the zip codes were in the primary rural recruiting area, and the remaining 25 were in a secondary recruiting area that was more urban and generated about 8% of the total participants.
[b] The number of DAS units was reduced from the originally planned 450 to 420.

Table 3. Summary of SHRP 2 Safety Data [8]

Data	Description
Naturalistic Driving Study (NDS)	Six data collection sites: Tampa, Florida; Central Indiana; Durham, North Carolina; Erie County, New York; Central Pennsylvania; and Seattle, Washington.
	3,147 drivers, all age/gender groups.
	3,958 data years; 5 million trip files; 49.7 million vehicle miles.
	3 years of data collection.
	Vehicle types: light duty vehicles.
Road Information Database (RID)	Four different data sources.
	ESRI: baseline data for entire country.
	State roadway inventory data from 6 State studies.
	Mobile van data: very detailed, about 12,500 centerline miles; 43,195 intersections, 518,570 MUTCD signs; includes forward video.
	Supplemental data from 6 State studies.

The SHRP 2 NDS data has been known by states and local transportation agencies. State and local engineers are interested in and encouraged to take advantage of the new available dataset to improve local traffic safety. The NDS data collection occurred in six city areas, so it does not cover all the areas by any means. Drivers in different areas may have different driving patterns and different traffic safety issues. Researchers and engineers need to select the NDS data collected from the site with similar conditions as their local or study areas. Therefore, there is the need to compare the local area characteristics with that of the six NDS sites. The NDS data is not a public dataset that can be downloaded for free. With the concern of protecting the personal identification information (PII) included, data users need to submit a data request with a clear description of when, where and what data is needed. Then the NDS data operator, the Virginia Tech Transportation Institute (VTTI), will process the data request for data preparation. For anyone wants to use the SHRP 2 safety data, the following three questions need to be answered first:

1. How should SHRP 2 NDS and RID data be selected for local safety analysis?

Drivers' behavior are related to road condition, traffic rules, common driving habits and many other factors. When selecting NDS data for safety analysis of a local area, the background attributes of data collection sites need to be considered. Data from sites with similar traffic conditions as the study area should be used.

2. How should SHRP 2 NDS and RID data be requested and obtained?

The NDS data have been grouped into different security levels for protection of personal identification information. Data requests are different for the different security levels that are sent to data users through different approaches. A guidance is required to clarify what are the steps and requirement for SHRP 2 NDS and RID data request.

3. How should the NDS data be used?

Information included in NDS data is new for most engineers and researchers, so suggestions and examples are expected for new data users.

NDS data usage guidelines have been developed to assist and extend the data usage in Nevada by answering the three major questions. This entailed collecting background data for the major cities and counties here in Nevada which was narrowed down to Clark County and Washoe County. The two counties were with the highest concentration of the population allowing the most data. This also involved comparing data of a local/study area to the NDS data collection sites. As well as collecting the crash data, roadway characteristics, State Highway safety laws, age distribution, and the number of licensed/registered drivers. The detailed data of Nevada counties and cities can then be compared to the six NDS data collection sites. The guidance tool is developed in order to effectively compare traffic background information and data, so be able to select the NDS study site which best matches the site being compared such as Reno or Las Vegas. Therefore, researchers can analyze the local traffic problems with the best matching NDS data. Although the guidance is developed as a reference for Nevada Department of Transportation (NDOT), it can also be used by other states or regions for NDS data selection and request. This project report may also be used as a reference for future driver behavior data collection in Nevada.

The rest of this paper is organized as follows. Section 3 introduces how to access and request the SHRP 2 NDS data. Section 4 documents the procedure for selecting the best-match NDS data site and the decision matrix. The survey questions and responses for weight value decision are also presented in Section 4. Section 5 demonstrates how to apply the new SHRP 2 NDS and RID data to perform research on traffic safety. Section 6 is the conclusion to summarize this research project.

3. ACCESS TO SHRP 2 NDS AND RID DATA

The SHRP 2 NDS data is managed and maintained by VTTI, and the SHRP 2 RID data is managed by the Center for Transportation Research and Education (CTRE) at the Iowa State University. For protection of volunteers' private information, the data access, requesting and receiving is different from the normal public datasets. This section introduces the requirement and procedure of requesting the SHRP 2 NDS and RID data.

3.1 Requirements of Human Subjects Research

The SHRP 2 NDS is a federally funded study that involves human subjects, so the data are subject to Federal regulations governing human subjects' research and the protection of the volunteers and their privacy. Their use in the analysis is subject to the approval of institutional review boards (IRB) which are independent ethics committees formally designated under the Office for Human Research Protections (OHRP) of the Department of Health and Human Services. An IRB performs oversight by approving, requiring modifications to planned research prior to approval, or rejecting proposed research. IRB certifications and approval are required for requesting the SHRP 2 NDS data ta. The SHRP 2 RID data does not include any privacy information, so IRB certification or approval is not required for RID data request.

All data requests, at least initially, require the IRB approval of the researcher's home institution. Requests for the most sensitive data, i.e., the indirectly identifying and personally identifying data, will be carefully reviewed, and access to this data will be subject to the security procedures at the secure data facility, as appropriate. An IRB approval letter for applying the SHRP 2 NDS data on a research performed by CATER UNR is attached as an example in Appendix A.

3.2 NDS Data Access

The SHRP 2 Safety Data were divided into three levels for the security of volunteer privacy. The first level is the NDS Data Access Website - https://insight.shrp2nds.us/ , which has the lowest security level. For accessing the website data, a user needs to obtain an IRB training certification and also be verified by the NDS Data administrator. The website data do not include any personally identification information (PII). The available data on the website consist of NDS documentation, data dictionaries, sample data, descriptive data for whole data files, categorical data on all trips from trip summary and event data from crashes, near-crashes and baseline. It should be noted that the categorical data can be viewed at the website, but cannot be directly downloaded. When a data user needs any data presented on the website, a data sharing agreement and data request need to be submitted to VTTI. The second security level is full NDS data without PII, which is all data not requiring driver face video or trip start/end data. The IRB committee's review resulting in an IRB approval letter and data sharing agreement are required for requesting this level of data. All the time-series data from sensors, such as GPS, radar and onboard computers, are considered to be Level-2 data. Front and rear videos are also considered to be Level-2. When the requested Level-2 data being provided, the information around start/end of each trip is excluded, as the start/end information may be used to identify a volunteer's privacy information, such as the office or home.

The third level is full data including PII data, such as videos with the driver's face included. This level of data can only be viewed in the data secure enclave at VTTI, where computers or smartphones with a camera function are not allowed. To analyze the Level 3 data at the VTTI data enclave room, data users use either the software provided by VTTI or tools developed by users and verified by VTTI.

A data sharing agreement between VTTI and the data user is needed for any NDS data request. Data of different security levels can be included in one agreement if the data are for the same project. It is known that data service fee is charged by VTTI for preparing the request data. The detailed cost needs to be quoted by VTTI with consideration of the detailed data request. ***When working on a proposal, a data user should provide detailed data requirement description to VTTI and leave enough time for VTTI to give the quote price. Other than that, the final time and financial cost may be much higher than what is expected.*** In order to review NDS driver face and dashboard videos, data users need to perform the data extraction at the data security enclave at VTTI, so travel cost should be well planned. Video data extraction can take weeks. It is also known that VTTI can help to perform the data extraction from the Level-3 NDS data, which will save the travel cost for data analysis but limit the flexibility of data extraction. If a project will need the VTTI's service of data extraction, it needs to be clearly described in the data request for a correct data service quote.

Figure 1 [9] is a flowchart listing the steps for data request preparation. It can also be used to understand how to communicate with VTTI the required data. While not every data request involves all these steps, the figure illustrates key steps that data requestors should consider and plan for as they develop their data requests. The current data request is included in the data agreement form. Users need to provide brief information of projects for which the NDS data will be used, and also give a detailed description of the requested data elements and scope. It is recommended that data users first get familiar with the available NDS data through the NDS InSight Data Access Website - https://insight.shrp2nds.us/. A NDS data sharing agreement draft with data request description is included in Appendix B as an example. The data request and agreement can be adjusted with agreement of both VTTI and the data user. Any change to the original agreement requires an addendum, which needs to be signed by the data user and VTTI after being reviewed and approved by TRB.

It should be noted that the VTTI NDS data team may update the policy and data sharing agreement. The information presented in this report is for engineers and researchers to understand the general requirement and procedure. Data users need to contact VTTI for the latest requirement and procedure of NDS data request.

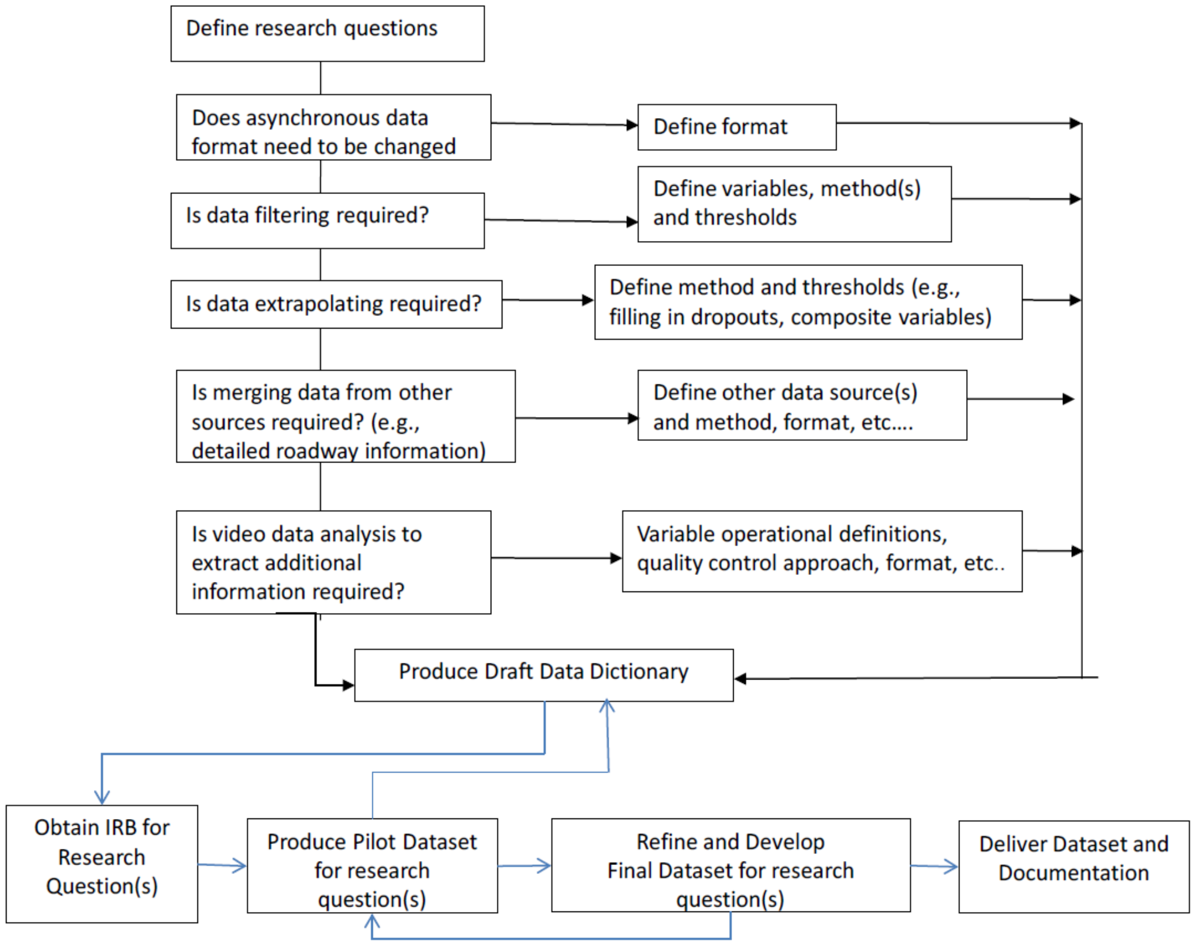


Figure 1. Steps for SHRP 2 NDS data request. [9]

As a summary of the requirement and procedure introduced above, the steps for NDS data request are listed in the following [9]:

1) A research proposal, and a general data request are sent to VTTI;
2) A data sharing agreement with detailed description of required NDS data is prepared by the data user based on a data sharing agreement template from VTTI;
3) The data sharing agreement and data request is reviewed by VTTI and TRB;
4) A quote of data service fee is provided to the data user by VTTI;
5) Signatures are collected for the approved data sharing agreement;
6) Payment to VTTI is processed by the data user;
7) After receiving the purchase order, VTTI works on data processing and preparation to meet the request;
8) The data user receives the final dataset. Analysis of Level-3 data will happen at the data security enclave at VTTI.
9) Addendums for minor adjustment to the data request which need to be signed by both VTTI and the data user, and need to be approved by TRB.

3.3 RID DATA Access

A separate effort was made for SHRP 2 NDS to collect about 4,500 miles roadway data at the six sites for NDS data collection. Roadway geometry was collected, i.e., horizontal curvature, grade, cross slope; lane and shoulder characteristics; speed limit signs; intersection locations and characteristics; and more for the roads most frequently used by the participants. [11] The major data elements are listed in the following.

- Horizontal curvature:
    - Radius
    - Length
    - Point of curvature (PC)
    - Point of tangency (PT)
    - Direction of curve (left or right based on driving direction)
- Grade
- Cross-slope/Superelevation
- Lanes: number, width, and type (turn, passing, acceleration, car pool, etc.)
- 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

The roadway data was connected to the driving data using GPS location coordinates. The roadway data does not involve human subjects, therefore it should not raise confidentiality issues or require IRB approval. A data sharing agreement is needed and will be signed by the data user and the data operator - CTRE. Data service fee is charged by CTRE for preparing the RID data. An external hard drive with the full RID data except road videos will be mailed to the data user. The data can also be distributed through an ftp server by CTRE.

RID data is accessible utilizing geographic information system (GIS) tools. The RID enables data users to look at the data sets of selected road characteristics and study matching NDS trips to explore the related driver, vehicle, and trip data. This capability of the RID makes it a very useful tool for NDS users interested in the roadway characteristics and features. In addition to the data from the mobile data collection project, roadway data from existing public resources (e.g., Highway Performance Monitoring System (HPMS) and comprehensive data items available from state transportation agencies) and a list of supplemental data items were acquired and included in the RID. 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 SHRP 2 RID is a spatially enabled database, or Geodatabase, which was designed to store, query, and manipulate geographic data, including points, lines, and polygons. It needs to be noted that only the mobile data collected for the SHRP 2 NDS routes are explained by a RID data dictionary. To understand data obtained from the state DOTs, the data user can contact CTRE for explanation or the state owners for data dictionaries.

RID data users need to contact the CTRE first for the data service cost and estimated data preparation time. A template of data request and data sharing agreement in the same form is provided by CTRE and needs to be completed by the data user with brief project information and research objectives. Data users need to complete the form, and then sign and return to CTRE. After the data request and agreement being reviewed and approved, an invoice will be sent to the data user for the data service fee. CTRE will work on data preparation after receiving the payment. A draft of data sharing agreement and request for a research project performed by CATER UNR is attached in Appendix C as an example.

It should be noted that the CTRE RID data team may update the policy and data sharing agreement. The information presented in this report is for engineers and researchers to understand the general requirement and procedure. Data users need to contact CTRE for the latest requirement and procedure of RID data request.

4. NDS DATA SELECTION

The Naturalistic Driving Study (NDS) has collected a wealth of information from the six different sites. This data can be used to study traffic safety and the interaction between drivers and their surroundings. The difficulty in using the data by other regions is to correlate the data from one specific site of the six ones to the local region. Each region has its own characteristics which influence on driver behavior and driver safety. Therefore, it is needed to select a NDS site best matching the local traffic situation before a NDS data request. By analyzing the attributes of each area, NDS study sites can be readily compared to each other and to the study areas without NDS data collected. In order to effectively compare the different sites, attributes of an area were first selected as a basis for comparison. When a NDS site is found to be the most comparable one, the NDS data collected from this site can be used for the study region in question. In this study, the city of Las Vegas and Reno were selected as examples for selection of compatible NDS sites.

This section describes the Data selection guidance for using NDS data. Data selection for Reno and Las Vegas are used as examples to demonstrate how the guidance can be applied. In order to properly select a NDS study site which is most comparable to a study area, it is essential that the selected attributes match as closely as possible and the data being used is readily available to compare. The selected background attributes used to compare the NDS study sites to the desired study area consist of geography, population, traffic safety laws, weather, education attainment, income, the median driver age and crash data. The selected attributes take into consideration several factors but mainly those addressing traffic safety. The portion of obtaining background attribute data is an important component of NDS data selection as well. It determines what background data of a study area can be obtained and compared to the NDS sites.

4.1 Traffic Background Data of NDS Sites

The traffic background condition of NDS sites have been comprehensively reviewed at the beginning stage of the NDS project [10], based on which the representative NDS data collection sites were selected. The reviewed area background condition included geographic size, populations, licensed drivers, registered vehicles, motor vehicle crash data for 2010, roadway characteristics and state highway safety laws.

Geographic size

The geographic size of the study area is an important factor for the comparison of the different sites. Each of the NDS study sites were comprised of several counties which made up the study area, some were much larger than others. This data also included information regarding the size of the land area, the water area and the total size (sq. mi) of the study site. Table 4 shows the geographic information for each of the NDS study sites which can be used to compare against other sites for further research.

Table 4. Geographic Size of NDS Data Collection Sites [10]

Study Center	County	Percentage of County in Study	Water Area (sq. mi.)	Land Area (sq. mi.)	Total Area (sq. mi.)	Notes
Bloomington	Brown	81.3%	3.8434	253.688	257.531	Values provided are for the 39 zip codes for the primary recruiting area. Secondary recruiting area included additional parts of these counties and significant areas of Marion and Bartholomew Counties.[a]
	Dubois	2.6%	0.0454	11.466	11.512	
	Greene	55.1%	1.5957	299.085	300.681	
	Johnson	19.0%	0.5141	60.684	61.198	
	Lawrence	94.8%	2.7608	425.851	428.611	
	Martin	52.6%	2.5698	176.483	179.052	
	Monroe	97.8%	16.8120	385.588	402.399	
	Morgan	67.5%	4.2562	272.241	276.497	
	Orange	85.6%	6.9348	342.327	349.262	
	Owen	64.6%	0.9396	249.718	250.658	
	Putnam	0.7%	0.0000	3.350	3.350	
	Primary total (sq. mi.)		40.2718	2,480.481	2,520.751	
	Total of all primary and secondary (towns, cities, unincorporated areas)				3,800.000	
Buffalo	Erie	100%	183	1,043	1,227	
	Total (sq. mi.)		183	1,043	1,227	
Durham	Chatham	49.5%	23.36	330.81	354.1	Values provided are for targeted zip codes in each county.
	Wake	51.3%	12.21	427.41	439.62	
	Orange	14.0%	0.20	55.90	56.10	
	Durham	89.1%	7.92	257.73	265.65	
	Granville	3.3%	0.58	17.01	17.59	
	Johnston	0.3%	0.06	2.10	2.16	
	Hartnett	1.6%	0.02	9.72	9.74	
	Total (sq. mi.)		44	1,101.00	1,145.00	
Seattle[b]	King	100%	191.3	2,115.57	2,306.87	
	Pierce	100%	136.93	1,669.51	1,806.44	
	Snohomish	100%	109.03	2,087.27	2,196.30	
	Total (sq. mi.)		437.00	5,872.00	6,310.00	
State College	Blair	100%	1	526	527	
	Cambria	100%	5	688	693	
	Centre	100%	4	1,108	1,112	
	Clearfield	100%	7	1,147	1,154	
	Clinton	100%	7	891	898	
	Huntingdon	100%	15	874	889	
	Juniata	100%	2	392	394	
	Mifflin	100%	3	412	415	
	Snyder	100%	1	332	333	
	Union	100%	0	317	317	
	Total (sq. mi.)		45	6,687	6,732	
Tampa	Hillsborough	100%	215	1,051	1,266	
	Pasco	100%	123	745	868	
	Total (sq. mi.)		338	1,796	2,134	

Population

The population data for the NDS study sites were broken into different age groups as well as male or female gender. This data was important to take into account since finding a study site that represents the general population is very important. Each of the NDS sites had a wide range of populations from a low of 243,283 for Bloomington, IN and a high of 2,788,204 for the site of Seattle, WA. As shown in Table 5, the populations vary quite a bit. The median age was also calculated for each of the NDS.

Table 5. Population and Age Distribution of NDS Sites[10]

Age Group (years)	Bloomington Study Center Area[a]			Buffalo Study Center Area[b]			Durham Study Center Area		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
15–19	12,803	12,675	25,478	33,896	32,417	66,313	34,829	33,926	68,755
20–24	8,827	17,382	36,209	34,904	33,862	68,771	40,581	41,651	82,232
25–29	9,989	9,344	19,333	29,261	28,846	58,255	39,688	41,673	81,361
30–34	8,598	8,335	16,933	24,636	25,163	49,575	38,864	39,476	78,340
35–39	8,206	8,101	16,307	25,170	26,316	50,526	38,205	38,164	76,369
40–44	8,748	8,760	17,508	29,827	31,229	61,518	36,732	36,668	73,400
45–49	9,785	9,709	19,494	33,567	35,335	68,867	35,399	36,737	72,136
50–54	9,789	9,986	19,775	35,243	37,674	73,492	31,698	33,882	65,580
55–59	9,022	9,411	18,433	30,672	32,895	63,323	26,455	29,749	56,204
60–64	8,000	8,219	16,219	25,271	27,730	54,740	21,601	24,317	45,918
65–69	5,931	6,279	12,210	18,151	21,360	37,761	14,473	16,508	30,981
70–74	4,166	4,701	8,867	13,204	17,214	31,804	9,185	11,544	20,729
75–79	2,961	3,864	6,825	11,135	15,890	26,357	6,848	9,108	15,956
80–84	2,046	3,000	5,046	9,139	14,664	24,931	4,702	7,769	12,471
>84	1,482	3,164	4,646	7,060	16,547	23,697	3,851	8,708	12,559
Totals	120,353	122,930	243,283	361,136	397,142	758,278	367,710	384,295	752,005

Age Group (years)	Seattle Study Center Area[c]			State College Study Center Area			Tampa Study Center Area		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
15–19	114,669	108,695	223,364	29,579	28,310	57,889	59,084	56,720	115,804
20–24	117,520	112,917	230,437	38,899	33,020	71,919	55,637	58,407	114,044
25–29	136,109	132,718	268,827	23,463	19,556	43,019	55,401	58,041	113,442
30–34	129,389	125,754	255,143	22,158	18,947	41,105	53,893	55,749	109,642
35–39	128,102	124,541	252,643	23,486	20,458	43,944	56,971	58,697	115,668
40–44	130,648	126,400	257,048	24,761	22,322	47,083	59,195	60,190	119,385
45–49	133,966	131,750	265,716	27,144	25,337	52,481	62,899	64,521	127,420
50–54	129,455	129,315	258,770	27,751	26,638	54,389	57,070	60,162	117,232
55–59	109,744	114,173	223,917	25,374	25,083	50,457	48,290	53,600	101,890
60–64	87,507	92,824	180,331	21,887	22,146	44,033	44,115	49,419	93,534
65–69	57,663	63,052	120,715	16,210	17,581	33,791	34,466	39,269	73,735
70–74	37,697	44,261	81,958	12,267	14,810	27,077	26,182	30,725	56,907
75–79	27,993	35,731	63,724	9,797	12,843	22,640	20,229	24,849	45,078
80–84	19,933	30,505	50,438	7,353	11,650	19,003	14,506	20,138	34,644
>84	18,309	36,864	55,173	5,567	12,355	17,922	10,937	20,181	31,118
Totals	1,378,704	1,409,500	2,788,204	315,696	311,056	626,752	658,875	710,668	1,369,543

Highway safety laws

The highway safety Laws were collected for the six NDS sites, which impact drivers directly. A few of the laws are the same such as the drunk driving blood alcohol content (BAC) in which all six NDS study sites use .08. Some of the laws which are newer, such as the cell phone use and handheld cell phone use, have had changes to the laws in the recent years and changes are going into effect while the study took place. An area where there is quite a bit of variability is the age and restriction requirements for applying driver licenses. The other law that varies a bit are the speed limits so it is important to see how those differences have an effect. The highway safety laws for each of the NDS sites are shown in Table 6.

