ROADWAY SAFETY INSTITUTE

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Using GIS to Improve Tribal Safety: Applications, Trends, and Implementation Dimensions

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Final Report

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16. Abstract (Limit: 250 words) Traffic safety is a significant transportation and health concern among tribal travelers. Among Native American populations, motor vehicle-related injuries are the leading cause of death for ages up to 5- 34 years old. Over the last three decades, the number of fatal crashes on Indian reservations increased dramatically, while nationally they have declined. Moreover, several recent reviews have noted that potentially effective approaches have been hampered by a lack of timely data and robust tools to guide appropriate strategies in Tribal lands. This study investigated the potential of new advances in Geographic Information Systems (GIS) to enhance the collection, availability and use of transportation safety related information. This investigation resulted in development of several promising GIS applications for tribal use, identified spatial analytic approaches to understanding tribal safety trends, and explored a framework for considering GIS implementation within the context and culture of Tribal independence and governance.		
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FINAL REPORT

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Despite general declines in overall motor vehicle deaths, segments of the US population remain disproportionately burdened by these injuries. The American Indian population has the highest motor vehicle death rate, which is twice the national rate (US Department of Transportation, 2016). Across the United States, the motor vehicle death rate varies significantly, and in many states the American Indian rate is four times the rate for the general US population (Center for Disease Control, 2017; National Council of State Legislators, 2004). Similar to other US populations, motor vehicle-related injuries are the leading cause of death up to ages 5 - 34 (Iragavarapu, et al, 2015). From 2009-2013, there was a noteworthy decline in overall motor vehicle fatalities, including on tribal lands (Bureau of Indian Affairs, 2016). However, overall motor vehicle deaths have begun to increase once again surpassing 40,000 (in 2016 and 2017) for the first time since 2007 (NSC, 2017).

For these reasons, there are ongoing efforts aimed at improving traffic safety among Indian Tribes. Minnesota has one of the highest (Indian Tribe) fatality rates in the country (Quick, Narváez and Saunders, 2015). A recent national conference held in Minnesota (2013) outlined a range of efforts that Tribes could take to achieve reductions in traffic fatalities (National Tribal Transportation Conference, 2013). However, all parties recognize myriad factors affect both the nature of travel in Tribal lands and the capacity to affect travel safety on those lands. Among those factors is the technical and organizational capacity to obtain and utilize this information for transportation planning and implementation (Bailey & Huft, 2008).

Among the tools available to Tribal lands, GIS represents a potentially important platform for gathering and making traffic safety information readily available (Taylor, et. al., 2012). While access has traditionally been a barrier for such utilization, recently several steps have been taken to reduce this barrier. For example, the Bureau of Indian Affairs has worked closely with Esri (the largest provider of GIS software, and a partner in this research) to conduct training and demonstration workshops as well as access to GIS software. Moreover, the rapid movement of GIS to a low-cost cloud-based service has further reduced the cost and implementation barriers. Experts agree that GIS could be utilized in an enhanced manner to assist Tribes in timely, efficient and effective analysis of transportation safety. This need and opportunity formed the basic scope of the research: how GIS could be used to improve Tribal traffic safety.

Throughout the study, various stakeholders were consulted, including both experts in Tribal Traffic Safety and GIS. In preparing this report, stakeholders consulted included: TRB Committee on Tribal Affairs (with includes a BIA representative), TTAP Director for the Midwest, White Earth Transportation Planning Director, MNDOT Safety Engineer and Safety Planner, Esri Global Transportation Industry Manager, and several transportation researchers and consultants active in the field of traffic safety, including tribal conditions associated with traffic safety. This research project was also done in collaboration and coordination with a related study by Quick & Narváez (2014), which examined qualitative and community factors affecting traffic safety in Tribal Lands. That study provided useful contextual information that informed the technical developments undertaken in this study.

1.2 OBJECTIVES AND METHODOLOGY

The iterative design research methodology followed the three following research objectives.

Objective 1: Design and Test Tribal Safety GIS Prototypes.

Drawing on a literature review and stakeholder outreach, a series of prototype applications were developed that could be used by Tribes to assist in their transportation safety planning, assessment and implementation. Activities included actual creation of six GIS prototypes analyzing and using traffic safety data, and then obtaining structured feedback on the value for Tribes.

Objective 2: Analyze Tribal Safety Spatial Patterns Using Hotspot Analysis.

Building on general traffic fatality data, a series of Hot Spot analyses were conducted on four data sets. Specifically, the hot spot analyses examined tribal locations and compared traffic safety in those locations in comparison to the immediate surrounding areas. Getis-Ord Gi* statistical method was used to statistically analyze hotspots in and across tribes and surrounding areas. The resultant z-scores and p-values indicated where features with either high or low values cluster spatially. This study was interested in identifying features that are statistically significant hot spots – a feature that has a high value and is surrounded by other features with high values. The statistical analysis was therefore as follows: the local sum for a feature and its neighbors was compared proportionally to the sum of all features; when the local sum was very different from the expected local sum, and that difference was too large to be the result of random chance, a statistically significant z-score resulted.

Objective 3: Explore Implementation Framework for Tribal Safety.

Drawing on the concept of Tribal Sovereignty, this analysis developed a framework for considering GIS Based Traffic Safety Analysis within the context of Tribal governance and management. This Data Sovereignty Framework had four dimensions that were assessed: 1) Tribal Community and Culture, 2) Tribal Governance, 3) Data Management, and 4) Data Domains. The value of this framework was then explored within the context of implementing GIS for traffic safety.

1.3 TASKS

Task 1: Review and assess current uses, data, and interests in using GIS for transportation safety

These activities included a literature review; interviews and focus groups with Tribal Safety experts and recommended contacts in the Tribal community. An analysis of current and potential data sources was also conducted, which included, but was not limited to, data from county safety plans and statewide crash analyses. This task also included an outreach to RSI research partners and others who identified the individuals from the Native American community who were valued for their assistance with the research described in all the tasks. Results of this task informed the subsequent tasks and have been folded into those task findings and descriptions.

Task 2: Prototype Development and Testing.

Based on task 1, a series of prototype applications that could be used by Tribes to assist in their transportation safety planning, assessment and implementation were devised. Tasks included actual creation of GIS prototypes using sample safety data, and structured feedback on the value for Tribes. This structured feedback was obtained during a workshop at the 2015 Minnesota Tribal Conference.