Table 6. Traffic Safety laws of NDS Sites[10]

Regulation/Law	Buffalo (New York)	Bloomington (Indiana)	Durham (North Carolina)	Seattle (Washington)	State College (Pennsylvania)	Tampa (Florida)
Aggressive driver actions defined by statute	No State Law	At least three of the following: following too closely, unsafe operation, passing on the right off of roadway, unsafe stopping or slowing, unnecessary sounding of the horn, failure to yield, failure to obey traffic control device, speeding, repeatedly flashing headlights	Speeding and driving carelessly and heedlessly in willful or wanton disregard of the rights or safety of others while committing at least two of the following violations: running a red light or stop sign, illegal passing, failing to yield right of way, following too closely.	No State Law	No State Law – Resolution passed to encourage drivers to drive courteously and defensively	At least two of the following: speeding, unsafe or improper lane change, following too closely, failure to yield right of way, improper passing, failure to obey traffic control devices. (Not enforceable-violator is cited for specific infractions)
Handheld Cell Phone Use	Banned for all drivers, primary	Not Banned	Not Banned	Banned for all drivers, primary	Not Banned	Not Banned
All Cell Phone Use	Not Banned	Banned only for novice drivers <18, primary	Banned only novice drivers <18, primary	Banned for Learner or Intermediate Driver, primary	Not Banned	Not Banned
Text Messaging	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers (10/1/13), secondary
Drug Impaired Driving Per Se Laws for Drugs (Forbidding Prohibited Substances in Driver's Body)	No Law	Yes	Yes	Yes for THC	Yes	No Law
Drunk Driving BAC defined as illegal per se	0.08	0.08	0.08	0.08	0.08	0.08
Graduated Driver Licensing (GDL) Pgm	Yes	Yes	Yes	Yes	Yes	Yes
Learner Stage min age (yrs/mos)	16	15 with driver ed 16 w/out driver ed	15	15 with driver ed 15/6 w/out driver ed	16	15
Intermediate Stage min age (yrs/mos)	16/6 night time driving & passenger restrictions	16/6 with driver ed 16/9 w/out driver ed (night time driving & passenger restrictions)	16 night time driving & passenger restrictions	16 night time driving & passenger restrictions Driver Ed required, no traffic violations or drug alcohol offenses	16/6 night time driving & passenger restrictions	16 & 17 (night time driving restrictions)
Full privilege min age (yrs/mos)	17 with driver ed 18 w/out driver ed	18 (night) 17 (passenger) with driver ed 17/3 w/out driver ed	16/6	18	17 with driver ed and 12 mos no crash or conviction 18 w/out driver ed	18
Length of Regular Driver License Renewal	Every 8 yrs	Every 6 yrs	Every 8 yrs	Every 5 yrs	Every 4 yrs	Every 8 yrs
Special Provisions Mature Driver License Renewal	None	For drivers 75 – 84, renewal every 3 yrs For drivers >84, renewal every 2 yrs	For drivers >65, renewal every 5 yrs	None	None	For drivers >79, renewal every 6 yrs with vision test
Speed Limits for Cars/Trucks (mph) Rural Interstates Urban Interstates Other Limited Access	65/65 55/55 55/55	70/65 55/55 60/60	70/70 70/70 70/70	70/60 60/60 60/60	65/65 55/55 65/65	70/70 65/65 70/70
Seat Belts	Primary <16 in rear seats All in front seats	Primary >15 all seats	Primary >15 in front seats Secondary >15 in rear seats	Primary >8 or >4'9" in all seats	Secondary >17 in front seats Primary 8-17 in all seats	Primary >5 in front seats 6-17 all seats
Child Seat		< 8 mandatory 8-15 seat belt allowed	<8 and less than 80 lbs Mandatory 8-15 (weigh 40-80 lbs Seat belt allowed	<8 and less than 4'9" Mandatory 8-15; <8 4'9" or taller; children who weigh more than 40 lbs Seat belt allowed	< 8 mandatory	<4 mandatory 4-5 seat belt allowed

Licensed drivers and vehicle registration

Since the Naturalistic Driving Study focuses on various drivers, it is important to take into consideration the number of licensed drivers as well as the number of vehicle registrations. Each of these will vary quite a bit from area to area but are dependent on the size of the driving population. For the number of licensed drivers, the data was also broken up by age group, starting at the age of 16, and by gender shown in Table 7. As before it is important to note the age groups and how the distribution of ages affects the results of the study since age is an important component in regards to traffic safety and the number of incidents that occur within each age group. The number of vehicle registrations is also an important component of the study, in this case the number of vehicle registrations is broken down by vehicle type. Breaking down the number of registrations by vehicle type as shown in Table 8, gives information the number of vehicle types per study area and helps in analyzing the impact one vehicle type may have over another.

Table 7. Population by age distribution for NDS Sites [10]

Bloomington[a]				Buffalo[b]				Durham[c]			
SHRP 2 Age Group	**Male**	**Female**	**Total**	**SHRP 2 Age Group**	**Male**	**Female**	**Total**	**SHRP 2 Age Group**	**Male**	**Female**	**Total**
16–17	2,054	1,987	4,041	16–17	3,111	2,851	5,962	16–17	12,893	12,557	25,450
18–20	5,864	5,573	11,437	18–20	9,054	13,354	22,408	18–20	22,856	23,108	45,964
21–25	10,978	10,457	21,435	21–25	24,515	25,679	50,194	21–25	46,015	48,424	94,439
26–35	21,286	20,236	41,522	26–35	41,041	47,250	88,291	26–35	107,872	112,027	219,899
36–50	32,467	31,764	64,231	36–50	61,018	80,933	141,951	36–50	152,683	156,296	308,979
51–65	31,659	31,559	63,218	51–65	57,826	84,743	142,569	51–65	100,781	111,355	212,136
66–75	11,813	12,025	23,838	66–75	24,064	33,183	57,247	66–75	28,526	32,015	60,541
75+	6,553	7,403	13,956	75+	28,318	35,440	63,758	75+	16,777	20,257	37,034
Total	122,674	121,004	243,678		248,947	323,433	572,380		488,403	516,039	1,004,442

Seattle[d]				State College[e]				Tampa[f]			
SHRP 2 Age Group	**Male**	**Female**	**Total**	**SHRP 2 Age Group**	**SHRP 2**	**Female**	**Total**	**FL DHSMV Age Group**	**Male**	**Female**	**Total**
16–17	16,157	16,740	32,897	16–17	3,247	2,880	6,127	16–17	14,479	14,182	28,661
18–20	52,770	48,763	101,533	18–20	11,015	10,138	21,153	18–20	30,671	30,137	60,808
21–25	117,988	108,550	226,538	21–25	20,207	19,010	39,217	21–30	117,578	117,668	235,246
26–35	295,230	262,127	557,357	26–35	36,714	35,246	71,960	31–40	120,051	119,076	239,127
36–50	415,653	374,847	790,500	36–50	65,084	64,046	129,100	41–50	128,470	126,371	254,841
51–65	339,557	322,726	662,283	51–65	68,002	67,805	135,807	51–60	103,846	108,702	212,548
66–75	96,642	94,304	190,946	66–75	25,999	28,102	54,101	61–70	72,892	77,515	150,407
75+	53,531	58,537	112,068	75+	18,525	22,472	40,997	71–80	40,606	43,900	84,506
								81+	18,922	23,618	42,540
Total	1,387,528	1,286,594	2,674,122		248,793	249,699	498,462		647,515	661,169	1,308,684

Table 8. Vehicle Registrations for NDS sites [10]

Vehicle Type	Bloomington[a]	Buffalo[b]	Durham[c]	Seattle[d]	State College[e]	Tampa[f]
Passenger car	291,489[g]	557,434	833,691	2,223,547	415,183	1,149,645[h]
Truck	3,645[i]	54,233	162,746	587,708	149,297	62,159
Trailer	44,915[g]	24,314	76,916	201,990	99,374	143,009
Motorcycle/moped	12,810	22,782	17,542	NA	32,566	44,900
Recreational vehicle	1,727	NA	1,679	234,610	NA	95,964
Bus	690	1,668	1,862	NA	3,489	5,535
Farm vehicle	4,344	152	NA	NA	28	NA
Other/unknown	78	9,163[j]	536[k]	5,917[l]	179	79,927[g]
Total	359,698	669,746	1,094,972	3,253,772	700,116	1,581,139

4.2 Collection of Data for Study Areas

Based on the site background data included in the NDS site selection [10] and the public data availability to researchers and engineers, site background attributes were selected for comparing the study area and NDS sites. Eight attributes were selected for comparison between areas and are listed as the following:

- Geographic characteristics
- Population
- Education attainment
- Household income
- Weather
- Traffic safety laws
- Median driver age
- Historical crash data

The attribute data can be downloaded or obtained through the instruction in Table 9.

Table 9. Data sources of the eight selected site attributes

	Criteria							
	Geogrpahy Characterisitics	Population	Education Attainment	Household Income	Weather	Traffic Safety Laws	Median Driver Age	Crash Data
Source	USA.com	U.S. Census Fact Finder	U.S. Census Fact Finder	U.S. Census Fact Finder	U.S. Climate Data	Governors Highway Safety Assoc.	U.S. Census Fact Finder	City Police Department or City Records
Link	http://www.usa.com/	http://quickfacts.census.gov/qfd/index.html	r.census.gov/faces/tableservices/jsf/pages/pro	r.census.gov/faces/tableservices/jsf/pages/pro	http://www.usclimatedata.com/	a.org/html/stateinfo/bystate/index.html	r.census.gov/faces/tableservices/jsf/pages/pro	Use Link to selected City Webite
Instructions	Search for name of site then collect Land Area and Water area data.	Select study site from map then collect population data.	Add desired study site then focus on population 25 & over.	Add desired study site then focus on Median Income & Mean Income	Search desired study site then collect data: Annual High/Low Temp, Avg. Temp, Avg. Annual Rain, Avg. Annual Snowfall	Select desired study site then collect appropriate as shown in Figure X.	Add desired study site then record the median age at the bottom of table. (Focus only on Total Population age groups)	Collect data for Drivers in Injury crashes & Drivers in fatal Crashes.

The state of Nevada is divided into three districts of the Nevada Department of Transportation (NDOT), and each of these three districts is broken down into counties for which data were collected. The data collected for each of the counties included the population, the size of the county, and the weather. For each of the counties, data collection also involved collecting data from each of the major cities within each of those counties. For each of the counties the population was collected. The population and size of the cities within each of the counties was collected.

For each of the cities a small description of the weather was also collected, such as the average temperature of the city, average annual precipitation, average rainfall, and average snowfall per year which was obtained from the U.S. Climate Data website shown in Table 9. As the other area data, obtaining data for the smaller cities and counties was a bit difficult. Therefore, the focus of this study was placed on collecting the data for cities which contained a population higher than 200,000 in Nevada, which narrowed down the county selection into two counties which were Washoe County and Clark County, the two largest Counties in the state of Nevada. The largest cities consisted of Las Vegas with a population of 603,488, Henderson with a population of 270,811, and the city of Reno with a population 233,294 which was obtained from the U.S. census Bureau also shown in Table 10.

Table 10. Population, city size & weather for cities and counties

State	District	County	City	City Size (sq.mi)	Population	Average Temp (°F)	Annual precipitation (in)	Annual Days with precipitation	Annual snowfall (in)
Nevada	1	Clark	Las Vegas	135.82	603,488	69.3	4.17	21	0
	1	Clark	Henderson	107.73	270,811	62.8	6.92	x	x
	1	Clark	North Las Vegas	101.35	226,887	68.7	4.76	x	x
	1	Clark	Paradise	46.72	223,167	x	x	x	x
	1	Clark	Spring Valley	33.4	178,395	x	x	x	x
	1	Clark	Sunrise Manor	33.4	189,372	x	x	x	x
	2	Washoe	Reno	103.01	233,294	53.85	7.39	50	22
	2	Washoe	Sparks	35.76	93,282	52.45	8.26	44	6

The information of vehicle registrations was collected for various counties of Nevada which was broken down into the type of vehicles, as shown in Table 11. The numbers of vehicle registrations were used to compare to the six data collection sites in the SHRP 2 NDS study. The vehicle registration information of Nevada was obtained from the Nevada DMV for each of the counties.

Table 11. Vehicle Registrations for State of Nevada by County

COUNTY	CARS & RVS	TRUCK, VAN, BUS	TRAILER, UTLY, TENT	MOTORCYCLE	OFF-HIGHWAY VEHICLE	TRV-TLR & 5TH WHEEL	TOTAL
CARSON CITY	37,279	14,567	5,895	2,306	1,278	1,529	62,854
CHURCHILL	14,480	9,802	5,628	958	1,402	1,300	33,570
CLARK	1,066,725	235,176	60,077	37,658	12,094	10,548	1,422,278
DOUGLAS	37,193	16,774	9,176	2,770	2,165	2,266	70,344
ELKO	25,837	22,305	11,306	1,833	4,225	2,525	68,031
ESMERALDA	630	659	320	46	63	78	1,796
EUREKA	994	1,540	764	63	134	133	3,628
HUMBOLDT	9,635	8,446	4,961	724	1,235	885	25,886
LANDER	3,318	3,114	1,749	217	503	399	9,300
LINCOLN	2,866	2,598	1,591	102	459	356	7,972
LYON	33,291	18,330	9,210	2,639	2,626	2,342	68,438
MINERAL	2,841	2,113	893	165	209	256	6,477
NYE	29,328	17,092	7,653	1,946	1,691	2,062	59,772
PERSHING	2,585	2,487	1,436	150	354	233	7,245
STOREY	3,602	1,942	989	354	276	271	7,434
WASHOE	253,244	83,744	36,500	14,758	9,493	9,945	407,684
WHITE PINE	4,699	5,161	2,455	250	1,095	628	14,288
OTHER	11	16	5	1	21	0	54
TOTAL	1,528,558	445,866	160,608	66,940	39,323	35,756	2,277,051

Crash data

The crash data was obtained for this project. Historical crash records of Washoe County and Clark County were extracted from the Nevada crash database - Nevada Citation and Accident Tracking System (NCATS). This database was used to extract the crash data from 2006 until 2013 for Washoe County and Clark County. The number of fatalities as well as the number of injuries for the selected counties were used. The number of distracted drivers and impaired drivers was summarized. The historical crash data is an important index attribute two represent the traffic safety level of a city. The data of Washoe County was then plotted to display the trends as shown in Fig. 2 and Fig. 3. The data of Clark County is also shown in Fig. 4 and Fig. 5.

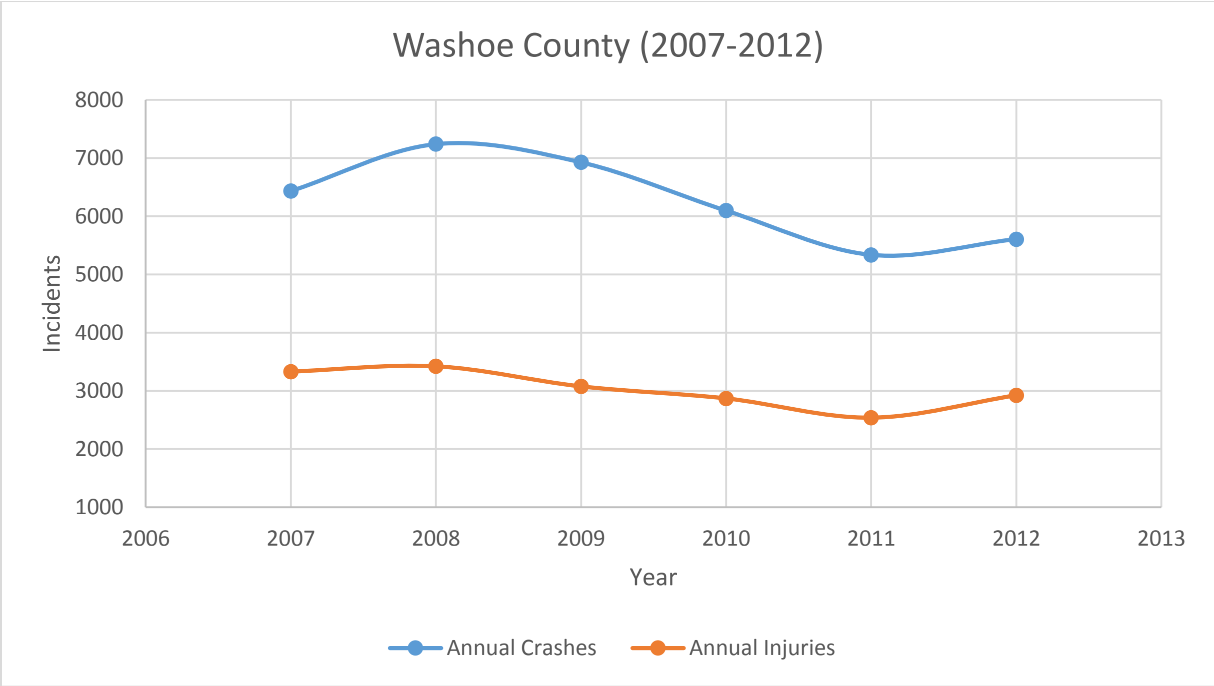


Figure 2. Annual crashes and injuries of Washoe County

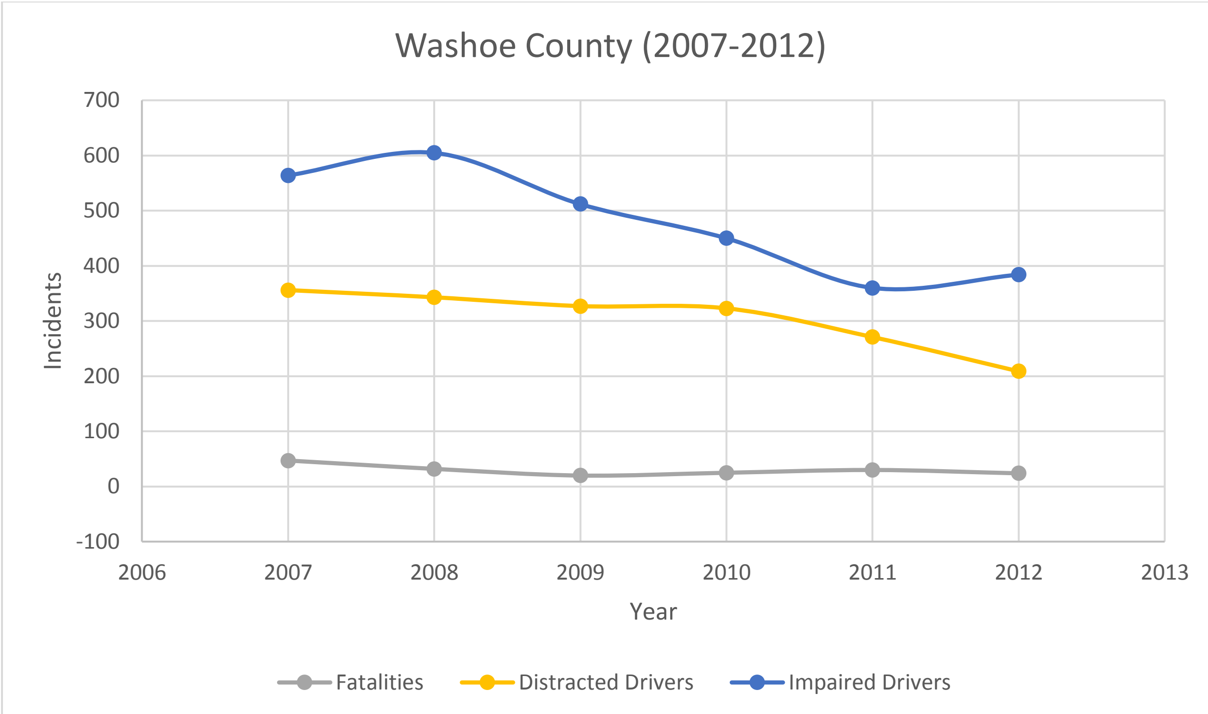


Figure 3. Annual fatalities, distracted drivers and impaired drivers of Washoe County