Task 3: Spatial Analysis of Tribal Safety

Crash data, for the ten-year period (2005-2014), was obtained using the Minnesota Crash Mapping Analysis Tool (MnCMAT). Five injury types were analyzed: fatal injury, incapacitated injury, non-incapacitating injury, possible injury, non-incapacitating injury, and possible injury. Hot Spot analyses were conducted on four data sets.

Task 4: Tribal Sovereignty Framework for GIS Deployment.

Activities included construction of a Data Sovereignty Framework for GIS deployment, including assessment guidelines for each of the four dimensions: 1) Tribal Community and Culture, 2) Tribal Governance, 3) Data Management, and 4) Data Domains. These were then explored within the context of Minnesota and South Dakota Tribes, albeit in a preliminary manner.

Task 5: Draft Research Report.

A draft research report documenting the research, including the problem, methodology/approach, and findings was prepared and submitted for peer review.

Task 6: Final Research Report.

This final research report has been updated per peer reviewer comments and submitted to the Roadway Safety Institute for publication.

CHAPTER 2: GIS PROTOTYPES FOR TRIBAL TRAFFIC SAFETY

2.1 INTRODUCTION

This research phase explored the use of GIS tools at every stage of the transportation safety information flow, from detection, reporting, analysis, and programming. The detailed benefits varied to the extent that Tribes had needs or saw opportunities in those areas. Determining the extent of those needs was part of this study. Potential benefits include:

- Detection – easier documentation of safety concerns, such as maps that pull in MN Safety Audit Findings, identifying seasonally adjusted areas for preventive action and communication.

- Reporting – ability to generate "multi-dimensional" traffic safety and conditions maps for use in reporting trends and conditions, including pulling MnDOT data and then checking with other demographic, travel data, and community data.

- Analysis – on demand hotspot analysis including of seasonal and non-traditional safety issues, such as pedestrian safety, as well as qualitative "StoryMaps" that provided insight into local transportation terms.

- Communication and Collaboration – ability to share GIS analysis and maps (through a porta) with other Tribes to encourage best practices.

- Education – better understanding of GIS capabilities, including orientation/training of Tribal representatives and students.

The potential uses were discussed with Minnesota's Advocacy Council for Tribal Transportation (April 17, 2015) as well as through individual discussions. Based on the result of these discussions, the research team decided to focus on a select set of six applications that would provide a focused demonstration of GIS Tribal capabilities. A portal was created to host these six applications, plus hotspot analyses (see Figure 2.1 and http://tribalsafety.maps.arcgis.com)

Figure 2.1 GIS for Tribal Safety Portal

2.2 APPLICATION DESCRIPTIONS

2.2.1 Roadway Safety Application

This application allows for visualization and analysis of road safety audits and related segment analysis on roads on or near Tribal lands. Road segment analysis identifies segments of roads and highways that are more prone to traffic incidents due to the characteristics of the roadway (such as potholes, curves, extreme slope grading, etc.). However, it is important to keep in mind several factors when using the information generated from this type of analysis. For example, the MnDOT Traffic Safety Fundamentals Handbook of 2015, Section B on Safety Improvement Processes, highlights a number of issues:

- The number of crashes at any location is usually a function of exposure. As the number of vehicles entering an intersection or the vehicle miles of travel along a roadway segment increase, the number of crashes typically increase.
- The use of crash rates (crash frequency per some measure of exposure) accounts for this variability and allows for comparing locations with similar designs but different volumes.
- Segment crash rates are expressed as the number of crashes per million vehicle miles (of travel).

The report further states that after identifying hazardous locations, the next step is to conduct supplemental analyses in order to better understand the nature of the problem and to help develop appropriate mitigative strategies. As explained, a more detailed understanding of contributing factors is necessary to develop countermeasures as there is no current expert system in place that supports the linking of hazardous locations (high crash rates) to a specific safety solution. Additional analysis of crash data comparing actual crash characteristics to expected characteristics may help further identify effective countermeasures.

To this end, the Roadway Safety Application was developed. This application is illustrated in Figure 2.2a for Regional view and Figure 2.2b for a Tribal view (using Millel Lacs as an example). In the Regional view, the results of crash analysis can be seen Minnesota-wide where road segment datasets and crash locations have been assigned to specific roadway segments. This risk map, created from the crash analysis results, can help inform decisions regarding safety improvement priorities or crash mitigation measures. In the Mille Lacs view, a more detailed visualization of this analysis is displayed. Specifically, this visualization utilizes graduated colors to represent quantitative information. In the case of this application, the darker the color (Red) the greater the number of crashes along that road segment. This application can be accessed at: http://tribalsafety.maps.arcgis.com/apps/webappviewer/index.html?id=f44fea8da2204bff99342f6646e41827

Regional   Mille Lacs

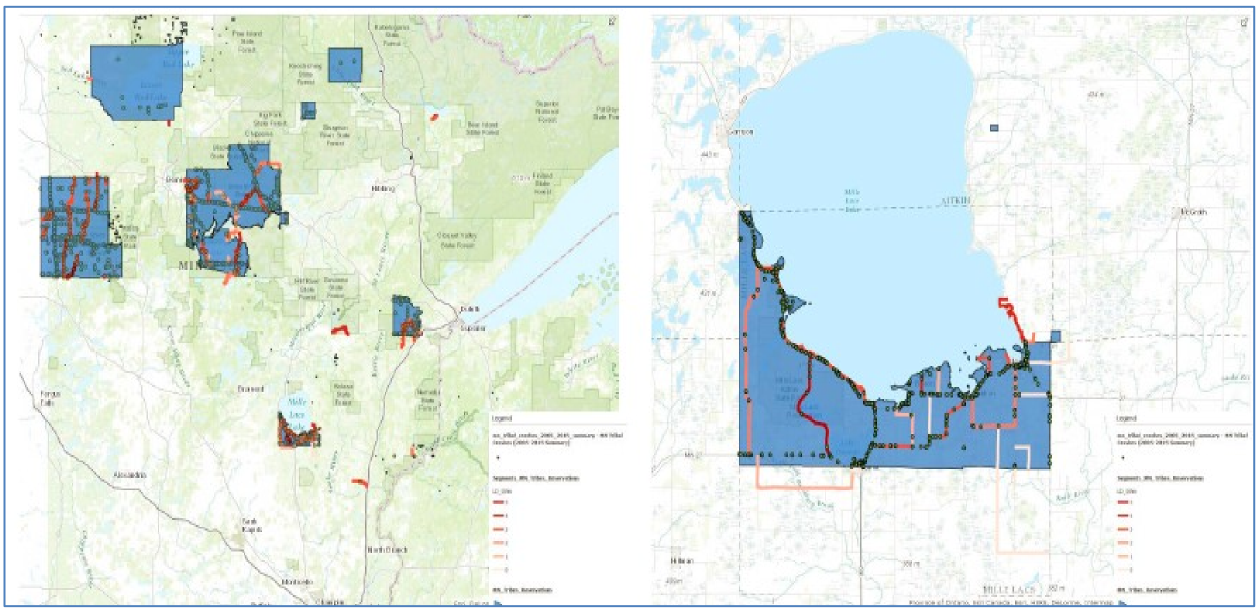
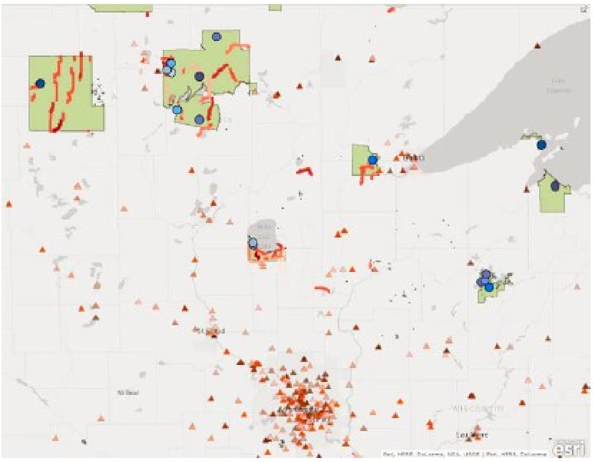