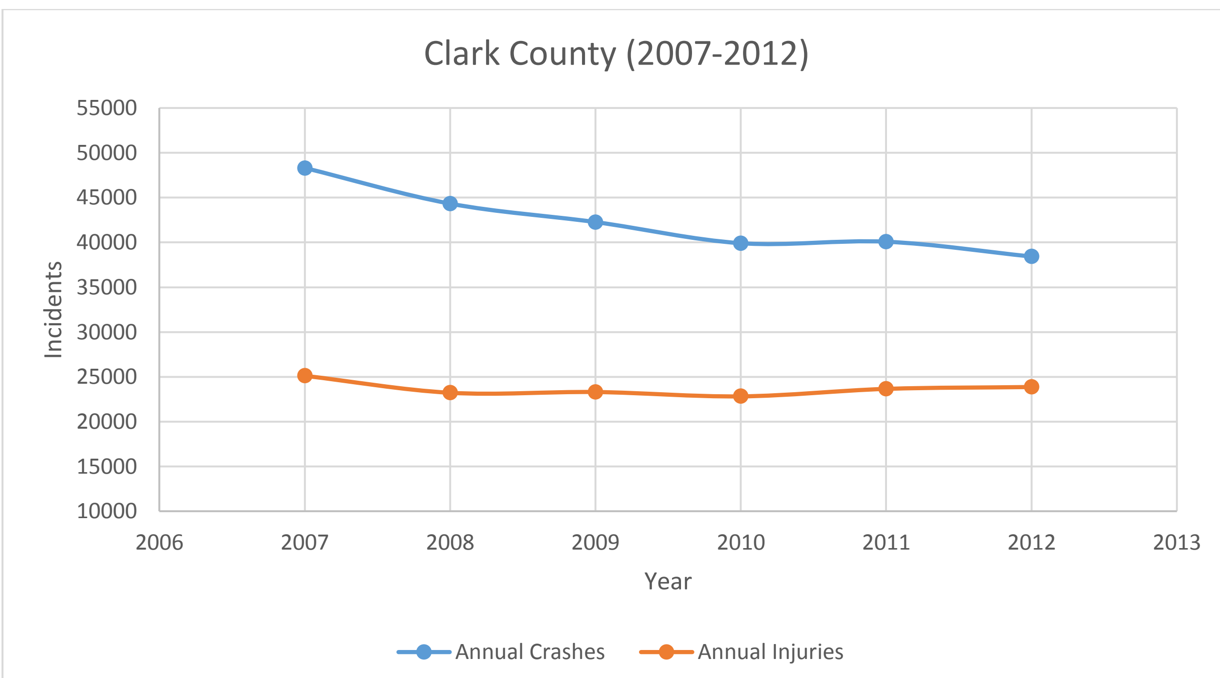


Figure 4. Annual Crashes and Injuries of Clark County

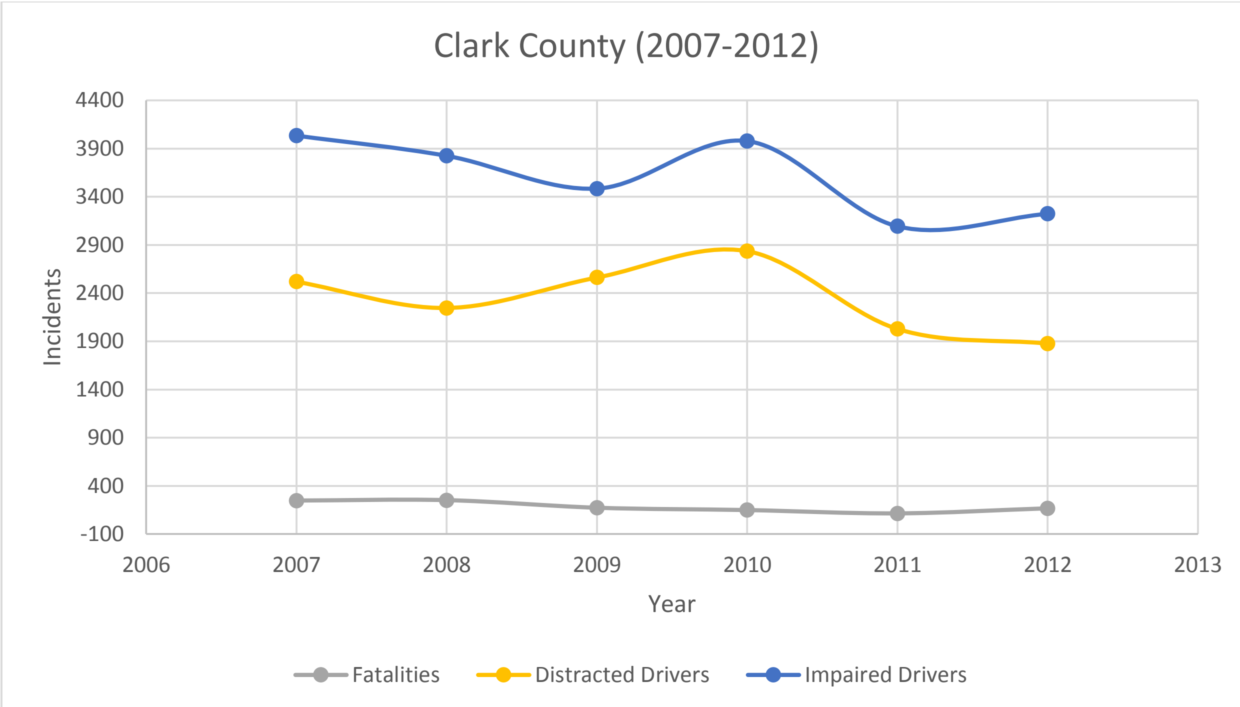


Figure 5. Annual fatalities, distracted drivers and impaired drivers of Clark County

Highway safety laws

In addition to collecting the detailed crash data, highway safety laws of Nevada were also needed to make the proper comparison between the selected areas here in Nevada and the six NDS sites. These laws mainly applied to highway safety and a table for comparison was made between the state of Nevada and the other six NDS sites in Table 12. This data of highway safety laws was obtained from the Nevada section of the Governor's Highway Safety Association using the most recent laws available.

There was a bit of variance in the laws that each state had but for the most part they were fairly similar. For the six NDS data sites the laws follow the same general form while some are stricter than others, such as laws applied to cell phone use but changes may have occurred to these laws over the few past years.

Table 12. Comparison of Highway Safety Laws for selected sites

Regulation/Law	Study Center(State)						
	Nevada	Buffalo (New York)	Bloomington (Indiana)	Durham (North Carolina)	Seattle (Washington)	State College (Pennsylvania)	Tampa (Florida)
Aggressive driver actions defined by statute	Within one mile, commits all of the following: 1) speeding; 2) at least two of the following: failure to obey traffic control device, passing on the right off of paved roadway, following too closely, lane violation, failure to yield right of way; and 3) creating an immediate hazard for another vehicle or person.	No State Law	At least three of the following: following too closely, unsafe operation, passing on the right off of the roadway, unsafe stopping or slowing, unnecessary sounding of the horn, failure to yield, failure to obey traffic control device, speeding, repeatedly flashing headlights	Speeding and driving carelessly and heedlessly in willful or wanton disregard of the rights or safety of others while committing at least two of the following violations: running a red light or stop sign, illegal passing, failing to yield right of way, following too closely.	No State Law	No State Law – Resolution passed to encourage drivers to drive courteously and defensively	At least two of the following: speeding, unsafe or improper lane change, following too closely, failure to yield right of way, improper passing, failure to obey traffic control devices. (Not enforceable- violator is cited for specific infractions)
Handheld Cell Phone Use	Banned for all drivers, primary	Banned for all drivers, primary	Not Banned	Not Banned	Banned for all drivers, primary	Not Banned	Not Banned
All Cell Phone Use	Banned for all drivers, primary	Not Banned	Banned only for novice drivers <18, primary	Banned only novice drivers <18, primary	Banned for Learner or Intermediate Driver, primary	Not Banned	Not Banned
Text Messaging	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers, primary	Banned for all drivers (10/1/13), secondary
Drug Impaired Driving Per Se Laws for Drugs (Forbidding Prohibited Substances in Driver's Body)	Yes	No Law	Yes	Yes	Yes for THC	Yes	No Law
Drunk Driving BAC defined as illegal per se	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Graduated Driver Licensing (GDL) Pgm	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Learner Stage min age (yrs/mos)	15/6	16	15 with driver ed 16 w/out driver ed	15	15 with driver ed 15/6 w/out driver ed	16	15
Intermediate Stage min age (yrs/mos)	16 night time driving & passenger restrictions	16/6 night time driving & passenger restrictions	16/6 with driver ed 16/9 w/out driver ed (night time driving & passenger restrictions)	16 night time driving & passenger restrictions	16 night time driving & passenger restrictions Driver Ed required, no traffic violations or drug alcohol offenses	16/6 night time driving & passenger restrictions	16 & 17 (night time driving restrictions)
Full privilege min age (yrs/mos)	Night: 18, passenger: 16/6	17 with driver ed 18 w/out driver ed	18 (night) 17 (passenger) with driver ed 17/3 w/out driver ed	16/6	18	17 with driver ed and 12 mos no crash or conviction 18 w/out driver ed	18
Length of Regular Driver License Renewal	Every 4 years.	Every 8 yrs	Every 6 yrs	Every 8 yrs	Every 5 yrs	Every 4 yrs	Every 8 yrs
Special Provisions Mature Driver License Renewal	>70: mail renewal must include medical report	None	For drivers 75 – 84, renewal every 3 yrs For drivers >84, renewal every 2 yrs	For drivers >65, renewal every 5 yrs	None	None	For drivers >79, renewal every 6 yrs with vision test
Speed Limits for Cars/Trucks (mph) Rural Interstates Urban Interstates Other Limited Access	75/75(Rural), 65/65(Urban), 70/70 (limited Access)	65/65 55/55 55/55	70/65 55/55 60/60	70/70 70/70 70/70	70/60 60/60 60/60	65/65 55/55 65/65	70/70 65/65 70/70
Seat Belts	Secondary (age >6), All seats	Primary <16 in rear seats All in front seats	Primary >15 all seats	Primary >15 in front seats Secondary >15 in rear seats	Primary >8 or >4'9" in all seats	Secondary >17 in front seats Primary 8-17 in all seats	Primary >5 in front seats 6-17 all seats
Child Seat	<6 years (<60 pounds)		< 8 mandatory 8-15 seat belt allowed	<8 and less than 80 lbs Mandatory 8-15 (weigh 40-80 lbs Seat belt allowed	<8 and less than 4'9" Mandatory 8-15; <8 4'9" or taller; children who weigh more than 40 lbs Seat belt allowed	< 8 mandatory	<4 mandatory 4-5 seat belt allowed

Age distribution

Another important information collected is the population age groups of each of the selected counties. The six NDS sites needed to provide an adequate age range in order to make sure that the data collected matched the general population. The population for each of the selected sites were also collected from the Census Department in order to compare the proper age breakdown. The details for the age breakdown are shown in Tables 13 and 14 for the selected sites, displaying the age distribution among the various cities in Nevada. One of the aspects that makes obtaining the proper age groups for the selected sites important is that the recruitment of drivers needs to be a representation of the general public.

Table 13. Age distribution for City of Las Vegas

Geography: Las Vegas city, Nevada

Age	Number			Percent		
	Both sexes	Male	Female	Both sexes	Male	Female
Total population	583,756 (r46220)	294,100	289,656	100.0	100.0	100.0
15 to 19 years	40,523	21,104	19,419	6.9	7.2	6.7
20 to 24 years	36,749	18,960	17,789	6.3	6.4	6.1
25 to 29 years	41,697	21,226	20,471	7.1	7.2	7.1
30 to 34 years	41,140	21,044	20,096	7.0	7.2	6.9
35 to 39 years	42,737	21,655	21,082	7.3	7.4	7.3
40 to 44 years	43,007	22,239	20,768	7.4	7.6	7.2
45 to 49 years	42,140	21,630	20,510	7.2	7.4	7.1
50 to 54 years	38,246	19,414	18,832	6.6	6.6	6.5
55 to 59 years	33,096	16,421	16,675	5.7	5.6	5.8
60 to 64 years	29,706	14,462	15,244	5.1	4.9	5.3
65 to 69 years	23,120	10,955	12,165	4.0	3.7	4.2
70 to 74 years	17,737	8,400	9,337	3.0	2.9	3.2
75 to 79 years	13,174	6,171	7,003	2.3	2.1	2.4
80 to 84 years	9,233	4,176	5,057	1.6	1.4	1.7
85 to 89 years	4,832	1,902	2,930	0.8	0.6	1.0
90 years and over	1,947	590	1,357	0.3	0.2	0.5
Median age (years)	35.9	35.2	36.5	(X)	(X)	(X)

Table 14. Age distribution for City of Reno

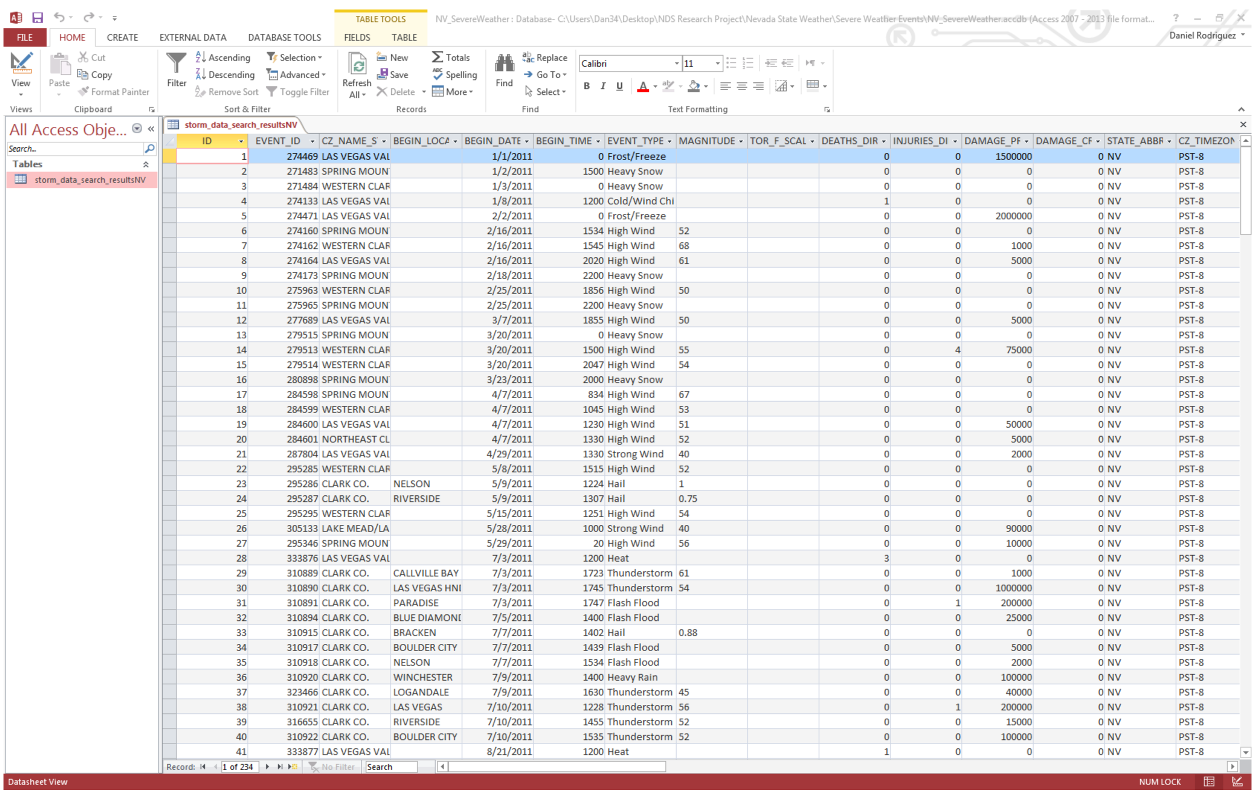
Geography: Reno city, Nevada

Age	Number			Percent		
	Both sexes	Male	Female	Both sexes	Male	Female
Total population	225,221	114,494	110,727	100.0	100.0	100.0
15 to 19 years	15,716	8,014	7,702	7.0	7.0	7.0
20 to 24 years	20,599	10,523	10,076	9.1	9.2	9.1
25 to 29 years	18,531	9,609	8,922	8.2	8.4	8.1
30 to 34 years	15,781	8,175	7,606	7.0	7.1	6.9
35 to 39 years	14,518	7,589	6,929	6.4	6.6	6.3
40 to 44 years	14,776	7,742	7,034	6.6	6.8	6.4
45 to 49 years	15,211	7,889	7,322	6.8	6.9	6.6
50 to 54 years	14,858	7,648	7,210	6.6	6.7	6.5
55 to 59 years	13,693	6,887	6,806	6.1	6.0	6.1
60 to 64 years	12,068	6,104	5,964	5.4	5.3	5.4
65 to 69 years	8,841	4,427	4,414	3.9	3.9	4.0
70 to 74 years	6,109	2,999	3,110	2.7	2.6	2.8
75 to 79 years	4,496	2,062	2,434	2.0	1.8	2.2
80 to 84 years	3,521	1,454	2,067	1.6	1.3	1.9
85 to 89 years	2,187	823	1,364	1.0	0.7	1.2
90 years and over	1,092	325	767	0.5	0.3	0.7
Median age (years)	34.6	34.2	35.0	(X)	(X)	(X)

Weather Data

Detailed weather data was collected from the National Centers for Environmental Information. This detailed weather data was comprised of Global Historical Climatology Network (GHCN) data as well as Quality Controlled Local Climatological Data (QCLCD). Using the GHCN the Automated Surface Observing System (ASOS) data was obtained which are sensors suites deigned to serve meteorological and aviation observing needs. The Cooperative Observer Network (COOP) data was also collected for the selected sites which entails more than 100,000 volunteers taking daily weather observations of various sites. Data in addition to that was included , such as Community Collaborative Rain, hail and Snow Network (CoCoRaHS) which is a community based network of volunteers to measure and map precipitation . The severe weather events were also obtained.

The detailed weather data for the selected sites, in the state of Nevada, was used in the same format as the six NDS sites. The collected data was then formatted into a Microsoft Access database where the data can be used. Demonstration of the weather data records is shown in Figure 6.



ID	EVENT_ID	CZ_NAME_S	BEGIN_LOCA	BEGIN_DATE	BEGIN_TIME	EVENT_TYPE	MAGNITUDE	TOR_F_SCAL	DEATHS_DIR	INJURIES_DI	DAMAGE_PF	DAMAGE_CF	STATE_ABBR	CZ_TIMEZON
1	274469	LAS VEGAS VAL		1/1/2011	0	Frost/Freeze			0	0	1500000	0	NV	PST-8
2	271483	SPRING MOUN		1/2/2011	1500	Heavy Snow			0	0	0	0	NV	PST-8
3	271484	WESTERN CLAR		1/3/2011	0	Heavy Snow			0	0	0	0	NV	PST-8
4	274133	LAS VEGAS VAL		1/8/2011	1200	Cold/Wind Chi			1	0	0	0	NV	PST-8
5	274471	LAS VEGAS VAL		2/2/2011	0	Frost/Freeze			0	0	2000000	0	NV	PST-8
6	274160	SPRING MOUN		2/16/2011	1534	High Wind	52		0	0	0	0	NV	PST-8
7	274162	WESTERN CLAR		2/16/2011	1545	High Wind	68		0	0	1000	0	NV	PST-8
8	274164	LAS VEGAS VAL		2/16/2011	2020	High Wind	61		0	0	5000	0	NV	PST-8
9	274173	SPRING MOUN		2/18/2011	2200	Heavy Snow			0	0	0	0	NV	PST-8
10	275963	WESTERN CLAR		2/25/2011	1856	High Wind	50		0	0	0	0	NV	PST-8
11	275965	SPRING MOUN		2/25/2011	2200	Heavy Snow			0	0	0	0	NV	PST-8
12	277689	LAS VEGAS VAL		3/7/2011	1855	High Wind	50		0	0	5000	0	NV	PST-8
13	279515	SPRING MOUN		3/20/2011	0	Heavy Snow			0	0	0	0	NV	PST-8
14	279513	WESTERN CLAR		3/20/2011	1500	High Wind	55		0	4	75000	0	NV	PST-8
15	279514	WESTERN CLAR		3/20/2011	2047	High Wind	54		0	0	0	0	NV	PST-8
16	280898	SPRING MOUN		3/23/2011	2000	Heavy Snow			0	0	0	0	NV	PST-8
17	284598	SPRING MOUN		4/7/2011	834	High Wind	67		0	0	0	0	NV	PST-8
18	284599	WESTERN CLAR		4/7/2011	1045	High Wind	53		0	0	0	0	NV	PST-8
19	284600	LAS VEGAS VAL		4/7/2011	1230	High Wind	51		0	0	50000	0	NV	PST-8
20	284601	NORTHEAST CL		4/7/2011	1330	High Wind	52		0	0	5000	0	NV	PST-8
21	287804	LAS VEGAS VAL		4/29/2011	1330	Strong Wind	40		0	0	2000	0	NV	PST-8
22	295285	WESTERN CLAR		5/8/2011	1515	High Wind	52		0	0	0	0	NV	PST-8
23	295286	CLARK CO.	NELSON	5/9/2011	1224	Hail	1		0	0	0	0	NV	PST-8
24	295287	CLARK CO.	RIVERSIDE	5/9/2011	1307	Hail	0.75		0	0	0	0	NV	PST-8
25	295295	WESTERN CLAR		5/15/2011	1251	High Wind	54		0	0	0	0	NV	PST-8
26	305133	LAKE MEAD/LA		5/28/2011	1000	Strong Wind	40		0	0	90000	0	NV	PST-8
27	295346	SPRING MOUN		5/29/2011	20	High Wind	56		0	0	10000	0	NV	PST-8
28	333876	LAS VEGAS VAL		7/3/2011	1200	Heat			3	0	0	0	NV	PST-8
29	310889	CLARK CO.	CALLVILLE BAY	7/3/2011	1723	Thunderstorm	61		0	0	1000	0	NV	PST-8
30	310890	CLARK CO.	LAS VEGAS HNI	7/3/2011	1745	Thunderstorm	54		0	0	1000000	0	NV	PST-8
31	310891	CLARK CO.	PARADISE	7/3/2011	1747	Flash Flood			0	1	200000	0	NV	PST-8
32	310894	CLARK CO.	BLUE DIAMONI	7/5/2011	1400	Flash Flood			0	0	25000	0	NV	PST-8
33	310915	CLARK CO.	BRACKEN	7/7/2011	1402	Hail	0.88		0	0	0	0	NV	PST-8
34	310917	CLARK CO.	BOULDER CITY	7/7/2011	1439	Flash Flood			0	0	5000	0	NV	PST-8
35	310918	CLARK CO.	NELSON	7/7/2011	1534	Flash Flood			0	0	2000	0	NV	PST-8
36	310920	CLARK CO.	WINCHESTER	7/9/2011	1400	Heavy Rain			0	0	100000	0	NV	PST-8
37	323466	CLARK CO.	LOGANDALE	7/9/2011	1630	Thunderstorm	45		0	0	40000	0	NV	PST-8
38	310921	CLARK CO.	LAS VEGAS	7/10/2011	1228	Thunderstorm	56		0	1	200000	0	NV	PST-8
39	316655	CLARK CO.	RIVERSIDE	7/10/2011	1455	Thunderstorm	52		0	0	15000	0	NV	PST-8
40	310922	CLARK CO.	BOULDER CITY	7/10/2011	1535	Thunderstorm	52		0	0	100000	0	NV	PST-8
41	333877	LAS VEGAS VAL		8/21/2011	1200	Heat			1	0	0	0	NV	PST-8

Figure 6. Severe Weather Detail Database

Vehicle Miles Traveled

Vehicle Miles Traveled (VMT) was also added to the data set for the state of Nevada, although it was not originally included for part of the study. The data was collected in order to provide background information when looking at the trends for the crash data which was collected and also to provide background travel information for the state of Nevada. The VMT was collected as a 12 month moving total for the state of Nevada a graphical representation of the graph is shown in Figure 7. Figure 8 displays the annual VMT trend for the state of Nevada, and is used to compare with the crash data and analyze the trends. Figures 9 and Figure 10 represent the fatalities per 100 million VMT and injuries per 100 million VMT for the State of Nevada respectively.

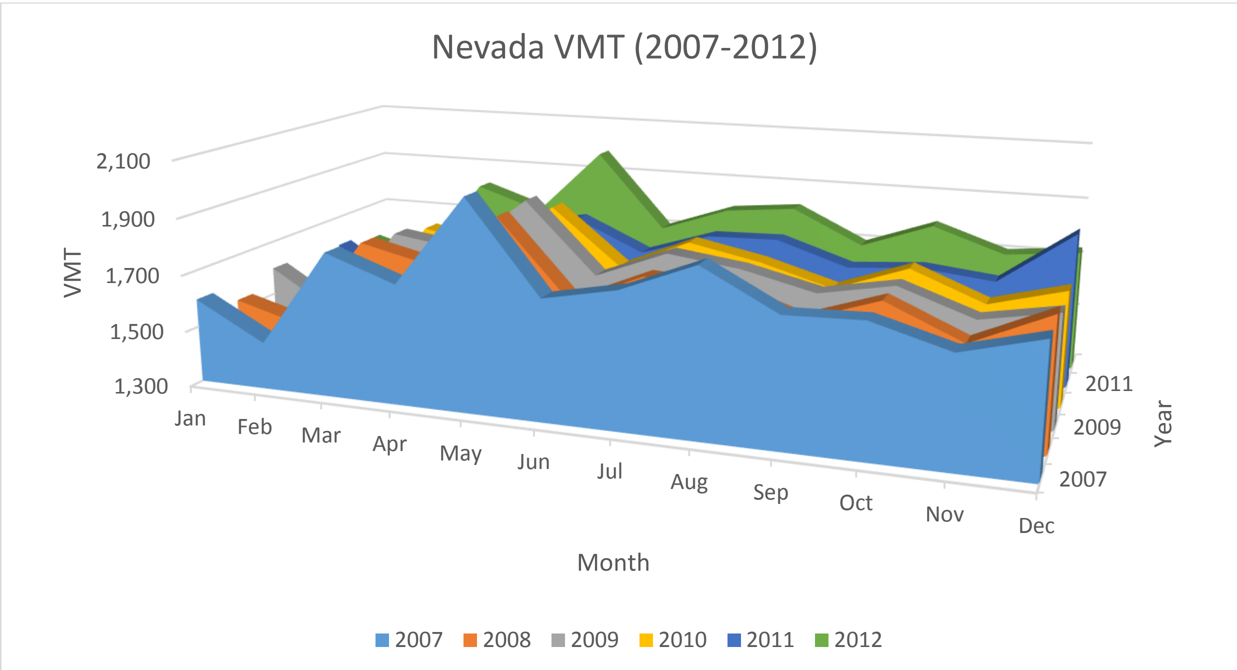


Figure 7. Nevada VMT monthly distribution (2007-2012)

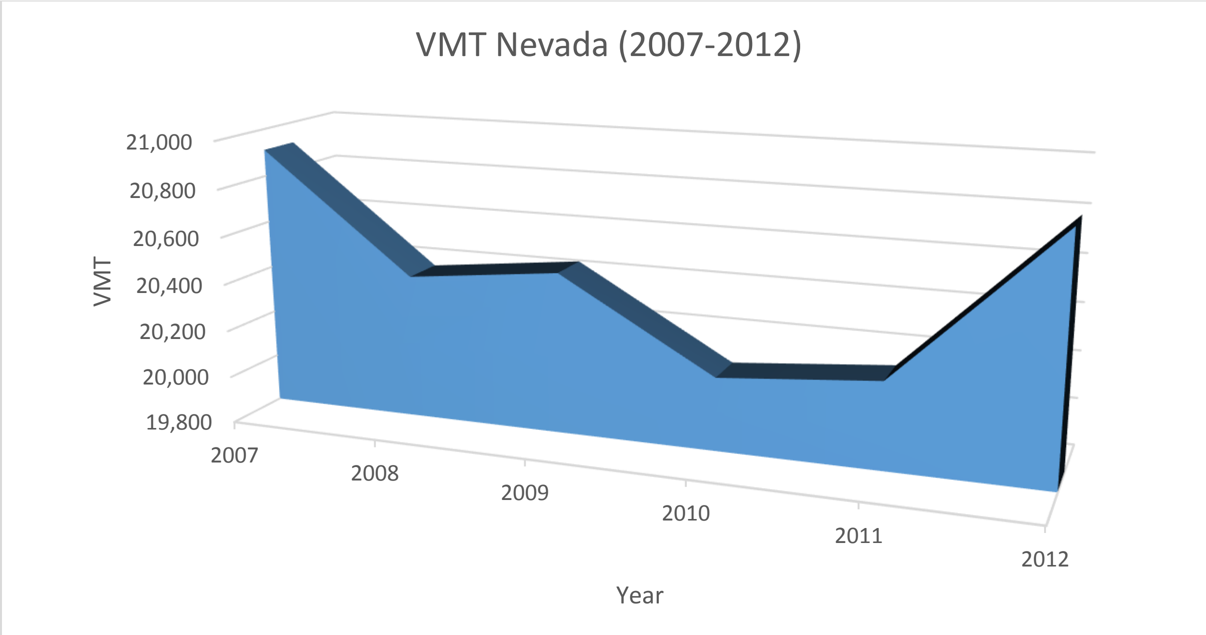


Figure 8. VMT for State of Nevada from 2007-2012

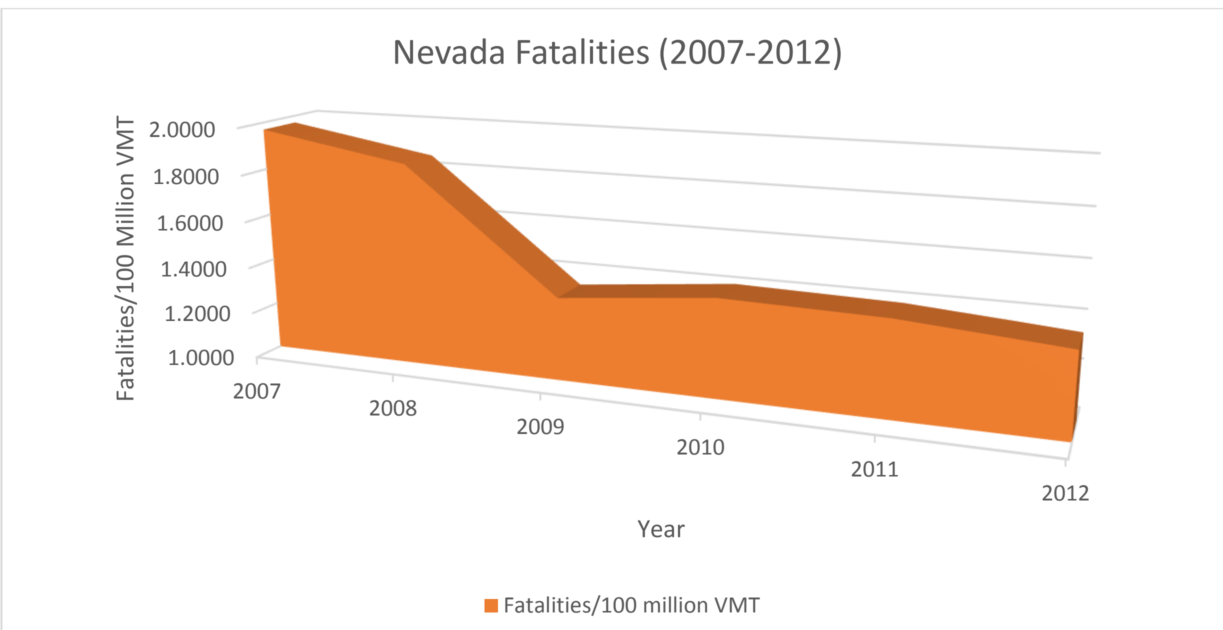


Figure 9. Fatalities per 100 million VMT for State of Nevada

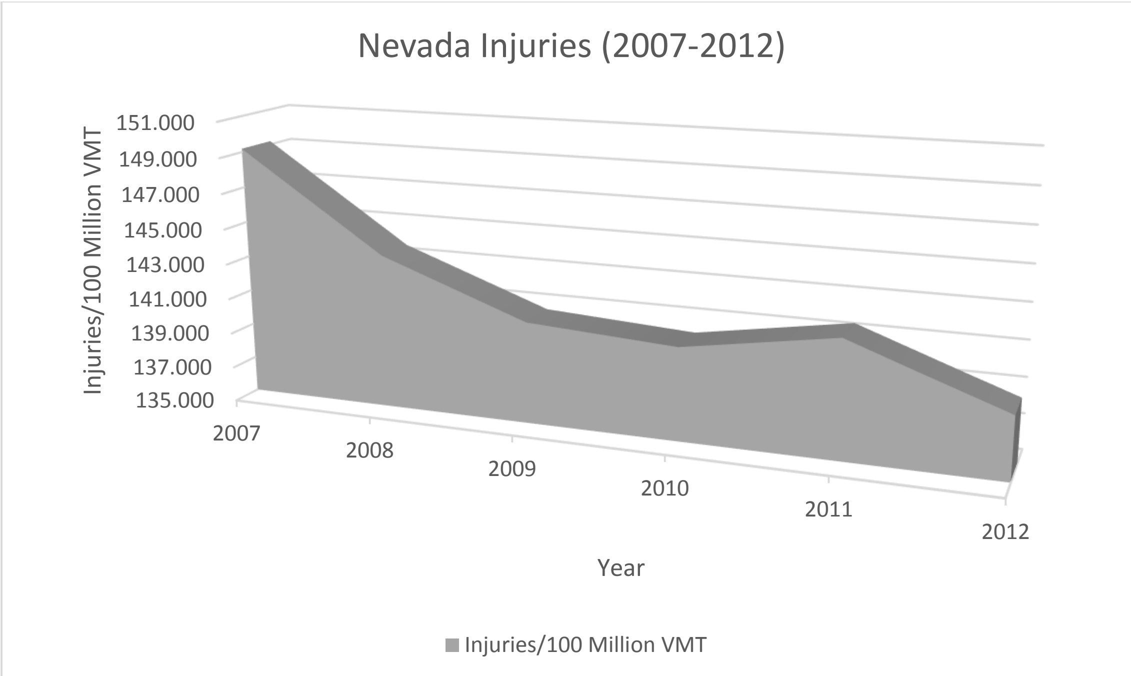


Figure 10. Fatalities per 100 million VMT for State of Nevada

4.3 Comparison of NDS sites and Nevada

While many different background characteristics of study areas can be considered to find the comparable NDS site, it is important to focus on the data and information that are available at the state DOT or public data sources. The SHRP 2 report [10] summarized the characteristics of the six NDS data collection sites. The site background data includes populations, licensed drivers and registered vehicles, motor vehicle crash data for Year 2010, roadway characteristics, state highway safety laws and weather. However, it is still a challenge to obtain the related local data and select the best-matching one from the six NDS sites. To solve this problem, the team identified eight site characteristics for site comparison, and the data sources of the different characteristic data. A procedure to compare and rank the NDS sites with a decision matrix was developed to find the best-match NDS site. The different site attributes have different influence on driving behavior and traffic safety, so the weight values need to be determined for each attribute. An online survey was conducted for the weight values, which are included in the decision matrix.

4.3.1 Attribute evaluation

To compare each selected attribute between the NDS sites, the obtained background data is input into eight ranking tables. Each of these tables has a column for a user to input the background characteristic data of the local site. The local attribute data will be compared to the data of the NDS sites for site ranking. An example is shown in Table 15.

Table 15. Ranking results of geography characteristics for Las Vegas

Criteria	Site	Six NDS Sites					
	LV	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Water Area(%) of Total Area	0.04	1.60	14.91	3.84	6.93	0.67	15.84
Land Area(%) of Total Area	99.96	98.40	85.09	96.16	93.07	99.33	84.16
	Rank for each Site	1	2	5	6	3	4

Each table follows a similar process to compare the local site attributes and that of the NDS sites. The process is demonstrated in the following sections. For the tables containing quantitative values, 1 or 0 values are assigned to the NDS site rows, which match or do not match data of the local site. For the tables with multiple data fields, such as two fields in Table 15, a sum-difference value is calculated to summarize the difference of the multiple fields between the local site and each of the NDS sites with Equation (1).

$$S_{diff} = \sum_{i=1}^{n} |A\_NDS_i - A\_Site_i| \quad (1)$$

S_{diff}, the sum_difference value for each of the six NDS data collection sites;

n, total field number in the ranking table;

i, the field index number, i=1… n;

A_NDS_i, the value of field i of the NDS site;

A_Site_i, the value of field i of the local site.

Geography characteristic

The geography characteristic means the size of the study area, including the land area and the water area. The geography characteristic includes two attributes of water area percentage of total area and land area percentage of total area. The most comparable site was chosen based on the comparison of the sum_difference values calculated by Equation (1). The sum_difference values of NDS sites are used to rank the NDS sites. Based on the comparison, each of the NDS study sites is ranked with a level number 1 through 6, where 6 is the most comparable to the local site and 1 is the least. Table 15 is the ranking table of geography characteristics with the example ranking results for Las Vegas.

Population

The population size of the geographic study area is another site attribute considered for NDS data selection. The U.S. Census population data is available to all researchers and engineers. The population size gives a perspective on how large the NDS study site is and whether it is an urban area or rural area. Each of the NDS study sites is ranked with a level number 1 through 6 by comparing the population sizes of the NDS sites and the local site, where 6 is the most comparable to the study area and 1 is the least. Table 16 is the ranking table of population size with the example ranking results for Las Vegas.

Table 16. Ranking results of population for Las Vegas

Criteria	Site	Six NDS Sites					
	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Total Population	584,044	243,283	758,278	752,005	2,788,204	626,752	1,396,543
	Rank for each Site	3	4	5	1	6	2

Education attainment

The level of education attainment is classified into several groups: "less than 9th grade education", "9th to 12th grade education", "high school grad", "some college no degree", "associates degree", "bachelor degree", and "graduate or professional degree". The percentage numbers in different education groups provides a way to directly compare the level of education between the NDS sites and the study area. Studies have found that academic intelligence does not necessarily represent good driving behavior or the likelihood of accidents on the road (12). However, the communities with similar education attainment are more possible to have similar driving patterns on average. Each of the NDS study sites is ranked with a level number 1 through 6 where 6 is the most comparable to the study area and 1 is the least. The ranking is based on the sum_difference of the percentage values in different education attainment groups. Table 17 is the ranking table of education attainment with the example ranking results for Las Vegas.

Table 17. Ranking results of education attainment for Las Vegas

Criteria	Site	Six NDS Sites					
	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Less than 9th grade(%)	8.3	3.8	3.5	3.7	3.4	4.1	4.7
9th to 12th grade, no diploma(%)	10.1	9.1	7.2	4.9	5.1	8.4	9.1
High School Graduate (GED)(%)	29.2	34.9	28.9	15.5	22.1	46.0	31.3
Some College, no degree(%)	24.3	19.8	18.5	16.9	23.0	14.0	21.6
Associates Degree(%)	7.0	6.7	11.4	6.9	9.4	7.6	9.1
Bachelor's Degree(%)	13.6	14.0	16.8	31.5	23.5	12.2	16.4
Graduate or professional degree(%)	7.5	11.7	13.7	20.7	13.6	7.8	8.0
	Rank for each Site	5	4	1	2	3	6

Household income

The household income consists of the median household income and the mean household income numbers. Comparison of the household income serves as a way to determine demographics within the area of a city. Each of the NDS study sites is ranked with a level number 1 through 6 based on the sum_difference of the median household income and the mean household income numbers. 6

is the most comparable to the study area and 1 is the least. Table 18 is the ranking table of household income with the example ranking results for Las Vegas.

Table 18. Ranking results of household income for Las Vegas

Criteria	Site	Six NDS Sites					
	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Median Household Income($)	54,334	42,917	48,805	64,460	65,400	40,000	51,905
Mean Household Income($)	71,637	56,300	64,959	85,114	86,729	54,819	68,071
	Rank for each Site	2	5	4	3	1	6

Weather

The weather attribute consists of annual high temp, annual low temp, average temp, average annual rainfall, and the average annual snowfall. Weather has a direct impact on traffic safety (*13*). The weather is an important factor to find the best-match NDS site. Each of the NDS study sites is ranked with a level number 1 through 6 based on the sum_difference of the different weather properties. 6 is the most comparable to the study area and 1 is the least. Table 19 is the ranking table of weather with the example ranking results for Las Vegas.

Table 19. Ranking results of weather for Las Vegas

Criteria	Site	Six NDS Sites					
	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Annual High Temp	80	63.4	56.3	70.2	60.3	59.1	81.7
Annual Low Temp	58.6	43.1	40.2	47.8	45	41.3	65
Avg. Temp	69.3	53.25	48.25	59	52.65	50.2	73.35
Avg. Annual Rainfall	4.17	47.32	40.47	48.1	37.13	39.6	46.31
Avg. Annual Snowfal	0	16	94	0	0	45	0
	Rank for each Site	4	1	5	6	2	3

Traffic Safety Laws

The traffic safety laws are also considered in the NDS site selection. The safety laws can be obtained from the Governors Highway Safety Administration (GHSA) website, which has the up-to-date traffic law data. The safety traffic laws used in this decision procedure include the seat belt laws, the learning stage for drivers in the process of obtaining a license, cell phone laws, driving under the influence, and the speed limit. The values of these data fields are not numeric values. The laws were converted to 1 or 0 values based on whether the NDS site law matches the local law. The sum_difference value is then calculated with the 1/0 values. 6 is the most comparable to the study area and 1 is the least. Table 20 is the ranking table of traffic safety laws with the example ranking results for Las Vegas.

Table 20. Ranking results of traffic laws for Las Vegas

Criteria	Site	Six NDS Sites											
	Las Vegas	Bloomington(IN)	Score	Buffalo(NY)	Score	Durham(NC)	Score	Seattle(WA)	Score	State College(PA)	Score	Tampa(FL)	Score
Seat Belt	Secondary (age >6), All seats	Primary >15 all seats	0	Primary <16 in rear seats All in front seats	0	>15 in front seats Secondary >15 in rear seats	0	Primary >8 or >4'9" in all seats	0	>17 in front seats Primary 8-17 in all seats	0	Primary >5 in front seats 6-17 all seats	0
Learner Stage min age (yrs/mos)	15/6	15 with driver ed 16 w/out driver ed	1	16	0	15		15 with driver ed 15/6 w/out driver ed	1	16	0	15	0
Full privilege min age (yrs/mos)	Night: 18, passenger: 16/6	17 (passenger) with driver ed 17/3 w/out	1	17 with driver ed 18 w/out driver ed	1	16/6	0	18	1	and 12 mos no crash or conviction	0	18	1
Handheld Cell Phone Use	Banned for all drivers, primary	Not Banned	0	Banned for all drivers, primary	1	Not Banned	0	Banned for all drivers, primary	1	Not Banned	0	Not Banned	0
Text Messaging	Banned for all drivers, primary	Banned for all drivers, primary	1	Banned for all drivers, primary	1	Banned for all drivers, primary	1	Banned for all drivers, primary	1	Banned for all drivers, primary	1	Banned for all drivers, primary	1
Driving Per Se Laws for Drugs (Forbidding	Yes	Yes	1	No Law	0	Yes	1	Yes for THC	0	Yes	1	No Law	0
Speed Limit	75/75(Rural), 65/65(Urban), 70/70 (limited Access)	70/65 55/55 60/60	0	65/65 55/55 55/55	0	70/70 70/70 70/70	1	70/60 60/60 60/60	0	65/65 55/55 65/65	0	70/70 65/65 70/70	1
	Rank for each Site		5		2		2		5		1		2

Driver Age

The driver age also has impact on the driving pattern and traffic safety. Its influence on traffic incidents rises as the age increases for the population, in this case the median driver age. As the age of drivers increases so does the fatality risk, once age exceeds 20 years old the fatality risk grows at a rate of 2.3% per year for males and 2.0% a year for females. At the age of 70 the fatality risk is about 3 times higher than the norm. Each of the NDS study sites is ranked with a level number 1 through 6 based on their median driving ages, where 6 is the most comparable to the study area and 1 is the least. Table 8 is the ranking table of driver age with the example ranking results for Las Vegas.

Table 21. Ranking results of driver age for Las Vegas

Criteria	Site	Six NDS Sites					
	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Median Driving Age	43.1	42.1	46.8	40.6	43.2	45.8	44.8
	Rank for each Site	5	1	3	6	2	4

Crash Data

The local crash data can be obtained from the local police offices or transportation agencies. Injury crashes per 1000 population and fatal crashes per 100,000 attributes are used for the crash data ranking. Each of the NDS study sites are ranked with a level number 1 through 6 based on the calculated sum_differenc values, where 6 is the most comparable to the study area and 1 is the least. Table 9 is the ranking table of traffic safety laws with the example ranking results for Las Vegas.

Table 22. Ranking results of crash data for Las Vegas

Criteria	Site	Six NDS Sites					
	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Drivers in Injury Crashes per 1000	18.46	27.35	9.61	11.44	12.93	32.11	19.51
Drivers in Fatal Crashes per 100,000	9.07	42.75	6.99	11.30	8.82	35.90	26.14
	Rank for each Site	1	4	5	6	2	3

4.3.2 DECISION PROCEDURE AND MATRIX FOR NDS DATA SELECTION

Taking into consideration the background data introduced in 4.3.1, the following procedure is proposed to select the most comparable NDS site for a local site. Each of the site attribute data can be readily obtained from the data sources provided in Table 1 in similar format, which can then be input into the ranking tables. Ranking numbers of the six NDS sites are calculated in each of the tables. Finally, the ranking results are used as the input into the decision matrix as shown in Table 10 to combine the ranking results of the different attributes. The most comparable NDS site for NDS data selection can then be identified with the final ranking of the decision matrix. The final ranking results are visualized with the filled radar chart in Figure 1.