Figure 2.2 Roadway Safety Applications

2.2.2 Pedestrian Safety Application

This application aggregates and analyzes a variety of information related to Tribal pedestrian safety. This information can include crash and fatality information, community input data, bike lane availability, and intersection cross-walk identification. This information is then "aggregated" and in so doing, analyzed for better visualization and representation of the concerns, for possible improvements, and for suitable locations of intersection-crosswalks and bike lanes as seen in Figure 2.3a for Regional view and Figure 2.3b for Mille Lacs view. The Regional view helps to understand, statewide, how it may be necessary to prioritize where safe walking routes are needed. To do this, state-level datasets on cross-walks, resident locations, and traffic volume, were assembled and with that, the user can suggest safe routes by connecting existing sidewalks with the safest crosswalks. These proposed safe routes could be published online and incorporated into the public-facing Pedestrian Safety Application web app. An example of this is seen in the Mille Lacs view. In the case of this application, this overlay analysis is applied to help identify these suitable / candidate locations. It is a technique for applying a common scale of values to diverse and dissimilar inputs to create an integrated analysis. This technique superimposes multiple data sets (representing different themes) together for identifying relationships between them. This application can be accessed at: http://tribalsafety.maps.arcgis.com/apps/webappviewer/index.html?id=793ae1129bcc488aa22436407a98a3b9

Regional



Mille Lacs

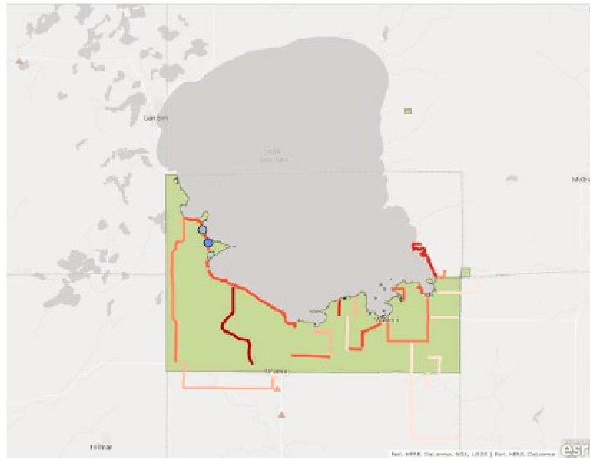


Figure 2.3 Pedestrian Safety Application

2.2.3 Hotspot Safety Application

Hotspot analysis is a spatial cluster detection method that identifies spatial concentrations of crashes and fatalities. It can provide preliminary indications of historical trends in Tribal safety conditions, crash and fatalities as shown in Figure 2.4a for Regional view and Figure 2.4b for Mille Lacs view. In the Regional view, Optimized Hot Spot Analysis identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots) where the focus is on presence or absence of an event (crash) rather than a measured attribute associated with each crash. Here, we see that there are significant clusters appearing in the Mille Lacs area. In the Mille Lacs view, the Hotspot Safety Application was used to "zoom-in" to those locations where the clusters of significant hot spots are located and appear as yellow surrounded by red coloring. Specifically, this analysis uses known quantities of a phenomenon along with their location and distributes them across the landscape based on the quantity at each location and the spatial relationship of the locations. In the case of this application, the density surfaces show where crashes are concentrated. By calculating density, you can create a surface showing the predicted distribution of the crashes throughout the landscape. This application can be accessed at: http://tribalsafety.maps.arcgis.com/apps/webappviewer/index.html?id=88c445ff4c464e9eb95c451701431d86