Table 10 Decision matrix to identify the most comparable NDS site

Decision Matrix									
List of NDS Study Sites	Geography Characteristics	Population	Education Attainment	Household Income	Weather	Traffic Safety Laws	Median Driver Age	Crash Data	Results
Bloomington(IN)									0.000
Buffalo(NY)									0.000
Durham(NC)									0.000
Seattle(WA)									0.000
State College(PA)									0.000
Tampa(FL)									0.000
Weight	6.4	6.8	5.4	5.3	7.0	6.6	6.8	6.7	51
Distribution	12.549%	13.333%	10.588%	10.392%	13.725%	12.941%	13.333%	13.137%	100%

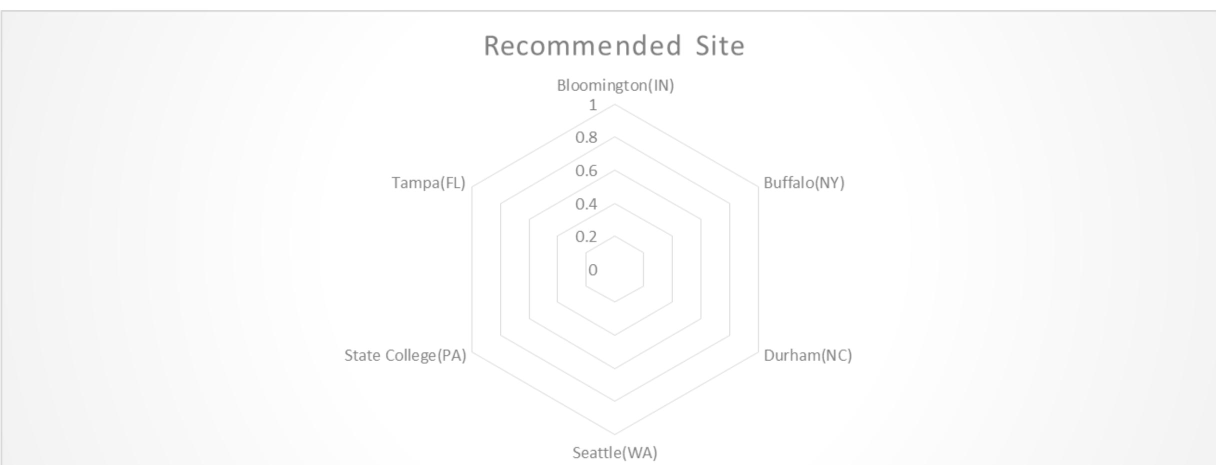


Figure 1. Filled radar chart to visualize the ranking results for NDS data selection

The NDS data selection procedure can be expressed by the flow chart in Figure 2.

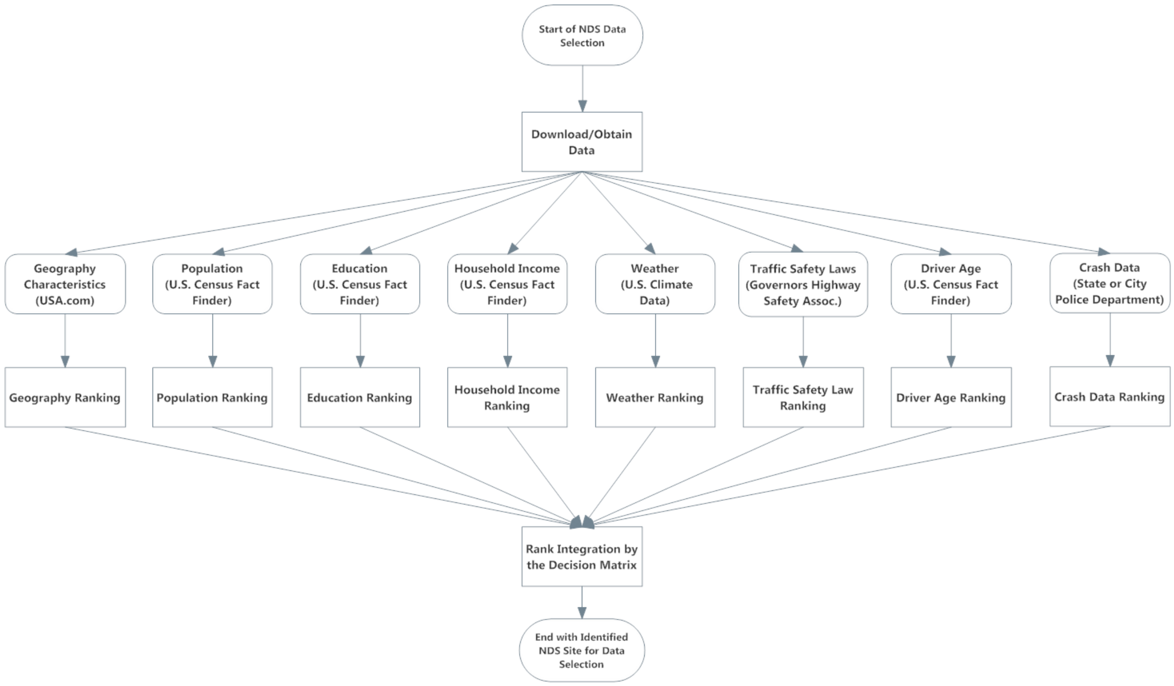


Figure 2 Procedure of NDS data selection

4.3.2 Weight Values of Different Site Attributes

An important aspect in using the decision matrix is the determination of the weight values of the different site attributes. Site attributes impact driving patterns and traffic safety in different approaches and at different levels, so the attribute weight values should be accommodated in the decision matrix. The literature review did not find any existing recommendations about the site attribute weight values. Therefore, the authors conducted an online survey to decide the weight values. The survey was created using the website of "survey monkey", which included the following 8 survey questions:

1) Geography Characteristics Weight Determination
2) Population Size Weight Determination
3) Education Attainment Weight Determination
4) Household Income Weight Determination
5) Weather Weight Determination
6) Traffic Safety Laws Weight Determination
7) Median Driver Age Weight Determination
8) Crash Data Weight Determination

For each question, weight values from 0 to 10 were given to surveyees for selection. The online survey link was distributed on the ITE boards for members and was sent to DOT engineers. By the end of this study, 43 responses were obtained. And the summarized weight values are shown in Table 23.

Table 23. Weight values from the survey

Criteria	Weighted Average
Geography Characteristics Weight Determination	6.4
Population Size Weight Determination	6.8
Education Attainment Weight Determination	5.4
Household Income Weight Determination	5.3
Weather Weight Determination	7.0
Traffic Safety Laws Weight Determination	6.6
Median Driver Age Weight Determination	6.8
Crash Data Weight Determination	6.7
Avg	6.38
STDEV	0.66

A very important aspect in using the decision matrix is the determination of the weights being used in the process. Each of the background criteria uses a weight which was determined by conducting a survey. This background criteria serves as a way to compare the NDS selected study sites with a desired study site, and determines the importance of each criteria in relation to traffic safety. The survey consisted of having seven questions in which users are allowed to choose a number between one and ten, one signifying the least importance and ten signifying the most important. The survey was distributed among traffic/transportation engineers and professionals who dealt with traffic safety in order to determine what the proper weight should be for each of the criteria. The survey was conducted over a period of a week in which 43 responses were obtained from survey respondents. The use of a survey allowed proper determination of the weights by using their experience and background to make the proper selection.

The results from the survey indicate the average weight for the criteria points was 6.4 with a standard deviation of .66.For the geography characteristics the weight was determined to be a 6.4 out of 10, which falls very close to the average weighted value coming out to be a 6.3. For the population the weighted value was determined to be 6.8 slightly above the average which was expected. The education attainment weight was determined to be 5.4 which is one of the two lowest weighted criteria in comparison to the average. The household income weight was determined to be 5.3, the lowest weighted average out of the seven. For the weather weight determination the score was determined to be a 7.0, the highest weight out of the criteria which was to be expected considering its impact to traffic safety. The traffic safety laws were determined to be 6.6, one of the fourth highest weighted criteria which also was to be expected considering the traffic laws impact on traffic safety. For the median driver age the weight was determined to be a 6.8, the second highest weight behind the weather which is also expected given its impact to traffic safety among other factors. The crash data was also included in the end in which the weight was determined to be 6.7, the third highest weight. The weights for each of the criteria were determined to be as expected each having a differing impact on traffic safety, these determined weights will be discussed in more detail in the following section.

4.4 NDS site selection for Reno and Las Vegas

The geography characteristics for each of the sites is one of the criteria parameters used in the decision matrix for the comparison of the selected study site with that of the six NDS study sites. The geography characteristics were broken down into the size of the study area, consisting of land area. The other criteria for the geography characteristics was the size of the water area for the study site. The geography characteristics will have an impact on traffic safety and will be taken into consideration in the decision matrix. Each of the NDS study sites have criteria which was collected from the U.S. Census Fact Finder and a rank has been determined for each of the NDS study sites in relation to the desired study site. From this the most comparable site can be selected. For the city of Las Vegas the decision process is shown in Table 24 displaying the rank for each of the NDS study sites, where 6 is the most comparable and 1 is the least. For the city of Las Vegas, NV the city of State College, PA was determined to be the most comparable. For the city of Reno, NV the decision process is shown in Table 25, in which the city of State College, PA was also chosen as the most comparable site.

One important factor for the selection of the of a NDS study site is the determination of the weight to be used in the decision matrix for the geography characteristics. As discussed earlier, the weights for each of the criteria points significantly affect the decision matrix process, for this specific criteria a weight of 6.4 was used in the calculation to determine the most comparable site. The determined weight for this criteria matches the average of 6.4. Geography does have an impact on the outcome of traffic safety mainly in determining the size and features of the land but is not as important in relation to the other criteria points. The geography characteristics have differing impacts on traffic safety, the size of the land along with the population can be a determination of whether it is an urban or rural area. Population is taken into consideration in conjunction with the geography. For urban roads the percentage of total crashes in 2006 was 44.9% and for rural roads the percentage was 53.8%. This criteria is to be used in conjunction with the other listed criteria in order to see the effects of traffic incidents, most importantly with that of the population discussed in the next section. One example as such is the population density whereas the density increases the number of traffic incidents is decreasing due to less drivers using their vehicles and using alternative modes of transportation.

Table 24. City of Las Vegas Geography Characteristics Comparison

Geogrpahy Characterisitics							
Procedure: Step1: For each matching criteria a point is given Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.							
	Site	Six NDS Sites					
Criteria	LV	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Water Area(%) of Total Area	0.04	1.60	14.91	3.84	6.93	0.67	15.84
Land Area(%) of Total Area	99.96	98.40	85.09	96.16	93.07	99.33	84.16
	Rank for each Site	1	2	5	6	3	4

Table 25. City of Reno Geography Characteristics Comparison

Geogrpahy Characterisitics							
Procedure: Step1: For each matching criteria a point is given Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.							
	Site	**Six NDS Sites**					
Criteria	Reno	**Bloomington(IN)**	**Buffalo(NY)**	**Durham(NC)**	**Seattle(WA)**	**State College(PA)**	**Tampa(FL)**
Water Area(%) of Total Area	0.86	1.60	14.91	3.84	6.93	0.67	15.84
Land Area(%) of Total Area	99.14	98.40	85.09	96.16	93.07	99.33	84.16
	Rank for each Site	2	4	3	1	6	4

The size of the population was also used as one of the criteria points for the decision matrix. Each of the six sites included the size of the population for the geographic study area. When comparing the desired study site to the NDS study sites the population can be obtained from the U.S. Census then input into the decision making process for the decision matrix . The information from the population provides details regarding the study site and is important since it gives a perspective on how large the NDS study site is and whether is an urban area or rural area. Each of the NDS study sites have the population listed in the analysis portion of the decision matrix which can then be directly compared to the population of the desired study site shown in Table 26.The results for the city of Reno, NV and Las Vegas, NV are shown in Tables 26 and 27 respectively.

Whether it is a rural or urban area will have an impact on the type of setting for a city which can mean a densely populated area or a rural setting. In determining a city's population and the effect this will have on the selection process it is also important to weigh this criteria against the other criteria factors. The weight for the population used in the decision matrix was also determined through a study in which traffic safety experts could give their opinion based on experience. From this input the weight to be used in the decision matrix was determined to be 6.8 which is above the average of 6.4 and ranks it as the second most important criteria along with the median driver age. The size of the population was expected to have a larger impact on traffic safety since it gives a sense on the type of setting drivers face such as urban or rural and the amount of traffic incidents they encounter as mentioned in the previous section. When looking at the overall population it is important to take into consideration the number of fatalities and injuries that have occurred, one measure is the fatality rate per 100,000 population. From the National Highway Traffic Safety Administration it has shown that in 1966 the fatality rate per 100,000 was 25.89, as the years have went by and traffic safety has increased that number has decreased to 10.69 in 2012.

Another important consideration is to take into account the fatalities state by state since each of the states have a differing population. Data from the Centers for Disease and Control indicate that traffic deaths are not directly correlated with the size of the population. Considering deaths per 100,000 population several larger metropolitan areas have lower fatality rates than smaller areas. Such as the city of Los Angeles, CA had 7.7 deaths per 100,000 whereas the city of Memphis, TN had 17.4 per 100,000 (11) and this can be seen for many other cities of the same size. It is important to see that many other factors play a role in the number of traffic incidents and it is generally a combination of factors which lead to increased incidents.

Table 26. City of Reno Population Comparison

Population								
Procedure: Step 1: Using the population for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1. Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.								
	Site	Six NDS Sites						
Criteria	Reno	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)	
Total Population	233000	243,283	758,278	752,005	2,788,204	626,752	1,396,543	
	Rank for each Site	6	3	4	1	5	2	

Table 27. City of Las Vegas Population Comparison

Population								
Procedure: Step 1: Using the population for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1. Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.								
	Site	Six NDS Sites						
Criteria	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)	
Total Population	584044	243,283	758,278	752,005	2,788,204	626,752	1,396,543	
	Rank for each Site	3	4	5	1	6	2	

Education attainment is another criteria metric which was used for the comparison of the different NDS study sites. The level of education attainment was broken down into several areas which consisted of less than 9th grade education, 9th to 12th grade education, High school Grad, some college no degree, Associates degree, Bachelor degree, and graduate or professional degree. This information regarding education attainment provides a way to directly compare the level of education for each of the selected NDS study sites and the desired site to study. Education attainment is important in being able to determine the education level for the geographic location and compare between the NDS study sites and the selected site to be compared. Each of the NDS sites have detailed data for the education as shown in Fig. 15, which has a breakdown, as a percentage, of each level of education attainment.

The level of education breakdown for the selected NDS study sites was compared to the city of Reno, NV and to the city of Las Vegas NV in Fig. 15 and Fig. 16 respectively. For the city of Reno, NV the most comparable city was Tampa, FL and for the city of Las Vegas, NV it was also the city of Tampa, FL which was determined by having the highest rank of 6 for the selected NDS study site. The weight for education attainment used in the decision matrix was also very important in determining which site is the most comparable. From the survey conducted the weight was determined to be 5.4 for education attainment, which is the second lowest rated criteria. This value of 5.4 is also well below the average weighted value of 6.4 for all of the criteria combined which implies the level of education attainment is not as important as the other criteria factors but still plays a role which is supported by studies. Which have found that academic intelligence does not necessarily represent good driving behavior or the likelihood of accidents on the road, a more important factor would be emotional intelligence or emotional stability (13). In countries such as the U.S. the average level of education attainment does not vary so much which in comparison to other countries that have a lower socioeconomic status. If such is the case where the socioeconomic status varies quite a bit then the weight will be a bit higher.

Table 28. City of Reno Education Attainment Comparison

Education Attainment

Procedure:
Step 1: Using the education attainment for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1.

Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.

	Site	Six NDS Sites					
Criteria	Reno	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA	Tampa(FL)
Less than 9th grade(%)	5.2	3.8	3.5	3.7	3.4	4.1	4.7
9th to 12th grade, no diploma(%)	8.4	9.1	7.2	4.9	5.1	8.4	9.1
High School Graduate (GED)(%)	25.1	34.9	28.9	15.5	22.1	46.0	31.3
Some College, no degree(%)	27.3	19.8	18.5	16.9	23.0	14.0	21.6
Associates Degree(%)	7.5	6.7	11.4	6.9	9.4	7.6	9.1
Bachelor's Degree(%)	17.0	14.0	16.8	31.5	23.5	12.2	16.4
Graduate or professional degree(%)	9.6	11.7	13.7	20.7	13.6	7.8	8.0
	Rank for each Site	3	5	1	4	2	6

Table 29. City of Las Vegas Education Attainment Comparison

Education Attainment

Procedure:
Step 1: Using the education attainment for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1.

Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.

	Site	Six NDS Sites					
Criteria	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA	Tampa(FL)
Less than 9th grade(%)	8.3	3.8	3.5	3.7	3.4	4.1	4.7
9th to 12th grade, no diploma(%)	10.1	9.1	7.2	4.9	5.1	8.4	9.1
High School Graduate (GED)(%)	29.2	34.9	28.9	15.5	22.1	46.0	31.3
Some College, no degree(%)	24.3	19.8	18.5	16.9	23.0	14.0	21.6
Associates Degree(%)	7.0	6.7	11.4	6.9	9.4	7.6	9.1
Bachelor's Degree(%)	13.6	14.0	16.8	31.5	23.5	12.2	16.4
Graduate or professional degree(%)	7.5	11.7	13.7	20.7	13.6	7.8	8.0
	Rank for each Site	5	4	1	2	3	6

Household income is used as another metric for the decision matrix when comparing NDS study sites to the desired study site. The household income consisted of using the median household income as well as the mean household income in order to compare the criteria. Comparison of the household income serves as a way to determine demographics within the area of a city. The household income break down is shown in Fig. 17 for the City of Reno, NV and Fig. 18 for the

City of Las Vegas, NV, which can then be directly compared to the selected study site. When comparing the household income to the other criteria listed in the decision matrix it is important to determine the weight in relation to the importance of the criteria. The level of income does play a role in traffic incidents in fatalities which gives it a higher weight, but only slightly since the relation between traffic incidents and income varies only when there are large gaps so this is taken into consideration.

In using household income as a criteria here in the United States it should be noted that the median and the mean vary only slightly as opposed to that of other countries where gaps in income play a larger role in traffic safety. For the survey which was conducted the weight for household income was determined to be 5.3, which is the lowest weighted criteria of the group. The weight given for household income falls 1.1 points below the average of 6.4, therefore while household income does have a marginal effect on traffic safety as it is the least important according to the survey results with respect to the rest of the criteria. In countries such as the United States the median household income is relatively higher compared to that of other countries providing a higher standard of living. As shown by the Six NDS sites the income does not vary very much and the median income remains relatively close to each other. With such small fluctuations in the median and mean income the weight for household income will remain lower in comparison to the other criteria. When looking at income on an international level there is a correlation between the level of income and traffic incidents. High income countries in Europe have the lowest road traffic fatality rate (11.0 per 100,000 population) followed by those in the Western or Pacific Region (12.0 per 100,000) (13). This is in comparison to middle-income and lower-income countries such as the South-East Asia Region where the fatality rate is 18.6 per 100,000 (13). This should be kept in mind when comparing the various sites. The results are shown for the city of Las Vegas, NV and Reno, NV in Tables 30 and 31 respectively.

Table 30. City of Reno Household Income Comparison

Household Income							
Procedure: Step 1: Using the Household income for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1. Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.							
	Site	Six NDS Sites					
Criteria	Reno	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Median Household Income($)	55,724	42,917	48,805	64,460	65,400	40,000	51,905
Mean Household Income($)	74,656	56,300	64,959	85,114	86,729	54,819	68,071
	Rank for each Site	2	5	4	3	1	6

Table 31. City of Las Vegas Household Income Comparison

Household Income							
Procedure: Step 1: Using the Household income for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1. Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.							
	Site	Six NDS Sites					
Criteria	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Median Household Income($)	54,334	42,917	48,805	64,460	65,400	40,000	51,905
Mean Household Income($)	71,637	56,300	64,959	85,114	86,729	54,819	68,071
	Rank for each Site	2	5	4	3	1	6

Weather is another factor which was taken into consideration for the selection of a NDS study site. The weather data consisted of annual high temp, annual low temp, average temp, average annual rainfall, and the average annual snowfall. The weather information is an important factor for the comparison of the NDS study sites and the selected site to be compared. Weather has a direct impact on the safety of traffic and in order to select the most comparable site the weather pattern and information must fit that of the selected site closely. For the city of Reno, NV the most comparable site was Seattle, WA and for the city of Las Vegas, NV the most comparable city was also Seattle, WA, shown in Tables 32 and 33 respectively.

An important consideration for the decision matrix process is taking into account the weight of weather in comparison to the other criteria used in the analysis. Since weather does have a direct correlation with traffic safety it must weighed heavier than other criteria when the results are calculated in the decision matrix. Based on the survey conducted the weighted value for weather was determined to be 7.0, the highest out of the rest of the criteria factors and well above the average weight of 6.4. When looking into the impact of weather on traffic safety it is important to take note of how weather affects the drivers. An overall view of how weather impacts traffic safety shows that out of 5,870,000 vehicle crashes a year 23% or 1,312,000 are weather related incidents occurring in adverse weather (i.e., rain, sleet, snow, fog, severe crosswinds, or blowing snow/sand/debris) or on slick pavement (i.e., wet pavement, snowy/slushy pavement, or icy pavement) (7). Taking into account snow for example which data from Ontario, Canada shows that fatalities in January, February, and March are half of those in July mainly due to slower driving speeds in adverse weather conditions (1). While the number of crashes is lower because of slower speeds the average number of vehicles involved in fatal crashes on snow covered roads is substantially higher than on snow covered roads, on snow covered roads 55% of vehicles of fatal crashes are multiple vehicle compared to 43% on dry roads(1). Which are both aspects that should be taken into consideration when looking at the weather information.