Regional Mille Lacs

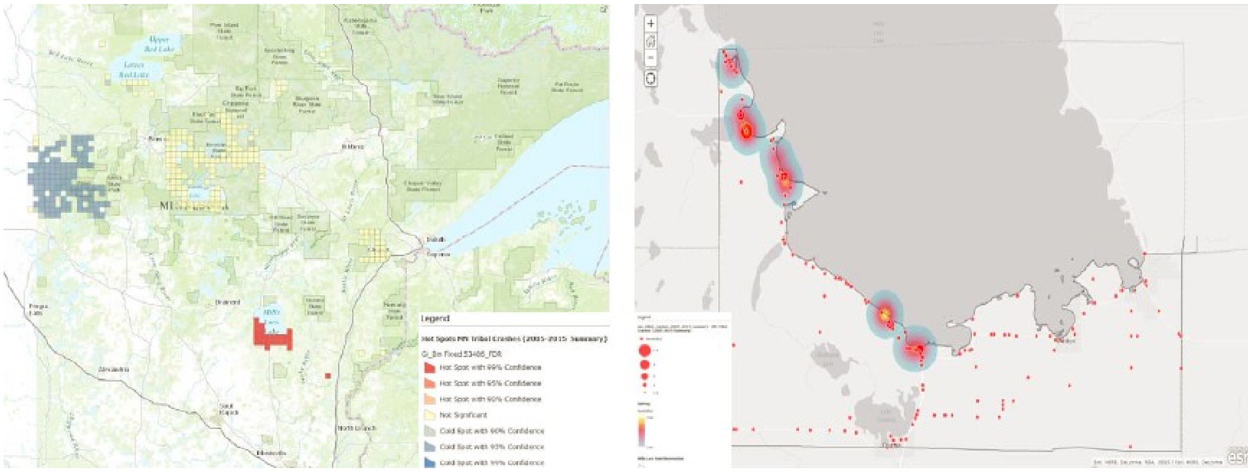


Figure 2.4 Hotspot Safety Application

2.2.4 Safety Emphasis Application

This application integrates a range of Tribal Safety quantitative and qualitative analyses into an integrated view of identified emphasis areas for safety improvement. In addition to the safety hotspot, segment, and community data, it allows for spatial identification of proposed emphasis areas into an integrated summary of proposed safety improvements and as seen in Figure 2.5a for Regional view and Figure 2.5b for Mille Lacs view. The Regional view displays all the features available to the user at the state-level. A more detailed view of this is seen in the Mille Lacs view where the user can zoom-in to identify local areas where an emphasis on road safety should be communicated to the local community. In the case of this application, layers represent geographic features such as points (e.g., Tribal Crashes 2005-2015 (MN)), lines (e.g., MN Trails), or areas (e.g., Tribal Lands). The type of layer determines how you can interact with the layer's data. For example, you can view and query the data to see a feature's attributes (e.g., in the case of crashes: the number of fatalities, injury severity, date/time). In general, web layers are categorized by the type of data they contain, and here these layers have been organized into three main themes: Tribal Crashes, MN Trails, and Tribal Data. This categorization, along with the icons and colors, illustrates the type of data in the layer, which helps users make the connection regarding what is displayed in the map. This application can be accessed at: http://tribalsafety.maps.arcgis.com/apps/webappviewer/index.html?id=79d926ad2fe14b8a9b8b2c1aa98e5b18

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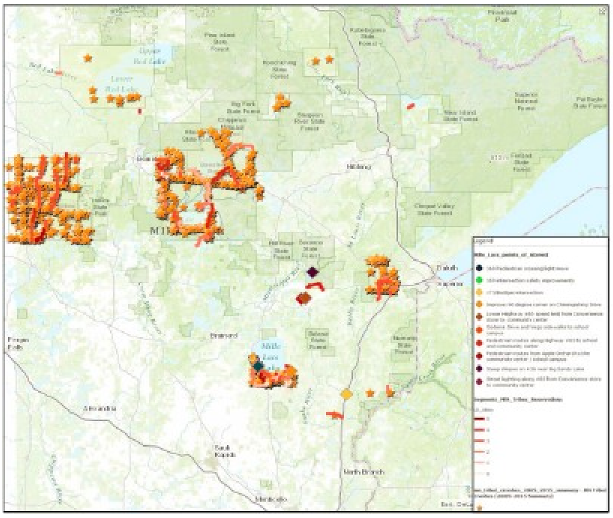


Mille Lacs

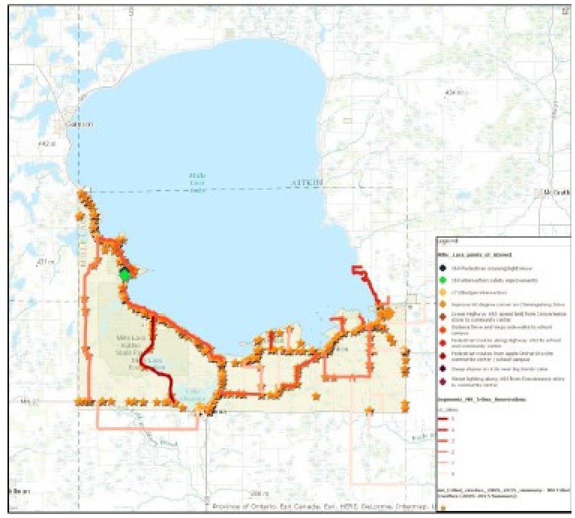
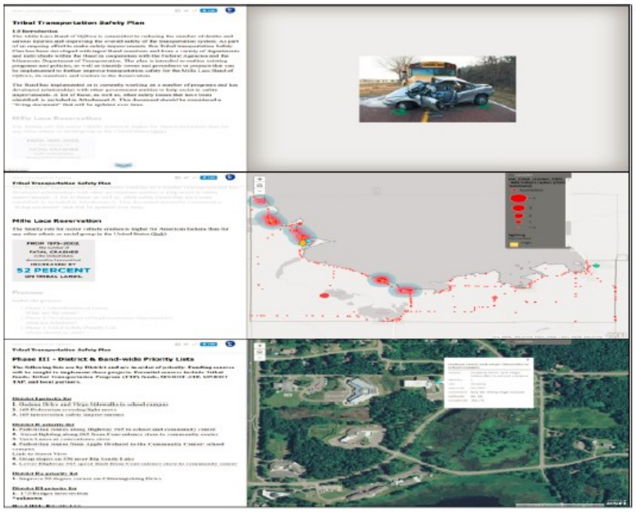


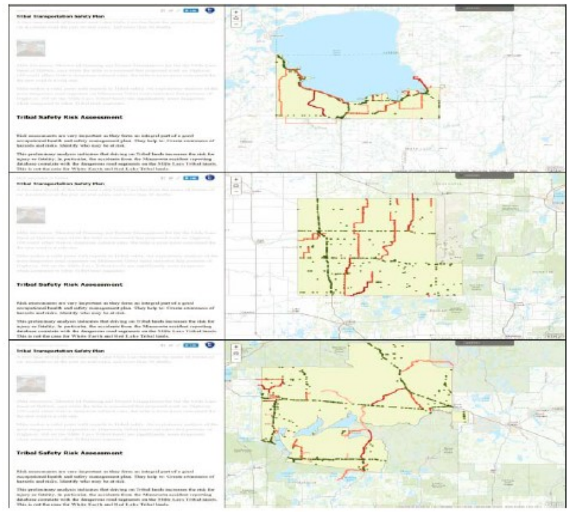
Figure 2.5 Safety Emphasis Application

2.2.5 Safety Story Application

This application allows the Tribal Transportation and Safety plans to be analyzed and displayed as a Story Map. Story Maps combine authoritative maps with text, images, and multimedia content, and make it easy to harness the power of maps and geography to tell a story. Story Maps can be used for a wide variety of purposes; for advocacy and outreach, virtual tours, travelogues, delivering public information, and many more. In the case of this application, it provides a narrative of Tribal Safety conditions, analyses, and priority improvements. The story map (see Figure 2.6) can used to convey the overall Tribal Safety approach to a variety of stakeholders and help to answer questions such as: Which intersections and roadways have the highest crash rates? Does the spatial pattern of fatalities differ from the spatial pattern of traffic accidents overall? Over time, which intersections or roadways are persistent problem areas for traffic accidents? In this regard, it could also be used for the teaching and instruction of Tribal Safety issues, Tribal public relations, or for Tribal stakeholder briefings and presentations. This application can be accessed at: http://tribalsafety.maps.arcgis.com/apps/Cascade/index.html?appid=c46f142bb417458ea3e6f9804dc6f3cd