Table 32. City of Reno Weather Comparison

Weather

Procedure:
Step1: For each matching criteria a point is given

Criteria	Site	Six NDS Sites					
	Reno	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Annual High Temp	67.6	63.4	56.3	70.2	60.3	59.1	81.7
Annual Low Temp	40.1	43.1	40.2	47.8	45	41.3	65
Avg. Temp	53.85	53.25	48.25	59	52.65	50.2	73.35
Avg. Annual Rainfall	7.39	47.32	40.47	48.1	37.13	39.6	46.31
Avg. Annual Snowfal	22	16	94	0	0	45	0
	Rank for each Site	4	1	5	6	3	2

Table 33. City of Las Vegas Weather Comparison

Weather		http://www.usclimatedata.com/					
Procedure: Step1: For each matching criteria a point is given							
Criteria	Site	Six NDS Sites					
	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Annual High Temp	80	63.4	56.3	70.2	60.3	59.1	81.7
Annual Low Temp	58.6	43.1	40.2	47.8	45	41.3	65
Avg. Temp	69.3	53.25	48.25	59	52.65	50.2	73.35
Avg. Annual Rainfall	4.17	47.32	40.47	48.1	37.13	39.6	46.31
Avg. Annual Snowfal	0	16	94	0	0	45	0
	Rank for each Site	4	1	5	6	2	3

The traffic safety laws were also added into the NDS study criteria which were a very important factor for traffic safety. Each of the safety laws taken into account are based on statewide traffic laws which are up to date based on the most recent data obtained from Governors Highway Safety Association where the highway traffic safety laws can be obtained from each state.. The safety traffic laws take into consideration the seat belt laws, the learning stage for drivers in the process of obtaining a license, cell phone laws, driving under the influence, and the speed limit. Each of these criteria factors are compared to the desired site and the NDS study site in order to find the most comparable NDS study site. The impact that the traffic safety laws have on the traffic safety is taken into account in the decision matrix by adjusting the weight factor accordingly. For the city of Reno, NV and Las Vegas, NV the results were the same for the ranking since these laws apply state wide. For the state of Nevada the most comparable site was Seattle, WA ranking a 6 as the highest rank shown in Table 34.

The weight factor for the traffic safety laws was determined by the survey in which the weighted value came to be 6.6, making it the fourth highest rated criteria used in the decision matrix. The traffic safety laws were weighted only slightly above the average of 6.4, this weight was a bit lower than expected but still has a large impact on traffic safety.

Table 34. State of Nevada Traffic Safety Laws

Safety Traffic Laws

Procedure:
Step 1: Step 1: Using the Race breakdown for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1.

Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.

Criteria	Site Reno	Six NDS Sites Bloomington(IN)	Score	Buffalo(NY)	Score	Durham(NC)	Score	Seattle(WA)	Score	State College(PA)	Score	Tampa(FL)	Score
Seat Belt	Secondary (age >6), All seats	Primary >15 all seats	0	Primary <16 in rear seats All in front seats	0	>15 in front seats Secondary >15 in rear seats	0	Primary >8 or >4'9" in all seats	0	>17 in front seats Primary 8-17 in all seats	0	Primary >5 in front seats 6-17 all seats	0
Learner Stage min age (yrs/mos)	15/6	15 with driver ed 16 w/out driver ed	1	16	0	15		15 with driver ed 15/6 w/out driver ed	1	16	0	15	0
Full privilege min age (yrs/mos)	Night: 18, passenger: 16/6	17 (passenger) with driver ed 17/3 w/out	1	17 with driver ed 18 w/out driver ed	1	16/6	0	18	1	and 12 mos no crash or conviction	0	18	1
Handheld Cell Phone Use	Banned for all drivers, primary	Not Banned	0	Banned for all drivers, primary	1	Not Banned	0	Banned for all drivers, primary	1	Not Banned	0	Not Banned	0
Text Messaging	Banned for all drivers, primary	Banned for all drivers, primary	1	Banned for all drivers, primary	1	Banned for all drivers, primary	1	Banned for all drivers, primary	1	Banned for all drivers, primary	1	Banned for all drivers, primary	1
Driving Per Se Laws for Drugs (Forbidding	Yes	Yes	1	No Law	0	Yes	1	Yes for THC	0	Yes	1	No Law	0
Speed Limit	75/75(Rural), 65/65(Urban), 70/70 (limited Access)	70/65 55/55 60/60	0	65/65 55/55 55/55	0	70/70 70/70 70/70	1	70/60 60/60 60/60	0	65/65 55/55 65/65	0	70/70 65/65 70/70	1
	Rank for each Site		5		2		2		5		1		2

The median driver age is also taken into consideration for the selection of NDS study site criteria. The driver age will have a large impact on the amount of traffic incidents and traffic fatalities therefore making it an important factor for the decision matrix. One important distinction is that the median driver age is not the median age for the population of the selected NDS study site. The median driver age is compiled by taking by taking into account the age break down of the population which is given in intervals of 5 years beginning with age 16 and calculating the value. The age groups were then adjusted to only represent the driving age of the population for the selected NDS study site, from this the median driver age was then calculated for each of the six sites. The median driver age consisted of eliminating the age groups under 15 years, which is the age group in which new drivers will begin to have driving privileges. The median driver age for the selected NDS sites is shown in Table 35.

With the large variance of the age of drivers determining the most comparable median driver age is an important factor in the calculation of the decision matrix. The impact on traffic incidents will be affected as the age increases for the population, in this case the median age. As the age of drivers increases so does the fatality risk, once the driver age exceeds 20 years old the fatality risk grows at a rate of 2.3% per year for males and 2.0% a year for females(2). At the age of 70 the fatality risk is about 3 times higher than the norm (2), making the age of drivers an important factor for use in the decision matrix. When taking the median driver age into consideration for the decision matrix, it is important to note the significance between the median driver age and other criteria for the decision matrix. The weight to be used in the decision matrix was determined by conducting a survey in which traffic safety experts can use their experience and background to give a weight to the median age. This weight, after conducting the survey, was determined to be 6.8, which was added into the decision matrix in order to calculate the most comparable site. This weight was the second highest rated criteria used in the decision matrix and signifies the view that the age of drivers does have a larger impact on traffic safety and number of incidents. The results for the city of Reno, NV and Las Vegas, NV are shown in Tables 35 and 36 respectively.

Table 35. City of Reno Median Driver Age Comparison

Median Driver Age							
Procedure: Step 1: Using the age distribution for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1. Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.							
	Site	Six NDS Sites					
Criteria	Reno	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Median Driving Age	42	42.1	46.8	40.6	43.2	45.8	44.8
	Rank for each Site	6	1	4	5	2	3

Table 36. City of Las Vegas Median Driver Age Comparison

Median Driver Age							
Procedure: Step 1: Using the age distribution for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1. Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.							
	Site	Six NDS Sites					
Criteria	Reno	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Median Driving Age	43.1	42.1	46.8	40.6	43.2	45.8	44.8
	Rank for each Site	5	1	3	6	2	4

The next set of data collected was crash data for the cities of Las Vegas, NV and Reno, NV. Crash data for the original six NDS sites was obtained from the SHRP2_S07 Report where this information was provided for injuries to drivers from crashes per 1000 population and also drivers in fatal crashes per 100,000 population. This data was used to compare the crash data for each of the NDS sites with that of the cities for Las Vegas and Reno for the state of Nevada. The data collected here is an important metric that is used to compare the crash statistics for each of the cities and study areas which can be used as a direct comparison for each of the sites. For injuries to drivers from crashes per 1000 population, comparing the six NDS sites, the study site of Buffalo, NY had a value of 9.61 which was the lowest value and a value of 27.35 for the study site of Bloomington, IN shown in Table 37. For drivers in fatal crashes per 100,000 the lowest value among the six NDS study sites was again Buffalo, NY and the highest NDS site was Bloomington, IN shown in Fig. 24. For the city of Reno, NV the injuries to drivers per 1000 population was 4.01 and for fatal crashes 6.44, which were both the lowest among NDS study sites shown in Figure 24. For the city of Las Vegas, NV the value for injuries to drivers was 18.46 and for fatal crashes 9.07 shown in Table 38.

The data obtained for the cities of Las Vegas, NV and Reno, NV were obtained from the police departments from each city who collected such data over the years for traffic related injuries as well as traffic related fatalities. These two data points are important in analyzing and comparing each of the sites to one another when taking into consideration the other various factors and are the result of such various factors.

Table 37. City of Reno Crash Data Comparison

Crash Data

Procedure:
Step 1: Using the Household income for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1.

Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.

	Site	Six NDS Sites					
Criteria	Reno	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Drivers in Injury Crashes per 1000	4.01	27.35	9.61	11.44	12.93	32.11	19.51
Drivers in Fatal Crashes per 100,000	6.44	42.75	6.99	11.30	8.82	35.90	26.14
	Rank for each Site	1	6	4	5	2	3

Table 38. City of Las Vegas Crash Data Comparison

Crash Data

Procedure:
Step 1: Using the Household income for each NDS site the the chosen site will be compared and the site which matchest the closest will be given a 6 and least closest a 1.

Step 2: After each mathcing criteria is given a point the options will be rated from 1-6. With 6 being the option with which matchest the closest to the slected site.

	Site	Six NDS Sites					
Criteria	Las Vegas	Bloomington(IN)	Buffalo(NY)	Durham(NC)	Seattle(WA)	State College(PA)	Tampa(FL)
Drivers in Injury Crashes per 1000	18.46	27.35	9.61	11.44	12.93	32.11	19.51
Drivers in Fatal Crashes per 100,000	9.07	42.75	6.99	11.30	8.82	35.90	26.14
	Rank for each Site	1	4	5	6	2	3

Data selection recommendation for Reno and Las Vegas

After each of the sites were ranked using the criteria from the NDS study site, the ranking of each of the sites was then transferred into the decision matrix where each site can be evaluated and directly compared against each other. The two sites that were chosen to compare against the NDS study sites were Reno, NV and Las Vegas, NV. Using these two sites the data was obtained allowing for a comparison to be done with the NDS study sites. It is important to note that when comparing the criteria for each of the cities in Nevada to that of the NDS study sites the same methodology for collecting the data and inputting the data was used allowing for a direct comparison.

From this the rank for each of the sites for that specific criteria can now be transferred into the decision matrix where all of the criteria can now be evaluated and a NDS study site can be selected based on the decision matrix shown in Figure 11. One important parameter in the decision matrix is the use of the weights for each of the criteria. The weights for the criteria determined from the survey, are reflected in the decision matrix as a percentage that each criteria carries and its impacts to traffic safety.

The results for the City of Reno, NV are displayed in Figure 12, in which the selected NDS study site was determined to be Bloomington, IN, based on the criteria entered into the decision matrix and the determined weights for the criteria. Shown in Figure 12 the ranking for the criteria was transferred into the decision matrix where the final value can then be calculated and the highest value results in the most comparable NDS study site to be used as a guidance. Using this approach a quantifiable value can be determined based on the background criteria, which gives a more accurate result when determining the NDS study site to be used as a guidance for data. The site Bloomington, IN received a score of 4.1 based on the criteria ranking and the weights for the criteria used. Once the decision matrix has selected this NDS site it is appropriate to use the data collected from that site, in this case Bloomington, IN. While more data would allow for a more accurate result the problem lies in being able to effectively collect all the necessary data from each specific sited since some may not be available. The data used in this decision matrix is information which can be easily obtained for each site as described earlier allowing for a general comparison of each site which takes into account the effects of traffic safety.

	Criteria								
List of NDS Study Sites	Geography Characteristics	Population	Education Attainment	Household Income	Weather	Traffic Safety Laws	Median Driver Age	Crash Data	Results
Bloomington(IN)	2	6	3	2	4	5	6	1	3.573
Buffalo(NY)	4	3	5	5	1	2	1	6	2.480
Durham(NC)	3	4	1	4	5	2	4	4	2.910
Seattle(WA)	1	1	4	3	6	5	5	5	3.131
State College(PA)	6	5	2	1	3	1	2	2	2.543
Tampa(FL)	4	2	6	6	2	2	3	3	2.961
Weight	6.4	6.8	5.4	5.3	7.0	6.6	6.8	6.7	51
Distribution	12.549%	13.333%	10.588%	10.392%	13.725%	12.941%	13.333%	13.137%	100%

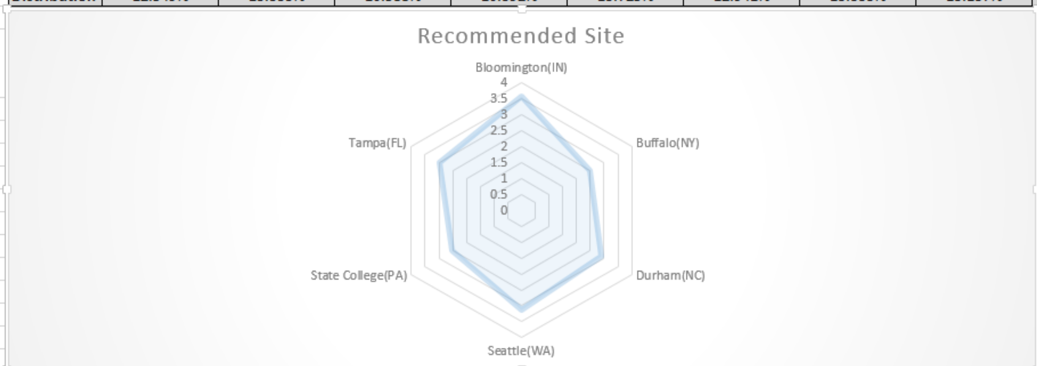


Figure 11. City of Reno Decision Matrix Output

The results for the city of Las Vegas, NV are displayed in Figure 12 where the selected NDS study site chosen, based off the criteria, was Seattle, WA. This result takes into account the background criteria for the NDS study site as well as the weights for the criteria. Figure 12 displays the decision matrix results for the city of Las Vegas, NV and how Las Vegas, NV compared to each of the NDS sites in matching the criteria. For the selection of this NDS site of Seattle, WA the weights for the criteria were each accounted for which had an effect in determining the final result shown below in the figure.

	Criteria								
List of NDS Study Sites	Geography Characteristics	Population	Education Attainment	Household Income	Weather	Traffic Safety Laws	Median Driver Age	Crash Data	Results
Bloomington(IN)	1	3	5	2	4	5	5	1	3.125
Buffalo(NY)	2	4	4	5	1	2	1	4	2.257
Durham(NC)	5	5	1	4	5	2	3	5	3.161
Seattle(WA)	6	1	2	3	6	5	6	6	3.680
State College(PA)	3	6	3	1	2	1	2	2	2.269
Tampa(FL)	4	2	6	6	3	2	4	3	3.231
Weight	6.4	6.8	5.4	5.3	7.0	6.6	6.8	6.7	51
Distribution	12.549%	13.333%	10.588%	10.392%	13.725%	12.941%	13.333%	13.137%	100%

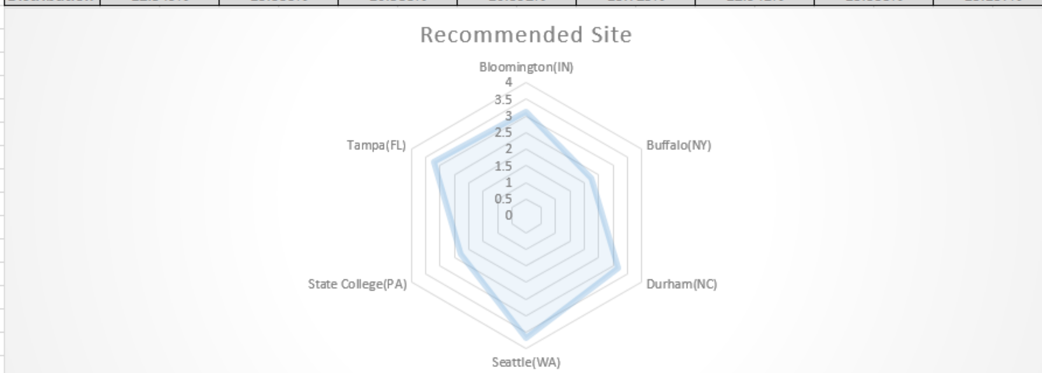


Figure 12. City of Las Vegas Decision Matrix Output

Fig. 27: City of Las Vegas Decision Matrix Output

5. TRAFFIC SAFETY ANALYSIS USING SHRP 2 NDS DATA

The research team has reviewed recent research activities of applying SHRP 2 NDS data for traffic safety analysis [16] and one application for driving cycle analysis which is not directly related to safety. The non-safety example is to show that the new SHRP 2 safety data can be used traffic analysis more than safety.

5.1 Assessing the Influence of Driver, Vehicle, Roadway and Environmental Factors on Pedestrian-Turning-Traffic Crashes at Intersections

Research team

University of Nevada, Reno

Research objective

Vehicle drivers are expected to yield to pedestrians when there are conflicts, however drivers may fail to see pedestrians and react to pedestrians when they are influenced by various factors such as the surrounding traffic, intersection geometric, vehicle condition or driver condition. This Implementation Assistance Program (IAP) project sponsored by SHRP 2 is to study how driver, vehicle, roadway and environmental factors affect the turning-drivers vision and yielding to pedestrians at intersections with the RID and NDS data.

Data used

To answer the question of how driver, vehicle, roadway and environmental features affect the turning driver's vision of conflicting pedestrians, the RID data and NDS data at selected intersections were requested. The NDS data included time series records (sensor data records) and front videos of 600 trips collected at 6 intersections including 4 intersections in Washington and 2 intersection in Florida. Driver videos of the 600 trips were reviewed and analyzed at the VTTI data enclave. The 4 intersections located in Washington consist of the highest pedestrian-crash frequencies for the years 2006-2013. They were selected to analyze the driver's behavior which may have caused the high crash frequency. The two intersections in Florida were selected to compare the possible influence of the "Right Turning Yield to Pedestrian" signs. One of the Florida intersections had the signs installed, while the other one is a similar intersection and in a similar area but without the "Yield to Pedestrian" signs. The roadway information was in the Geographic Information System (GIS) data format also located by the linear referencing system (LRS). The ESRI GIS software package ArcGIS was applied to process the SHRP 2 RID data.

The crash data were first selected by location, in the 300 feet radius range of the intersection nodes, in order to identify the intersection crashes. The results were further queried by the number of pedestrian involved (>0) and vehicle actions before the crash (turning left/turning right). The final query results were the crashes between pedestrians and turning vehicles which occurred at intersections. The pedestrian-turning-vehicle crashes were then joined with the RID intersection layer, the supplemental Highway Performance Monitoring System (HPMS) layer (roadway properties), the RID alignment layer (detailed curve data) and the RID location layer (grade and cross slope data). After the spatial join procedure, a new pedestrian-turning-vehicle dataset was generated by integrating the crash attributes with its related road and intersection attributes.

An IRB approval letter was obtained from the Research Integrity Office of the University of Nevada, Reno (UNR), and all researchers directly working on the NDS data received their IRB training certificates.

Research methods

Analysis of Historical Crash Data and RID Data

Although the crash frequency has been analyzed by several existing studies, the crash data analysis was also performed for possible new findings or to update to conclusions by existing studies. The pedestrian-turning-vehicle crash frequency was studied for different times and dates, movement direction, severity, road conditions, driver situations and vehicle types. The frequency study is to identify the influencing factors of road, driver, vehicle and environment.

Driver Observations and Influencing Factors

The extracted driver observation behavior records include the attributes in Table 24, and the other extracted attributes related to the trips are in Table 25 and Table 26. A critical attribute is the observation type which were originally defined by VTTI in the "Eyeglance Definitions for SHRP2 Event and Baseline Video Reduction" Table 27.

Table 39. NDS data elements for phase I study

Time Series Data		Driver	Vehicle
day_of_week	vtti.odometer	age group	model year
file_id	vtti.pedal_brake_state	gender	vehicle classification
vtti.accel_x	vtti.pedal_gas_position	education	vehicle make
vtti.accel_y	vtti.range_rate_x_tn	work status	
vtti.accel_z	vtti.range_rate_y_tn	race	
vtti.elevation_gps	vtti.range_x_tn		
vtti.heading_gps	vtti.range_y_tn		
vtti.latitude	vtti.speed_gps		
vtti.longitude	vtti.speed_network		
vtti.month_gps	vtti.timestamp		
vtti.number_of_satellites	vtti.year_gps		
vtti.object_id_tn			

Table 40. Attributes extracted from driver face videos

Attribute	Description
File_ID	The file_id attribute of the trip record defined by VTTI
Event ID	The event_id attribute of the trip record defined by VTTI
Intersection ID	The intersection_id attribute of the intersection where the turning movement occurred
Turn	Turning direction: left turn/right turn

Begin Timestamp	The beginning timestamp for turning movement
End Timestamp	The end timestamp for turning movement
Weather	The weather condition when the turning movement occurred
Day/Night	The day/night condition when the turning movement occurred
Work Zone (Yes/No)	Whether there was a work zone at the intersection when the turning movement occurred
Sunglasses (Yes/No)	Whether the driver was wearing sunglasses
Observation ID	The ID of an observation record. Observation records of each trip start with ID number 1
Rear View Vehicle	Whether there was another vehicle following the NDS vehicle
Begin Timestamp of Observation	The beginning timestamp of an observation
End Timestamp of Observation	The end timestamp of an observation
Observation Type	The observation definitions for SHRP 2 by VTTI
Observation Target	The target of an observation, such as pedestrian, vehicle, traffic sign and traffic signal
Traffic_Signal	The traffic signal status when the vehicle arrived at the stop line
Note	Note

Table 41. Traffic condition attributes extracted from front videos

Attribute	Description
Conflicting Ped No.	The number of pedestrians who were going to cross the intersection and may conflict with the NDS vehicle
Total Pedestrian No.	The total number of pedestrians around the intersection, including the conflicting pedestrians
Yield to Pedestrian (Yes/No)	Whether the NDS driver yield pedestrians
Conflicting Traffic Direction	The conflicting traffic directions when the NDS vehicle was yielding to traffic in other directions
Conflicting Traffic Volume	The total conflicting vehicle numbers when the NDS vehicle was yielding to traffic in other directions
Conflicting Traffic Start Timestamp	The start timestamp when the NDS vehicle was yielding
Conflicting Traffic End Timestamp	The end timestamp when the NDS vehicle was yielding

Table 42. Driver observation types in Eyeglance Definitions

Type 1	Left Windshield
Type 2	Right Windshield
Type 3	Rearview Mirror
Type 4	Left Window/Mirror

Type 5	Right Window/Mirror
Type 6	Left Over-The-Shoulder
Type 7	Right Over-The-Shoulder
Type 8	Instrument Cluster
Type 9	Center Stack
Type 10	Cell Phone (electronic communications device)
Type 11	iPod (or similar MP3 device)
Type 12	Interior Object
Type 13	Passenger
Type 14	No Video
Type 15	No Eyes Visible- Glance Location Unknown
Type 16	No Eyes Visible. Eyes Are Off-Road
Type 17	Eyes Closed
Type 18	Other

The frequency of different observation types were analyzed for the different factors and factor values (ranges). High frequency with observation Type 1 through type 7 are considered to be behavior helping the drivers to better see pedestrians at an intersection. Type 8 to Type 17 may distract drivers from their driving task and cause drivers fail to see pedestrians. High frequency with these behavior are considered to be high risk for pedestrians. As the observation behavior can be very different for right turning drivers and left turning drivers on the same approach of the same intersection, the observation behavior analysis was performed for right-turning and left-turning separately. Stage, day time (day, night, sunset/sunrise), signal condition, conflicting traffic flow, conflicting pedestrian, total pedestrian at the intersection, driver age group, driver gender, driver work status, driver education, and vehicle type were analyzed as possible influencing factors in order to find their impacts on the different driver behavior.