Show specific areas of concern outlined in surveys or by



Identify Non-Obvious Safety Concerns

Figure 2.6 Safety Story Application

2.2.6 Safety Application Portal

The Tribal Roadway Safety Mapping Portal is dedicated to identifying the causes of, and solutions to, motor vehicle safety issues regarding tribal traffic safety. This portal provides an easy-to-access solution to access Tribal safety applications, store Tribal maps and analyses, and share among the Tribal community. It allows maps to be quickly used, updated, and integrated into a variety of reports as shown in Figure 2.7. Specifically, the Tribal Roadway Safety Mapping Portal is an online, collaborative web GIS that allows portal members to use, create, and share maps, scenes, apps, layers, analytics, and data. Members may also use the portal to collaborate, access maps and apps from any device, and view status reports. The portal is also used to administer member access to online learning materials, data collection and survey tools, and other GIS-based analytics solutions. This portal can be accessed at: http://tribalsafety.maps.arcgis.com/home/index.html

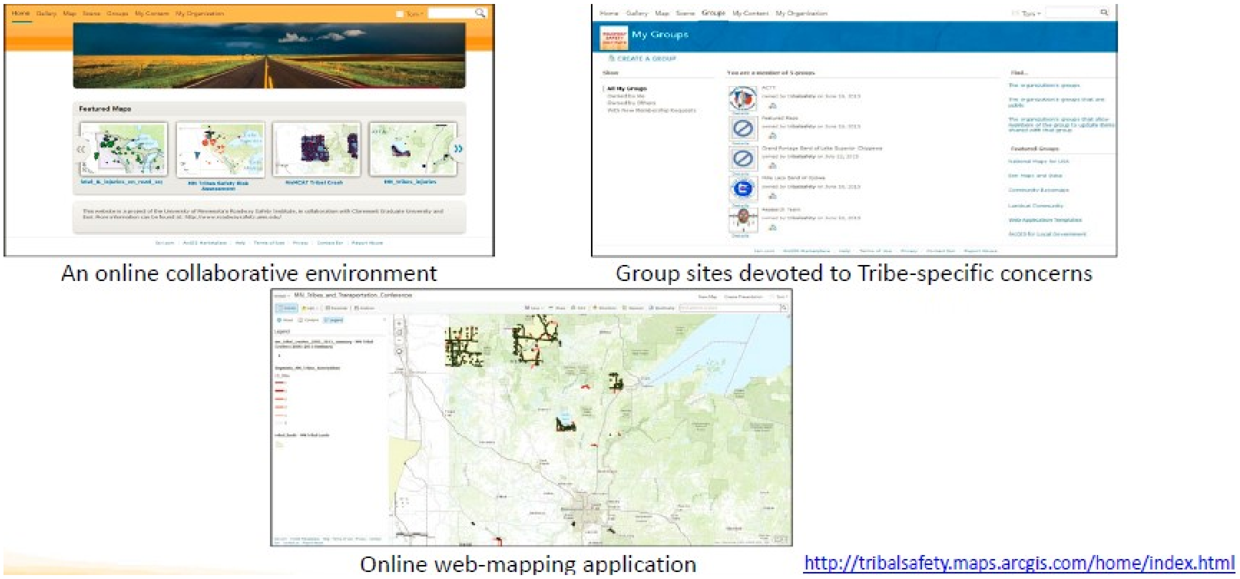


Figure 2.7 Safety Application Portal

2.3 APPLICATION FEEDBACK

2.3.1 Assessment of Applications

The potential of these applications was explored in several venues, including the 2015 Minnesota Tribal Conference. At that venue, a focus group of (16) stakeholders was held to review and assess these applications Conference (held on October 13, 2015 (see Figure 2.7). An instant polling technology was used to solicit feedback from the 16 attendees of the session. The following is their feedback to each of the applications.

Figure 2.8 Safety Application Portal

2.3.2 Roadway Safety Application Feedback

- A) Very useful
- B) Partially useful
- C) Somewhat useful
- D) Not very useful
- E) Not useful at all

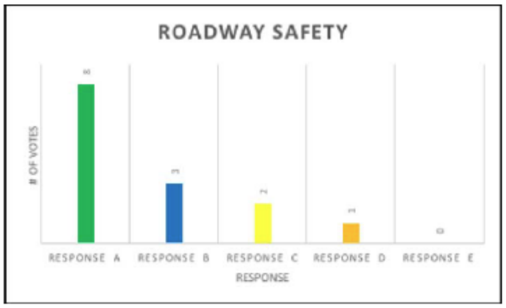


Figure 2.9 How useful is it to have mapping of high risk road segments?

78% (n = 14) of the responding stakeholders responded that the roadway safety application was partially useful to very useful, while 21% (3/14) viewed the application as somewhat useful or not very useful.

2.3.3 Pedestrian Safety Application Feedback

- A) Very useful
- B) Partially useful
- C) Somewhat useful
- D) Not very useful
- E) Not useful at all

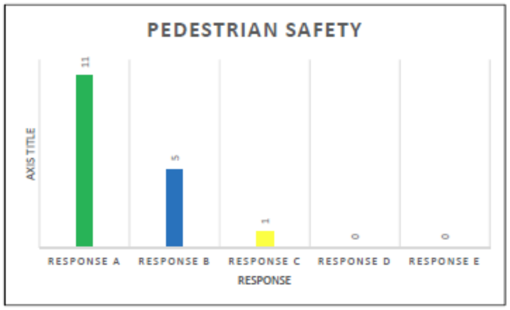


Figure 2.10 How useful is it to have maps of pedestrian safety incidents?