Research results

It was found that different factors influence driver observation behavior at different levels.
One example is shown in Figure 11 which is the comparison of right-turn driver observation at different conflicting traffic flow rates. The conflicting traffic is the vehicles to which a turning driver needs to yield before the turning activity. The comparative study of crash frequency and behavior shows the connection between the pedestrian crash frequency and the frequency of specific observation types. However, it should be noted that this conclusion is based on limited data at the four intersections. More accurate description of the relationship needs to be developed in Phase 2 study with sufficient NDS data. It was also concluded that that the traffic signs encouraged drivers to check both direction more often, which can reduce the risk of pedestrian-turning vehicle crashes.

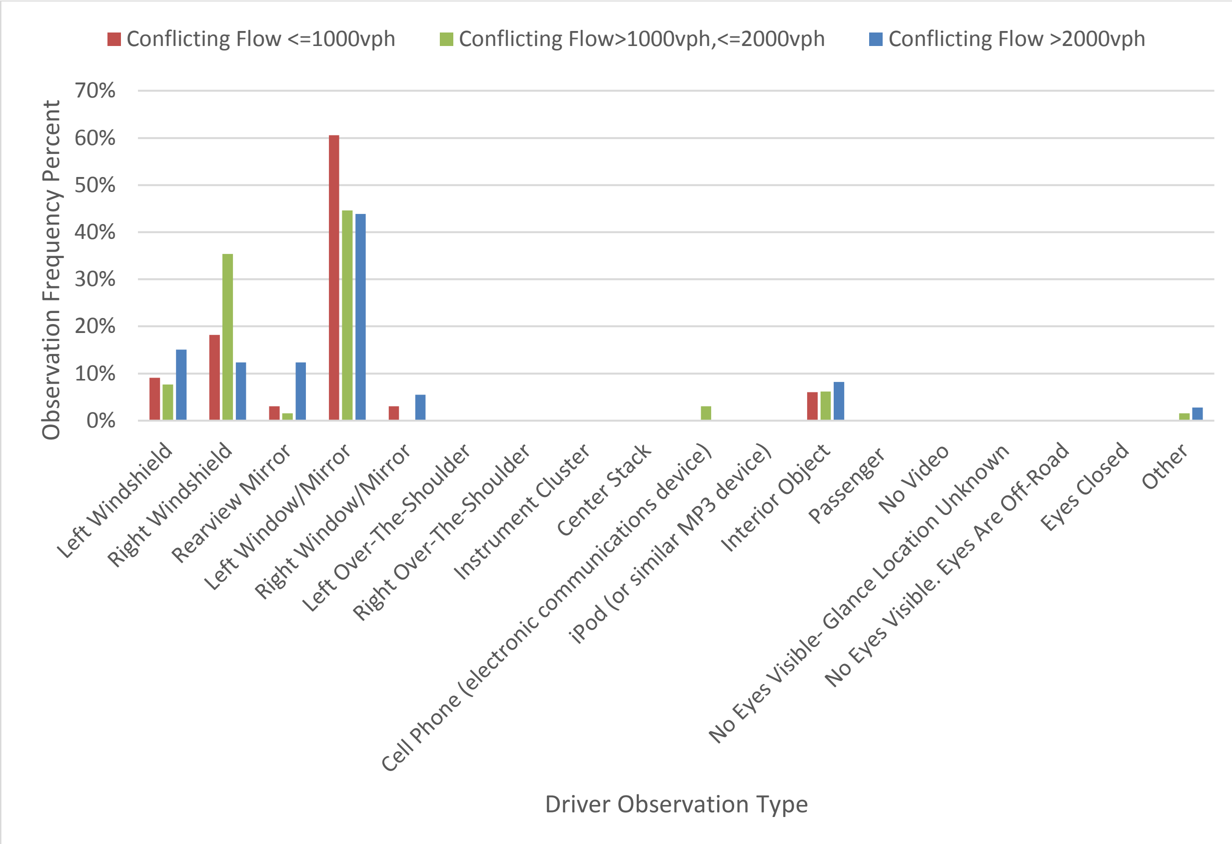


Figure 13. Driver observation with different conflicting traffic flow (right turn)

5.2 Crashes and near crashes involving more than one vehicle at intersections

Research team

University of Minnesota.

Research objective

The project was on crashes and near crashes involving more than one vehicle that occurs at intersections.

Data used

The data used in this project included: 1) data from the VTTI 100-car NDS study (a NDS study before the SHRP 2 one) [14], 2) using site-based video data from the University of Minnesota's Beholder system, 3) using site-based Doppler shift data collected by the University of Minnesota's Intelligent Vehicles Laboratory as part of the CICAS project.

Research methods

The team using a simple braking-to-stop model applied to trajectory data extracted from site-based video and then illustrates how once a fitted model is at hand, it is possible to quantify the expected number of crashes in a set of non-crash events. Then they takes up the problem of extending these ideas to more complicated situations, and the project team proposes a modeling strategy where driver behavior is treated as a piecewise constant sequence of acceleration changes. Given such an acceleration history and initial values for a vehicle's location and speed, it is logical to move toward a system of ordinary differential equations to get predicted histories of the vehicle's speed and position. Fitting such a model then involves identifying the appropriate break points in the acceleration profile, the corresponding acceleration levels, and the initial conditions that best fit observed trajectory data. The team illustrated model identification and estimation using speedometer, radar range, and radar range rate data for a near-crash event from the 100-car vehicle-based study. The team also illustrated a what-if counterfactual analysis where the final deceleration of the following vehicle is varied over a range of values, for each of which, other things being equal, the probability that a collision would have resulted is computed.

Research results

At least for situations where direction of travel is roughly constant, trajectory-based reconstruction of crash-related events, where trajectory data are used to fit parsimonious models of driver behavior, is feasible using both vehicle-based and site-based data.

It is possible to extend the methods of counterfactual analysis to more complicated structural models involving differential equations.

At least for rear-ending events, there is some limited evidence that the distributions of evasive actions for crashes and near crashes share some overlap, so that it should be possible to find near-crash events that are similar in other respects to crashes.

The usefulness of the data produced by the SHRP 2 vehicle-based field study will be strongly dependent on the ability to calibrate and maintain the data-collection systems.

5.3 Lane departure

Research team

Center for Transportation Research and Education (CTRE), Iowa State University

Research objective

The research focused on answering rural two-way-two-lane lane departure questions. Another goal of the research was to determine what data would be necessary to answer the identified lane departure research questions.

Data used

The team reviewed existing naturalistic driving study and roadway data to determine whether it was feasible to obtain each data element identified. This exercise provided insight as to whether data elements were likely to be available in the SHRP 2 field study and how feasible it would be to extract elements that were not readily available.

The team obtained a number of events from field operational tests conducted by the University of Michigan Transportation Research Institute (UMTRI) for a road departure curve warning system. The events contained instances where the drivers left their lane, as well as normal driving data on rural roadways. Raw data from their instrumentation system included vehicle variables (e.g., vehicle location, forward speed, forward acceleration, yaw, pitch, lateral acceleration) that were provided at 10 Hz and forward images that were provided at 2 Hz. Roadway and crash data were also obtained for the UMTRI study area from the Michigan Department of Transportation (MDOT).

The team also received 33 crash or near-crash lane departure events from the VTTI 100-car naturalistic driving study for rural roadways. A reduced data set rather than raw data was provided for each event for most variables. A video clip showing views outside the vehicle was also provided.

Research methods

Both the UMTRI and the VTTI data were examined to determine the feasibility of extracting relevant driver, vehicle, environmental, and roadway factors. The availability of the data in the UMTRI and VTTI databases were reviewed and the limitations described.

Four analytical approaches were identified that can be used to evaluate the data resulting from the SHRP 2 field study:

1. Data mining using classification and regression tree analysis;

2. Simple odds ratio and logistic regression;

3. Logistic regression for correlated data that accounts for repeated sampling among observations (e.g., repeated sampling for the same driver, trip); and

4. Time series analysis.

Research results

Method 1 (classification and regression tree) and Method 2 (simple odds ratio and logistic regression) evaluated the likelihood of a left- or right-side lane departure. A sample-based data aggregation approach was used in the classification and regression tree analysis, and an event-based data aggregation approach was used for the logistic regression. Although available sample sizes were limited, both methods produced similar results. Both indicated that curve radius, driver age, and type of shoulder were relevant in explaining lane departures. Logistic regression also indicated that both left- and right-side lane departures were more likely to occur at night and were less likely to occur as lane width increased. The model for left-side lane departures indicated that male drivers were more likely than female drivers to be involved in a lane departure, and the model for right-side lane departures indicated that lane departures are more likely on roadway sections with a higher density of lane departure crashes and for drivers who spend more time traveling 10 mph or more over the posted speed limit. The third method expanded on a varied logistic regression approach based on the logistic regression model just described, which may be better suited to the data from the full-scale study. The fourth method, time series analysis, used continuous data to develop a model to predict offset as a function of several vehicle kinematic variables. The method was developed and explained in such a way that it could be adapted to the SHRP 2 field study to include various explanatory variables, including driver behavior. This approach allows information, such as driver distraction in previous time periods, to be incorporated into the model.

5.4 Pre-crash events and roadway departure

Research team

Pennsylvania State University

Research objective

The research objective is to examine the relationship between various pre-crash events and identified methodological paradigms that can be used to answer research questions specific to roadway departures.

Data used

- The Penn State team used the following data:
- data collected by the Virginia Tech Transportation Institute (VTTI) during the 100-car naturalistic driving study [14]
- data from the automotive collision avoidance system [15]
- the road departure crash warning (RDCW) system field operational test conducted by the University of Michigan Transportation Research Institute (UMTRI).

Research methods

Two parallel tracks were pursued in the analysis of the 100-car study data: event-based modeling and driver-based modeling. The first approach modeled the occurrence of each event in detail. The focus was on understanding the interactions of the many factors that led to event occurrence. This initiative fit nicely with the data provided by VTTI, as it allowed events to be compared at three levels:

- Crash—any contact with an object, either moving or fixed, at any speed, in which kinetic energy is measurably transferred or dissipated;
- Near crash—a circumstance that requires a rapid, evasive maneuver by the subject vehicle, or any other vehicle, to avoid a crash; the maneuver causes the vehicle to approach the limits of its capabilities (e.g., vehicle braking greater than 0.5 *g* or steering input resulting in lateral acceleration greater than 0.4 *g*); and
- Crash-relevant incident (in this report referred to as a critical incident)—a circumstance that requires a crash avoidance response on the part of the subject.

Penn State developed a structured analysis framework for these event-based data; the model specified driver attributes, the context in which the event occurred (including roadway and environmental variables), and attributes describing details about the event itself, particularly in the few seconds before and during the event. Examples of event-level variables include whether the driver was observed to be distracted just before the event and whether the vehicle crossed over the lane or road edge. One may think of these models as exploring the details of factors associated with the events.

Various model formulations were used to find variables associated with crashes and near crashes, and the attributes of vehicle motion associated with such events (e.g., vehicle over lane or road edge) that could serve as surrogate measures for crashes were investigated. If these event related measures were shown as being positively associated with a crash or near-crash event, they were considered as potential surrogates. A set of non-incident control events was received with the original data, but it was not useful in the modeling because it contained none of the predictors used in the event analysis. The team tested the specific measures available in the data set and attempted to supplement the available vehicle kinematic data by downloading information from the NHTSA website. Unfortunately, kinematic data were only available for a small number of rashes; near crashes and critical incidents were not represented, and this approach was, therefore, abandoned.

Research results

The VTTI data set was primarily used to answer this question. The general structure of the event-based models was to use predictor variables representing driver, context (i.e., roadway and environment), and event attributes. Models were estimated with context-only, driver-only, and event-only variables (and combinations of only two of these components). Resulting parameter estimates changed substantially depending on how many of the three components were represented in the model; importantly, the exclusion of any of the components led to major changes in estimated parameters (see Chapter 3). The exclusion of any of the set of variables (i.e., driver context, or event) is likely to result in biased parameter estimates, obscuring the effect of any one variable on event occurrence. To avoid this bias, future analyses of SHRP 2 event-based data (such as in proposed research for the S08 project) should include variables representing driver, context, and event attributes. In addition, thorough tests should be conducted to explore changes in parameter values and significance. The Penn State team is concerned that parameter estimates may exhibit the same characteristics, even in data sets with large sample sizes.

The strongest variables (i.e., those showing the greatest association with crashes or near crashes) were the driver distraction variables. The efficacy of using categorical-outcome models (such as logit or binary hierarchical models) to compare crash and non-crash events was explored within the limits of the VTTI data by comparing crash and near-crash events (combined) with critical incidents.

Gender was important in both driver- and event-based models.

Two hierarchical models are reported with the VTTI data: one was applied to event modeling and the second to driver-based models. A third hierarchical model was estimated with the UMTRI data using a cohort approach.

5.5 Associations among highway factors, crashes, and driving behavior for road-departure crashes

Research team

University of Michigan Transportation Research Institute

Research objective

The research focused on capturing the associations among highway factors, crashes, and driving behavior for road-departure crashes.

Data used

The group uses UMTRI Naturalistic Driving Data, and Highway Data and cash data from same region.

Research methods

Further research questions were formulated around the variables and methods for performing a joint analysis of the crash data and driving data. As a starting point, a common measure of exposure was found in the form of normalized road segment traversals. The same road segment definitions were used for both data sets, though segments with zero exposure in the NDD were excluded from the study. A unified approach was adopted for the combined analysis of crash rates and surrogate events. The seemingly unrelated regression (SUR) method was adopted because it allows for the use of common explanatory variables in the two data sets and is flexible enough to include additional explanatory variables that are not available in both. This is an important property for future analysis in SHRP 2, in which driver attention variables may be included in the explanatory set for NDD (and no such quantitative information is usually available for crashes). Bayesian estimation was used to determine posterior distributions of the SUR model parameters and also to estimate relative risk (RR) between surrogate and crashes. The posterior distributions of the logarithm of the relative risk (log RR) provided a set of validity tests of the surrogate used. The difference in log RR between crash and surrogate events should be zero for any particular comparison, meaning that zero should be contained within an associated confidence interval. On the one hand, it was found that the simplest surrogate, LDEV, did not satisfy this criterion in the case of a curve/no-curve comparison, and therefore LDEV was not seen as acceptable for use as a crash surrogate. On the other hand, the corresponding log RR distributions for LDW and TTEC did satisfy this criterion. This analysis was not exhaustive, and was conducted as an exemplar of the method. In the future it will be important to increase the number of explanatory variables (including driver attention variables, if available) and apply multiple log RR comparisons to prioritize the wider range of metrics for lane-keeping control.

Since TTEC was found to be a reasonable candidate crash surrogate, its distribution of extremes was applied to the prediction of road departure frequencies for a single example road segment. By using extreme value theory and annual average daily traffic (AADT) counts, it was possible to estimate the number of road departures. An estimate of 12 road departures per year was obtained, compared to the actual crash number of 1.8 per year (police-reported, single-vehicle road departure crashes, averaged over a 5-year period). Since not every road departure is expected to result in a crash, this sample result is considered plausible at least. The crucial point is that a validated surrogate was needed for this type of analysis, and the surrogate needed be based on an underlying continuous variable.

Research results

Overall, this exploratory study has demonstrated the use of the SUR analysis method for the combined analysis of crash data and naturalistic driving data. The approach provides a way to assess crash risk in a common framework and to validate or invalidate candidate surrogates. More detailed analysis of individual sites can be carried out by using extreme value theory, though it is important that surrogates be continuous and display the same RR as measured crash data. Although only a small number of surrogates were analyzed, the study demonstrates the importance of surrogate choice, and a new metric—the YRE—has been defined and proposed for use in future statistical analysis. When YRE is applied to data from the future SHRP 2 NDS, the increased statistical power resulting from the much larger data set will provide more definitive conclusions about surrogate validity and factors influencing overall crash risk.

5.6 Driving cycle development with SHRP 2 NDS data

Research team

University of Nevada Reno

Research objective

Improve the Vehicle Operation Cost (VOC) estimation of different road conditions (such as access control, lane number, speed limit, horizontal alignment and grade) and different traffic condition (Level of Service). The research first developed driving cycles of different road and traffic conditions with the SHRP 2 NDS data. Then the fuel consumption and other operation cost is estimated based on the driving cycles.

Data used

4,400 trips (minimum 20 minutes for each trip) collected at the six NDS sites (approximately 50% rural trips and 50% urban trips) from the SHRP 2 NDS data. For the driving cycle development, the SHRP 2 RID data were obtained from the Center for Transportation Research and Education (CTRE) at the Iowa State University and pre-processed for use in this study.

Research methods

The road segment grouping procedure was performed to classify the different highway scenarios. The procedure took into consideration the roadway properties of access control type, area, facility type, one-way versus two-way, one direction through lane number, speed limit, the horizontal curve level, and grade level. The SHRP 2 NDS time-series data and vehicle front videos were obtained from the Virginia Tech Transportation Institute (VTTI). Trip speed of the different vehicle types were extracted by using the NDS sensor data and front videos. Light duty vehicles profiles were directly extracted from the NDS time series data which includes speed, acceleration, location, time and other trip data of the volunteer vehicles. Trip speed profiles of the other vehicle types were generated by integrating the NDS volunteer vehicle location, speed, front radar data and forward videos to extract leading vehicle data. The leading vehicle's type can be identified by the front video, and its speed can be calculated with the NDS vehicle speed and relative speed between the NDS vehicle and the leading vehicle. The extracted or generated trips were map-matched onto the RID road segments based on the Global Positioning System (GPS) coordinates and grouped based on the properties of matched road segments. The trips of each scenario accommodate different traffic conditions which could be described by Levels of Service (LOS). The LOS standard in the Highway Capacity Manual (5) defines the traffic flow quality by using letters A through F. The LOS levels are connected to different traffic densities, delays, or average travel speeds. For full-access-control facilities, the average travel speed of each trip was calculated by dividing the total travel distance by the total travel time. Trips for each highway scenario were further grouped into different LOSs (A, B, C, D and E) based on their average travel speeds which accommodates the different traffic conditions. The generated trip speed profiles were then used for development of driving cycles.

Research results

As a major component of the project to improve vehicle operation cost estimation models, driving cycles of different vehicle types, traffic conditions, and road properties were developed for the access controlled facilities. The driving cycle development was based on the SHRP 2 RID and NDS datasets which offer significant advantages from the perspectives of size and data details.

6. CONCLUSION AND RECOMMENDATION

SHRP 2 Safety Data, including the NDS data and the RID data, provide a continuous description of drivers, vehicles roadways and environments. The NDS data includes time-series records from the sensors installed on the volunteer vehicles and multi-directional video clips. The RID contains comprehensive roadway and environmental data related to the NDS road network. The SHRP 2 dataset is currently considered to be better than other existing transportation datasets in the U.S. when taking into consideration the information details and data size. The SHRP 2 Safety Data will play a significant role in research for traffic safety improvement.

It is known that the SHRP 2 Safety Data has a limited coverage of the country, so it is a common question for traffic safety engineers to select the appropriate data for a local study. The use of the data comparison procedure for each of the sites can be compared, and the decision matrix allows researchers to best select a NDS site that is most comparable to study. This tool serves as a guidance which allows user to effectively compare and analyze site criteria and determine which NDS site best compares and use the data from that site. The decision matrix uses 8 criteria points as the 8 background area attributes, while it may be beneficial to add more criteria points it becomes more difficult in trying to obtain and manage more data. The data used for the criteria is readily available and the process is fairly simple, more criteria points may be added but with more criteria points it becomes more difficult in obtaining the data and based on the survey this criteria should suffice as a general guidance tool. If a more in depth analysis is needed for a specific site more criteria can be added and the same format can be followed in order to obtain a comparable site that suits the user’s needs. The tool’s main purpose serves as a guidance but as mentioned can be refined to suit the user’s preference such as focusing the criteria on number of traffic incidents at a specific location. As of now this tool can provide the most comparable NDS site based on the criteria previously discussed. The proposed procedure can be further improved by calibrating the attribute weight values in the matrix by using statistical methods.

When the importance and advantages of the new SHRP 2 NDS Data has been repeated in different reports and papers. Data users should also understand some limitations of the dataset. Only six areas were involved in the data collection may bring bias to research results. Data service cost can be high and required time for data preparation can be long. Before applying the data into a specific research, the researchers are responsible to verify the data quality and pre-process the data to make sure it can serve the research objective. The driver behavior videos are significant and unique data in the SHRP 2 NDS dataset, but they can only be studied at the VTTI data enclave for now. Travel schedule and budget need to be planned well.

7. REFERENCE

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APPENDIX A. IRB Approval Letter for SHRP 2 NDS Data Request

University of Nevada, Reno

Research Integrity Office
218 Ross Hall / 331,
Reno, Nevada 89557
775.327.2368 / 775.327.2369 fax
www.unr.edu/research-integrity

DATE:	October 14, 2014
TO:	Hao Xu
FROM:	University of Nevada, Reno Social Behavior and Education IRB
PROJECT TITLE:	[669020-1] SHRP 2 Safety Data: Different road factors on driving cycles
REFERENCE #:	
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF NOT HUMAN SUBJECT RESEARCH
DECISION DATE:	October 14, 2014

Thank you for your submission of New Project materials for this project. The Research Integrity Office has reviewed the scope of work for the above referenced project, and determined that it does not require human research protection oversight by this Institution Review Board.

Project Summary:The GPS trajectory data, vehicle front videos, vehicle computer data and radar sensor data on specified road facilities will be analyzed. No drivers' videos or origin-destination data or identifiers will be included.

The regulations at 45 CFR 46.102(d) state: "Research means a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge."

The regulations at 45 CFR 46.102(f) state: "Human subject means a living individual about whom an investigator (whether professional or student) conducting research obtains (1) Data through intervention or interaction with the individual, or (2) Identifiable private information."

If you have any questions, please contact Nancy Moody at 775.327.2367 or nmoody@unr.edu. Please include your project title and reference number in all correspondence with this committee.

Sincerely,

Nancy Moody JD MA
Director, Research Integrity Office
University of Nevada Reno

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Nevada, Reno Social Behavior and Education IRB's records.

APPENDIX B. NDS DATA AGREEMENT

Data Sharing Agreement

Offsite Use of Non-Identifying Driving, Vehicle, Participant, and Crash Data

Disclaimer: This data sharing agreement template has been developed in accordance with the terms specified in the consent forms that participants signed and thus represents a required minimal set of safeguards for participant data. Additional safeguards going above and beyond what the consent document requires may be specified by the individual Institutional Review Boards as they review requests for analyses of the data. Thus, any future modifications or additions to this template will provide additional protections for the use of participant data and will never reduce the protections accorded in the consent document.