94% (n = 17) of the responding stakeholders responded that the pedestrian safety application was partially useful to very useful, while only 6% viewed the application as somewhat useful.

2.3.4 Hotspot Application Feed

- A) Very useful
- B) Partially Useful
- C) Somewhat Useful
- D) Not very useful
- E) Not useful at all

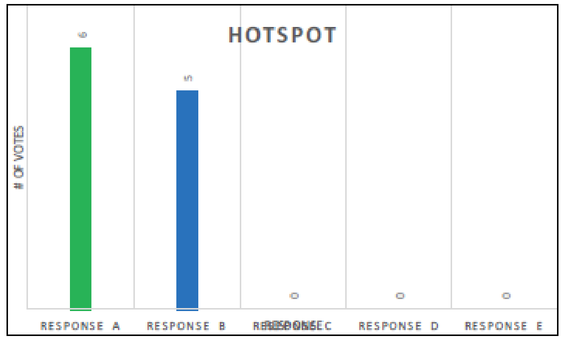


Figure 2.11 How useful is it to have hotspot identification of crash clusters?

100% (n = 11) of the responding stakeholders responded that the hotspot application was partially useful to very useful.

2.3.5 Safety Emphasis Application Feedback

- A) Very useful
- B) Partially useful
- C) Somewhat useful
- D) Not very useful
- E) Not useful at all

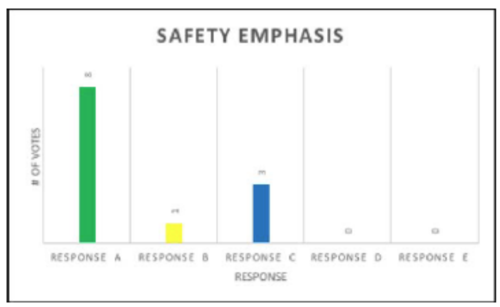


Figure 2.12 How useful is it to have maps linking high risk safety areas to (proposed) priority areas?

75% (n = 12) of the responding stakeholders responded that the safety emphasis application was very useful or partially useful

2.3.6 Safety Story Application Feedback

- A) Very useful
- B) Partially useful
- C) Somewhat useful
- D) Not very useful
- E) Not useful at all

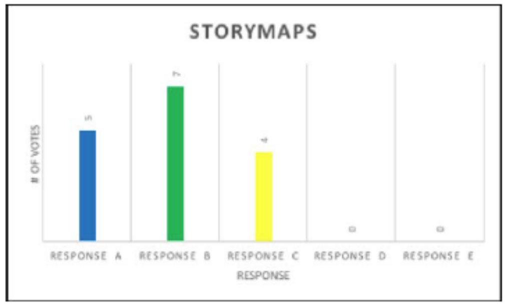


Figure 2.13 How useful is to have maps and related data integrated into safety plans via Story Maps?

75% (n = 16) of the responding stakeholders responded that the safety story application was very useful or partially useful, while 25% (4/16) viewed the application as somewhat useful.

2.3.7 Safety Application Portal Feedback

- A) Very interested
- B) Interested
- C) Indifferent
- D) Partially interested
- E) Not interested

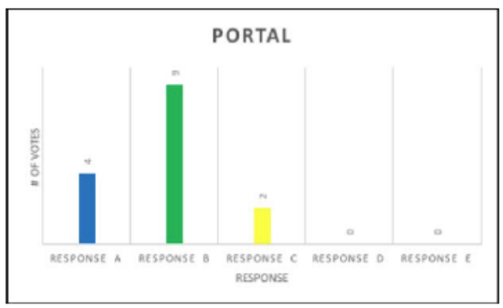


Figure 2.14 How useful is it to have a safety application portal?

87% (n = 15) of the responding stakeholders responded that they would be interested or very interested to have the safety application portal, while 13% were indifferent to having the portal.

2.4 SUMMARY AND DISCUSSION

A summary of the feedback is provided in Figure 2.8. In general, all applications were viewed positively and in particular hotspot analysis and pedestrian safety.

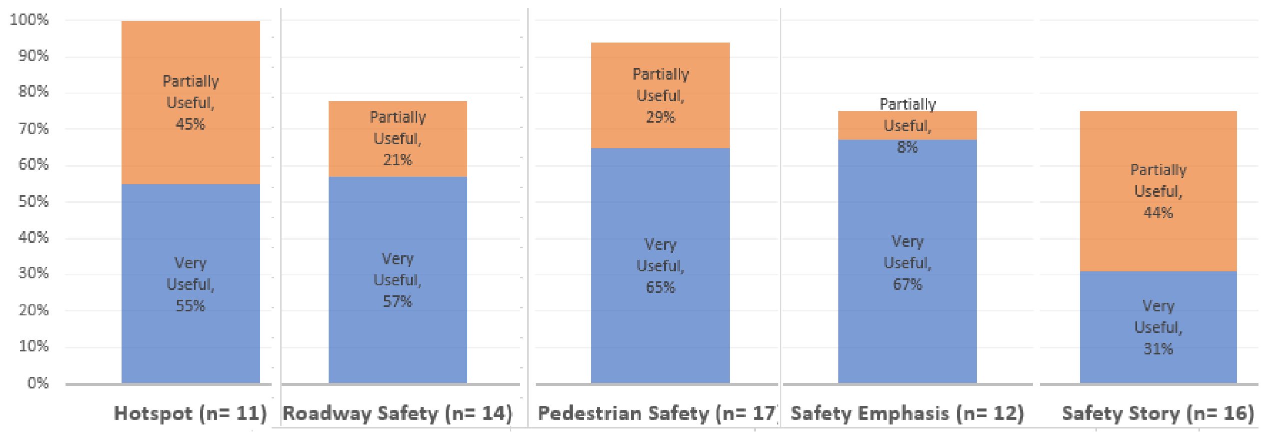


Figure 2.15 Feedback Summary

In sum, this phase of the research found that the development and preliminary assessment of GIS-based applications could provide promising insight into how GIS can be used as a tool in achieving important in traffic safety.