Use of Identifiable Video and Driving Data in Secure Data Enclaves
When a researcher, research team, or research institution (hereafter referred to as the receiving agency) requests access to an existing SHRP 2 dataset containing identifying data, the data analysis shall be conducted in a designated secure data enclave within VTTI's facilities. Identifying data for the purposes of this agreement include face video, GPS coordinates, and any other data by which the identity of the participant may be revealed. In this situation, the client comes to the data warehouse site to run analyses in coordination/cooperation with VTTI researchers. The data enclave will be physically and securely separated from other data reduction and analysis efforts at VTTI. All work will be monitored and supported by VTTI staff and completed within the confines of the enclave. There will be an hourly all-inclusive fee for use of the enclave/data which will include the cost of VTTI support.

Release of Non-Identifying Driving, Vehicle, Participant, and Crash Data
Release of streamed data describing driving epochs requires thorough de-identification of data prior to release. De-identification activities (performed by VTTI personnel) and shipping costs will be paid for by the receiving agency. De-identification includes removing at a minimum:

- Dates and times (for example, March 15, 2010 06:45am could be changed to March, Monday, 6am-12pm)
- Voiceprints
- Full face photos, videos, & comparable images
- De-identifying GPS coordinates
- Full trip files with starting and ending locations shown via forward video
- Files with identifiable highway signs and footage of a high-profile incident (such that research participant identity could be uncovered via news reports)
- Any other types of data that could be used to identify a research participant
- Data Sharing Agreement

- Use of the data enclave and offsite use of non-identifying driving epochs requires a data sharing agreement signed by the receiving agency. This document indicates agreement with the following:
- The receiving agency must provide a detailed proposal with researcher qualifications prior to beginning work with the dataset. Qualifications should indicate familiarity with and previous use of confidential or proprietary data using human research participants.
- The receiving agency must first obtain IRB permission to conduct the data analysis, and all parties who will be working with identifying data must undergo IRB training. The original research participant consent form will be shared with the receiving agency as part of this process (attached, with data sharing clauses highlighted).
- The receiving agency may not copy or remove files containing identifying data from the data enclave. Reduced, non-identifying files will be provided to the receiving agency by VTTI staff. To ensure data have been de-identified, it may be necessary for VTTI staff to further review the content of files before delivery.
- All personnel working with the data must agree to the working conditions such as leaving cell phones and cameras at the entrance of the data reduction laboratory.
- The receiving agency must agree not to attempt to learn the identity of research participants (e.g., using GPS and video data to locate the research participant's home or work address).
- If the receiving agency discovers identifying information or data in a dataset that was intended to be non-identifying, they must agree to provide that information to VTTI so that it can be properly de-identified for future use (for example, a pedestrian's face is visible and identifying in the forward view).
- The receiving agency must agree not to use data for purposes other than specified in the analysis plan; an additional data sharing agreement will be required for each new set of analyses.
- The receiving agency must agree not to show any identifying data at research conferences.
- The receiving agency agrees to properly acknowledge the source of the data in any reports or articles resulting from the analyses.
- Optional: The receiving agency agrees to return the reduced dataset to VTTI for to be made available to future researchers. In some cases the reduced dataset will have a proprietary nature and can be placed on hold for up to five years before it is provided to other researchers (for example, an OEM develops a crash avoidance algorithm that they hope to incorporate in their future fleet).
- All personnel who will be working with the data must agree not to release or share information leading to the identification of participants or to release or share non-identifying raw data.

Instructions – please fill out the form and send it back to the Data Sharing Manager at VTTI (datasharing@vtti.vt.edu). The Data Sharing Manager will review the information and send it back to you. You may then sign it and either send a scanned copy of the signed form to datasharing@vtti.vt.edu or fax it to 540-231-1555, attn. Suzie Lee. The Data Sharing Manager will then sign the form and send it back to you, at which point the data sharing process will begin, assuming that the appropriate fiscal contracts are in place at that point.

Data Sharing Agreement between Receiving Agency and Virginia Tech Transportation Institute.

1. Please describe the scope of the proposed analysis (1 paragraph). Please include the full project title and the research sponsor.

Project Title: Enhanced Prediction of Vehicle Fuel Economy and Other Vehicle Operating Costs

Project Sponsor: FHWA

The proposed analysis with NDS data: It is critical to improve the VOCs estimation by taking consideration of changes in vehicle technology and extended transportation factors, such as lane numbers, speed limit, horizontal alignment and grade. One of the key tasks for improving VOCs estimation is to develop driving cycles for different vehicles in different transportation scenarios. A driving cycle in the VOCs context is a vehicle speed-time profile, which is normally one hertz vehicle speed. The cycles are a critical input for simulating fuel consumption of different road situations, and are also a required input for advanced fuel consumption estimation tools. The research team has identified the SHRP 2 Safety Data as the new data source for developing driving cycles of different transportation scenarios. The SHRP 2 Safety Data is new, comprehensive, and large, which can be used to significantly extend existing driving cycles. The methodology for developing driving cycles has been selected and adjusted with considerations given to the new data source. It is based on the method used by Sierra Research in its 'Development of Generic Link-Level Driving Cycles' study in 2008.

1. Please describe the dataset you expect to receive (1 paragraph).

For the first step of data analysis in this project, we are requesting the time-series data collected in King County and Snohomish County of Washington State. Since this project needs to use as much trip data as possible, all the time-series data (no-identifying information) is expected by the research team.

2. Please describe the researcher qualifications (1 paragraph per researcher).

The Research Integrity Office at UNR has reviewed the scope of work for this project and determined that it does not require human research protection oversight by this Institution Review Board.

The researchers will have access to the data include:

Hao Xu, Ph.D., P.E., Assistant Professor

Yue Zhao, Ph.D. Candidate

Guangchuan, Ph.D. Student

Yuan Sun, Ph.D. Student

Daniel Rodriguez, Undergraduate Student Part-Time

All the researchers having access to the data have obtained IRB training certificates.

3. Please describe what you plan to do with the data when your analyses are complete.

The research team is planned to keep the received data for three years after the project completed. The data may be used for further detailed driving analysis of different scenarios. In the three years, the research team will comply with all the requirements documented in this data sharing agreement.

4. **Please provide proof of IRB permission to conduct the data analysis OR proof of an official exemption from IRB approval. As part of this, all researchers/analysts should provide proof of IRB training. These may be included as attachments.**

The official exemption letter and all the IRB training certificates were attached with this data sharing agreement.

5. **In signing this data sharing agreement, the receiving agency agrees not to attempt to learn the identity of research participants.**

Yes, the UNR research team for this project agrees not to attempt to learn the identity of research participants.

7. In signing this data sharing agreement, the receiving agency agrees to not distribute the data to other entities or use it for purposes other than those specified in the scope of the proposed analysis. The receiving agency agrees to hold the data in reserve only to answer questions relating to the project described in this data sharing agreement, and to seek an additional data sharing agreement prior to using the data for any other purpose. An additional IRB approval will also be required for additional uses of the data.

Yes, the UNR research team for this project agree with this term.

The receiving agency should not sign until all requested information has been received and the agreement has been approved and signed by the VTTI Data Sharing Manager.

______________________________ __________________

Name of researcher 1 Date

____

Signature of researcher 1

______________________________ __________________

Name of researcher 2 Date

____

Signature of researcher 2

Name of researcher 3 Date

Signature of researcher 3

Name of researcher 4 Date

Signature of researcher 4

Name of researcher 5 Date

Signature of researcher 5

Name of VTTI Data Sharing Manager Date

Signature of VTTI Data Sharing Manager

NOTE: Language from the Primary Driver Information Consent Form related to data sharing is attached to this data sharing agreement.

Primary Driver Informed Consent Language from the SHRP 2 Naturalistic Driving Study:

HOW WILL MY DATA BE KEPT CONFIDENTIAL AND SECURE AND WHO WILL HAVE ACCESS TO MY DATA?

Any data collected during this study that personally identifies you or that could be used to personally identify you will be treated with confidentiality. As soon as you begin participating in this study, your name and other identifying information will be separated from the raw data collected while you drive the vehicle and replaced with a number. That is, your raw data will not be attached to your name, but rather to a number (for example, Driver 0011). The raw data collected while you drive the vehicle will be encrypted (made unreadable) from the moment it is collected until it is transferred to one or more secure central storage locations. Your name also will be separated from any data about you, either provided by you in response to questionnaires or gathered by researchers during the study, including crash investigation data, and will be replaced by the same driver number (for example, Driver 0011).

Several types of information and data about you and the study vehicle will be collected during the study:

1. **Contact information** includes your name, address, email address, phone numbers, and similar information used to contact you when needed. It will be stored securely in electronic form during the course of the study and destroyed after the study is complete (unless you grant permission for us to keep your contact information when the study is over). This information will not be linked to or mingled with your study data, and will not be used in any research or analysis.

2. **Auxiliary study information** includes your Social Security Number, license plate number, bank account information (for those using direct deposit) and similar information. This information is used to verify your identity and to make payments for your participation. This information will be stored at the site in electronic form (securely encrypted) destroyed after the study is complete. This information will not be linked to or mingled with your study data, and will not be used in any research or analysis.

3. **Driver data** includes your answers to questionnaires, vision test results, and the results of the brief physical tests described above. This data will not contain your name or any identifying information and will be used in analyses, both on its own and in combination with the driving data, vehicle data, and additional crash data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).

4. **Vehicle data** includes the vehicle make and model, its condition, and how it is equipped. This data will not contain your name or any identifying information and will be used in analyses, both on its own and in combination with the driver data, driving data, and additional crash data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).

5. **Driving data** includes the data we collect from the vehicle while you are driving, including video data and sensor data. This information will contain video of your face and GPS coordinates of your trips, both of which could be used to personally identify you. These data will be encrypted (stored in an unreadable format) from the moment of their creation until they are downloaded from the vehicle, transferred to a secure data storage facility, and verified. From this point on they will be decrypted (made readable) on as as-needed basis for each analysis. These data will be used for analysis, both on their own and in combination with the driver data, the vehicle data, and the additional crash data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).

6. **Additional crash data** includes items we may collect after a crash, including answers to an interview with one of our researchers and the police accident report resulting from the crash. This data will not contain your name or any identifying information and will be used in analyses, both on its own and in combination with the driver data, vehicle data, and driving data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).

It is possible that an authorized Institutional Review Board (IRB) may view this study's collected data for auditing purposes. An IRB is responsible for the oversight of the protection of human subjects involved in research.

It is also possible that the study sponsors or investigators may view this study's driver data and driving data for quality control or administrative purposes; in this case, the study sponsors or investigators will be required to maintain the security and confidentiality of any data that personally identifies study participants or that could be used to personally identify study participants.

While driving the vehicle, a camera will videotape your face with some added space around the head to handle any head movements. An example is shown below. Also, video cameras will capture views of the forward view, the rear view, an external view to the right, as well as a dashboard/lap-belt view. A camera will also periodically take a permanently blurred snapshot of the vehicle interior which will allow researchers to count the number of passengers and make rough estimates of age, gender, and seatbelt use. Passenger identification will not be possible from these blurred snapshots. All video will be captured and stored in digital format (no tape copies will exist).

There will also be an ambient atmospheric analyzer that is capable of detecting the presence of alcohol in the passenger compartment under certain conditions. It may not be able to distinguish whether the alcohol was imbibed or applied (as in hand sanitizer), and it will be unable to determine whether it is emanating from the driver or a passenger. However, this sensor will flag the data for possible indications of impaired driving.

If a safety-related incident or crash occurs, you are asked to press a button on the unit mounted near the rearview mirror. You will know this button is working if a red light appears when you press it. This will allow researchers to find the incident in the database after the data have been collected. Also, pressing the button starts a microphone for 30 seconds. During these 30-seconds, you can tell us what happened. No audio will be captured except when you press this incident button. Please note that pressing this button does NOT make a phone call, unlike OnStar™. It simply records your voice in an audio file that remains in the vehicle until the data is collected.

During the data collection phase of this study, all data collected from the vehicle will be encrypted (made unreadable) from the time of its creation and then stored in a specific password-protected project folder on a secure server; the driving data will only be decrypted (made readable) once it has been stored in this folder. At the conclusion of the collection phase of this study, the driver data, driving data, and additional crash data will be permanently housed at one or more highly secure data storage facilities. One set of data will be permanently housed at Virginia Tech under the supervision of the Virginia Tech Transportation Institute, the organization overseeing the data collection for the entire study. It is possible that, after data collection is complete, one copy of study data will be transferred to the U.S. Department of Transportation (or other secure facilities as determined by the Transportation Research Board) for permanent storage and oversight.

Only authorized project personnel and authorized employees of the research sponsors will have access to study data that personally identifies you or that could be used to personally identify you. As explained below, other qualified research partners may be given limited access to your driver data, vehicle data, driving data, and additional crash data, solely for authorized research purposes and with the consent of an IRB. This limited access will be under the terms of a data sharing agreement or contract that, at a minimum, provides you with the same level of confidentiality and protection provided by this Consent Form. However, even these qualified researchers will not be permitted to copy raw study data that identifies you, or that could be used to identify you, or to remove it from the secure facilities in which it is stored without your consent.

Project personnel, the project sponsors and qualified, authorized research partners may show specific clips of video at research conferences. The project sponsors also may show specific clips of video to the media, driver's education teachers and students, and others involved in efforts to improve highway and road safety. The face portion of the video will be blurred, blacked out, or replaced with an animation for these purposes. Your name and other personally identifying information will never be associated with the showing of these video clips. Identifying location information will not be shown in association with these video clips.

It is expected that the data we capture throughout the course of the entire study, including that from all the approximately 3,100 primary participants, will be a valuable source of data on how drivers respond to certain situations and how the roadway and vehicle might be enhanced to improve driver safety. Researchers who study traffic congestion and traffic patterns may also find the data useful. Therefore, it is expected that there will be follow-on data analyses using all or part of the data for up to 30 years into the future. These follow-on analyses will be conducted by qualified researchers with IRB approval, as required by law, who may or may not be part of the original project team. In consenting to this study, you are consenting to future research uses of the information and videos we gather from you, consistent with the protections described above and elsewhere in this document.

If you are involved in a crash while participating in this study, the data collection equipment in the vehicle will likely capture the events leading up to the event. You are under NO LEGAL OBLIGATION to voluntarily mention the data collection equipment or your participation in this study at the time of a crash or traffic offense. We have provided a letter which you should keep in the glove box for these cases. The letter describes the vehicle's role in the study without identifying you as a participant in the study.

Because the vehicle camera system is storing continuous video, it may capture some incriminating evidence if an at-fault collision should occur. To help us protect your privacy, we have obtained a Certificate of Confidentiality from the U.S. Department of Health and Human Services National Institutes of Health. With this Certificate, neither the researchers nor study sponsors can be forced to disclose information that may identify you, even by a court subpoena, in any federal, state, or local civil, criminal, administrative, legislative, or other proceedings. Identifying information for the purposes of this study includes your contact information, your auxiliary study information, your driving data (including video of your face and GPS coordinates which may identify your home, work, or school locations), or any information in your driver data, vehicle data, or additional crash data that could be used to personally identify you. While your confidentiality is protected in most cases by the Certificate, you should know that in some rare instances involving alleged improper conduct by you or others, you may be prevented by a court from raising certain claims or defenses unless you agree to waive the confidentiality protection. The researchers and study sponsors will use the Certificate to resist any demands for information that would identify you, except as explained below.

The Certificate cannot be used to resist a demand for information from personnel of the United States Government that is used for auditing or evaluation of federally funded projects or for information that must be disclosed in order to meet the requirements of the federal Food and Drug Administration (FDA).

This Certificate of Confidentiality does not mean that the Federal government endorses this study. You should understand that a Certificate of Confidentiality does not prevent you or a member of your family from voluntarily releasing information about yourself or your involvement in this research. If an insurer, employer, or other person obtains your written consent to receive research information, then the researchers may not use the Certificate to withhold that information. If you are not the vehicle owner, you should know that the vehicle owner will not have access to your data.

The Certificate of Confidentiality also does not prevent the researchers from disclosing voluntarily matters such as child abuse, or subject's threatened or actual harm to self or others. This could also include behavior such as habitually driving under the influence of drugs or alcohol, allowing an unlicensed minor to drive the vehicle, or habitually running red lights at high speed. If this type of behavior is observed, we reserve the right to remove you from the study and inform the appropriate authorities of what we have observed. In most cases, we will notify you first of the behavior we have observed prior to removing you from the study or informing others of our observations. If you are removed from the study, your compensation will be prorated based on the time you have already spent as a participant in the study.

The protections of the Certificate of Confidentiality described herein may not apply to passengers or drivers of the vehicle who have not consented to being in this study. For this reason, Informed Consent will be sought from all other adults who drive the vehicle, and these individuals will be protected by the Certificate of Confidentiality to the same degree as you are.

To summarize, your level of confidentiality in this study is as follows:

1. There will be video of your face and portions of your body. There will be audio recorded, but only for 30 seconds if you press the red incident button. The study also will collect health and driving data about you. The video, audio, and other data that personally identifies you, or could be used to personally identify you, will be held under a high level of security at one or more data storage facilities. Your data will be identified with a code rather than your name.

2. All data collected from other drivers who have not signed a consent form will be deleted. No identifying information will be collected on passengers.

3. For the purposes of this project, only authorized project personnel, authorized employees of the project sponsors, and qualified research partners will have access to study data containing personally identifying information, or that could be used to personally identify you. The

data, including face video which has been blurred, blacked out, or replaced by animation, may be shown at research conferences and by the research sponsors for the highway and road safety purposes identified above. Under no circumstances will your name and other personally identifying information be associated with the video clips.

4. The personally identifying data collected in this study may be analyzed in the future for other research purposes by this project team or by other qualified researchers in a secure environment. Such efforts will require those researchers to sign a data sharing agreement which will continue to protect your confidentiality, and will also require additional IRB approval. The confidentiality protection provided to you by these data sharing agreements will be as great as or greater than the level provided and described in this document. Research partners will not be permitted to copy raw data that identifies you, or that could be used to identify you, or to remove it from the secure facility in which it is stored except with your consent.

5. A Certificate of Confidentiality has been obtained from the National Institutes of Health. With this Certificate, the researchers and study sponsors cannot be forced to disclose information that may identify you, even by a court subpoena, in any federal, state, or local civil, criminal, administrative, legislative, or other proceedings. However, the Certificate of Confidentiality does not prevent the researchers from disclosing voluntarily matters such as child abuse, or a participant’s threatened or actual harm to self or others. In terms of a vehicle, this could also include items such as driving under the influence of drugs or alcohol, allowing an unlicensed minor to drive the vehicle, or habitually running red lights at high speed. Such behavior may result in your removal from the study and reporting of the behavior to the appropriate authorities. While your confidentiality is protected in most cases by the Certificate, you should know that in some rare instances involving alleged improper conduct by you or others, you may be prevented by a court from raising certain claims or defenses unless you agree to waive the confidentiality protection.

APPENDIX C. RID TERMS OF USE

DRAFT
Terms of Use
for SHRP2 Roadway Information Database

Version 1.0

The Second Strategic Highway Research Program (SHRP 2) Roadway Information System (RID) was developed to support transportation safety research in conjunction with the SHRP 2 Naturalistic Driving Study. The RID is available to highway safety professionals, university researchers, and others studying transportation safety.

Receipt of the SHRP2 Roadway Information Database (RID) ('the dataset') requires a Terms of Use Agreement between the organization responsible for providing access to the RID ('the database provider') and the requesting individual or agency ('the requester'). A completed Terms of Use agreement is required prior to receiving any data. For the purposes of this agreement the database provider will be the Data Access Director at Iowa State University (ISU).

The following process is required to initiate a request:

1. Draft Agreement Submittal - Requester agrees to the Terms of Use and provides complete answers regarding anticipated use of the data. This form is submitted to the database provider.
2. Draft Agreement Review - The database provider will review the information for completeness and alignment with the Terms of Use. Once the agreement has been completed to the satisfaction of the database provider, the unsigned agreement will be returned to the requester for final signature.
3. Final Agreement Submittal – Requester signs and returns the final document (scanned electronic copy or fax are both acceptable).
4. Final Agreement Acceptance - Upon receipt of the signed agreement the database provider will sign the form and return a copy of the completed agreement to the requester.

Terms of Use

Use of the SHRP 2 Roadway Information Database (RID) data requires a Terms of Use agreement signed by the requester and database provider. This document indicates agreement with the following:

A. The requester agrees to properly acknowledge the source of the data in any reports, articles, or public presentations resulting from the analyses, and will provide a listing of such uses back to the RID database provider. Use the following citation:

'Transportation Research Board of the National Academies of Science. (2014). *The Second Strategic Highway Research Program Roadway Information Dataset*. "

B. The requester agrees not to copy or further distribute the dataset.

C. Federal law 23 United States Code Section 409 governs use of the crash data included in the RID. Under this law, data maintained for purposes of evaluating potential highway safety enhancements:

" ... *shall not be subject to discovery* or admitted into evidence in a federal or state court proceeding *or considered for other purposes in any action for damages* arising from any occurrence at a location mentioned or addressed in such reports, surveys, schedules, lists, or data." *[Emphasis* added.]

D. The requester understands that the dataset is provided As Is with no stated or implied warranty and that use of the dataset by the requester is at their own risk.

Optional

E. If the requester adds additional data to their copy of the RID data, the requester is highly encouraged to provide a copy back to the RID operator to enhance future research. Additional data could include, for example, county or MPO data not currently in the RID that can be associated with the linear referencing system developed for the RID. Standard protocols and metadata documentation templates will be provided to the requester to achieve this step in supporting future research.

F. If the requester discovers issues with the data (e.g., missing data, data quality issues, etc.) they are encouraged to report these to the RID Data Access Director. Standard feedback templates will be provided to the requester.

Provide a description of the anticipated use of the SHRP 2 Roadway Information Dataset:

Insert here

Acknowledgement

By signing this Terms of Use Agreement the requester agrees to adhere to the Terms of Use (A-D) stated above. The requester further agrees to be responsible for making any technical support arrangements, including financial considerations, with the database provider necessary to support their access to the dataset as requested. The requester understand that the dataset is provided As Is with no stated or implied warranty and that use of the dataset by the requester is at their own risk.

Signatures are on the next page.

________________________________ ________________
Name of Requester (project PI) Date

____
Signature of Requester

________________________________ ________________
Name of Authorized Official for Requester Date

____
Title of Authorized Official for Requester

____
Signature of Authorized Official for Requester

________________________________ ________________
Name of [ISU Data Access Director] Date

____
Signature of [ISU Data Access Director]

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Rudy Malfabon, P.E. Director
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