These findings were presented at the 2016 Roadway Safety Showcase featuring Greg Winfree, USDOT Assistant Secretary of Transportation for Research and Technology on May 21, 2015 and the value discussed. One official noted: *"I look forward to seeing the outcome of your current project as simplified or "canned" GIS analysis tools have the potential to be very useful for rural transportation agencies that have very limited resources."* [1]

We concur that it does have potential and hope Tribes and entities that work with Tribes will consider utilizing easy to use applications such as these that can assist in analyzing and improving transportation safety. Some of the applications, such as Story Maps, provide an opportunity to better communicate about traffic safety issues, as they can pull together a variety of perspectives and data into a single online story. Other applications, such as pedestrian safety analysis, can help highlight specific pedestrian travel problems in the community. The hot-spot analysis is probably the most sophisticated application. While it is viewed with high importance, it requires analytical knowledge of spatial statistics. We turn to this style of analysis in Chapter 3.

[1] Email correspondence, May 21, 2015.

CHAPTER 3: SPATIAL ANALYSIS OF TRIBAL TRAFFIC SAFETY

Given the high interest in hot-spot analysis, in 2016 the research team commenced a series of spatial analysis of crashes (specifically those crashes involving fatal and non-fatal injuries) occurring on the Tribal Areas within the State of Minnesota. Based on available data, four Tribal Areas (Leech Lake, Mille Lacs, Red Lake, and White Earth) were selected for additional GIS-based statistical analysis. These areas were selected due to their high percentage of Fatal and Incapacitating Injuries, as well as for containing a sufficiently large sample size.

Route Segments data represents road centerlines for all public roads within the state of Minnesota. This data was obtained from the Minnesota Department of Transportation (MnDOT). The Route Segments dataset was developed to fill a need at MnDOT for a continuous, statewide GIS base map of the transportation system. Other pertinent aspects of the analysis are as follows:

- There are 15 Tribal Areas within, or overlapping, the boundaries of the State of Minnesota
- Route Segments data, obtained from the Minnesota Department of Transportation, represents road centerlines for all public roads within the state of Minnesota
- Annual average daily traffic (AADT) traffic segments represents the most current AADT on sampled road systems in any given year
- Crash Data for four Tribal Areas was selected based on their occurrence both within the Tribal Area and, within a 10-miles distance from the Tribal area
- Various Hot Spot analyses were conducted on the four data sets

3.1 ANALYSIS METHODOLOGY

3.1.1 Crash Data

Crash data, for the ten-year period (2005-2014), was obtained using the Minnesota Crash Mapping Analysis Tool (MnCMAT). The MnCMAT system contains crash data as reported to Department of Public Safety. Crash data enters this system in two ways – through a Citizen Accident Report and/or Police Accident Report. A “crash” occurs when the following three measures are met: 1) it occurs on a road open to the public; 2) it has at least $1,000 worth of damage or a personal injury; and 3) there was a motor vehicle in transport. Due to changes emerging from the new Minnesota crash records system, and implementation of the new Linear Referencing System within MnDOT, the latest available data was from 2014. The descriptive statistics for crashes both within Tribal Areas and nearby Tribal Areas are outlined in Table 3.1- State of Minnesota Tribal Area Crashes and Table 3.2- State of Minnesota Tribal Area Crashes (within 10 Miles of Tribal Area).

Four injury types were analyzed:

1. Fatal Injury - An injury that results in an unintentional death within 30 days of the crash.
2. Incapacitating Injury - An injury (other than fatal) that prevents the injured person from walking, driving or normally continuing with the activities the person was performing before the injury occurred. This type of injury includes severe lacerations, broken or distorted limbs, skull

fracture, crushed chest, internal injuries, unconsciousness, etc. Hospitalization is usually required.

3. Non-Incapacitating injury - An injury (other than fatal or severe) that is evident to the officer at the scene of the crash. Includes abrasions, minor lacerations, bleeding, etc. May require medical treatment, but hospitalization is usually not required.
4. Possible Injury - An injury (other than fatal, severe, or moderate) that is reported by a person involved in the crash. Includes complaint of physical pain when no cause is evident, momentary unconsciousness, limping, nausea, hysteria, etc.

3.1.2 Tribal Areas

American Indian/Alaska Native/Native Hawaiian Areas National (AIANNH) Areas data (2015 edition) was obtained from the United States Census Bureau. The AIANNH data includes the following legal entities: federally recognized American Indian reservations and off-reservation trust land areas, state-recognized American Indian reservations, and Hawaiian home lands. The statistical entities included are Alaska Native village statistical areas, Oklahoma tribal statistical areas, tribal designated statistical areas, and state designated tribal statistical areas. The boundaries for federally recognized American Indian reservations and off-reservation trust lands are as of January 1, 2015, as reported by the federally recognized tribal governments through the Census Bureau's Boundary and Annexation Survey. The boundaries for state-recognized American Indian reservations and for state designated tribal statistical areas were delineated by a state governor-appointed liaison for the 2010 Census through the State American Indian Reservation Program and Tribal Statistical Areas Program respectively.

There are 15 Tribal Areas within, or overlapping, the boundaries of the State of Minnesota. Table 1 contains the descriptive statistics for the crashes occurring with these areas. Table 2 contains the descriptive statistics for the crashes occurring with these areas including those crashes occurring within 10 Miles of the Tribal Area.

Table 3.1 Minnesota Tribal Area Crashes (2005-2014)

	Fatal		Incapcitating Injury		Non-Incapcitating Injury		Possible Injury		Total
Bois Forte	1	12.50%	0	0.00%	4	50.00%	3	37.50%	8
Fond du Lac	7	5.26%	18	13.53%	47	35.34%	61	45.86%	133
Grand Portage	0	0.00%	1	5.56%	3	16.67%	14	77.78%	18
Ho-Chunk Nation	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0
Lake Traverse	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0
Leech Lake	32	6.40%	65	13.00%	150	30.00%	253	50.60%	500
Lower Sioux	2	15.38%	2	15.38%	5	38.46%	4	30.77%	13
Mille Lacs	16	5.26%	24	7.89%	100	32.89%	164	53.95%	304
Minnesota Chippewa	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0
Prairie Island	0	0.00%	0	0.00%	4	28.57%	10	71.43%	14
Red Lake	6	54.55%	1	9.09%	0	0.00%	4	36.36%	11
Shakopee Mdewakantor	1	1.96%	4	7.84%	22	43.14%	24	47.06%	51
St. Croix	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0
Upper Sioux	0	0.00%	1	14.29%	1	14.29%	5	71.43%	7
White Earth	22	6.61%	49	14.71%	113	33.93%	149	44.74%	333

Table 3.2 Minnesota Tribal Area Crashes within 10 Miles of Tribal Area (2005-2014)

	Fatal		Incapcitating Injury		Non-Incapcitating Injury		Possible Injury		Total
Bois Forte	5	3.03%	16	9.70%	58	35.15%	86	52.12%	165
Fond du Lac	65	1.31%	224	4.50%	1,237	24.86%	3,449	69.33%	4,975
Grand Portage	0	0.00%	1	3.23%	6	19.35%	24	77.42%	31
Ho-Chunk Nation	6	1.16%	34	6.55%	167	32.18%	312	60.12%	519
Lake Traverse	2	2.47%	6	7.41%	26	32.10%	47	58.02%	81
Leech Lake	65	5.66%	135	11.75%	370	32.20%	579	50.39%	1,149
Lower Sioux	15	4.29%	27	7.71%	98	28.00%	210	60.00%	350
Mille Lacs	81	4.83%	138	8.23%	537	32.04%	920	54.89%	1,676
Minnesota Chippewa	26	2.96%	69	7.85%	218	24.80%	566	64.39%	879
Prairie Island	16	1.12%	100	6.99%	407	28.44%	908	63.45%	1,431
Red Lake	39	9.82%	49	12.34%	125	31.49%	184	46.35%	397
Shakopee Mdewakanton S	81	1.13%	269	3.75%	1,744	24.30%	5,083	70.82%	7,177
St. Croix	3	21.43%	0	0.00%	3	21.43%	8	57.14%	14
Upper Sioux	8	3.90%	23	11.22%	63	30.73%	111	54.15%	205
White Earth	46	5.86%	103	13.12%	276	35.16%	360	45.86%	785

Four Tribal Areas (Leech Lake, Mille Lacs, Red Lake, and White Earth) were selected for additional GIS-based statistical analysis. These areas were selected due to their high percentage of Fatal and Incapacitating Injuries, as well as, containing a sufficiently large sample size.

3.1.3 Route Segments

Route Segments data represents road centerlines for all public roads within the state of Minnesota. This data was obtained from the Minnesota Department of Transportation (MnDOT). The Route Segments dataset was developed to fill a need at MnDOT for a continuous, statewide GIS base map of the transportation system. The Route Segments dataset was created in the summer 2013.

3.1.4 Annual Average Daily Traffic (AADT) Current Traffic Segments

AADT Current Traffic Segments represents the most current AADT on sampled road systems in any given year. This information is displayed using the road centerlines within the state. This centerline layer is a subset of all public roads within the state of Minnesota. Counts are taken on portions of this system each year so complete coverage for a given jurisdiction is accomplished on a two- or four-year cycle. The AADT data values for the years 2004, 2006, 2008, 2010, and 2012 were averaged to arrive at an Average AADT Value that was utilized in the following analysis.

3.2 SPATIAL ANALYSIS

These data were analyzed using various techniques including GIS-based spatial analysis.

3.2.1 Spatial Data Selection

As mentioned, Crash Data for four Tribal Areas was selected based on their occurrence both within the Tribal Area and, within a 10-miles distance from the Tribal area. An example for the White Earth Tribal Area is shown below in Figure 3.1

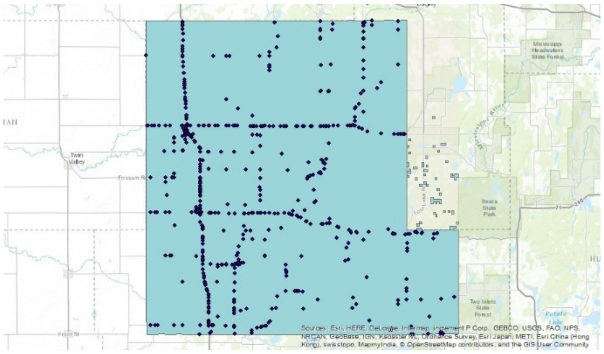
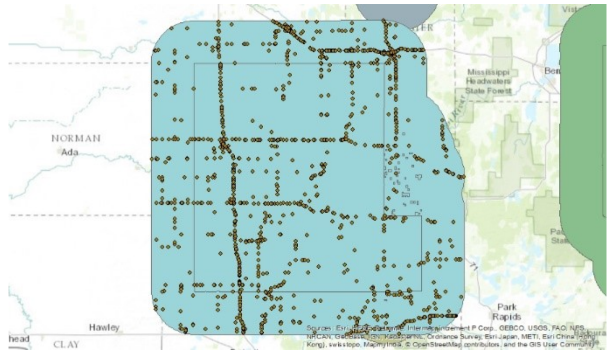
Within the Tribal Area	Within the Tribal Area and within a distance of 10 miles
	

Figure 3.1 Comparison of Crash Data White Earth Tribal Area

However, it was decided that a more accurate method to identify crashes adjacent to these Tribal Areas would be drive-time analysis and the resultant area/polygon. A drive-time polygon is an area that encompasses all accessible streets that lie within a specified drive time from a specific point. Drive-time polygons are used to evaluate the accessibility of a point with respect to some other features. In this case, points were created where Route Segments intersected the boundaries of the Tribal Areas and a 15-minute drive-time analysis was performed. Figure 3.2 illustrates this analysis for the White Earth Tribal Area.

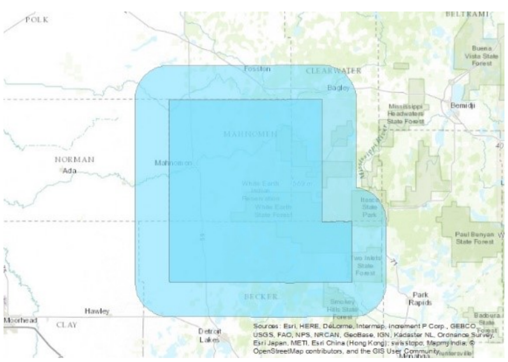
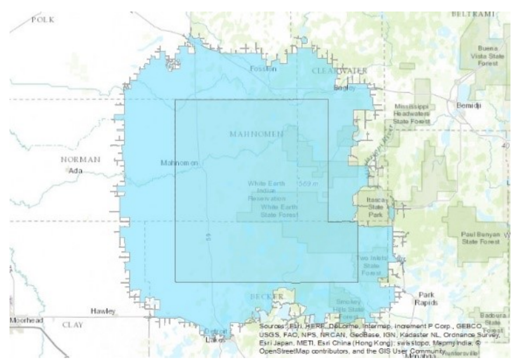
10-mile Distance	15-minute Drive-time
	

Figure 3.2 Comparison of 10-mile Distance and 15-minute Drive-time for the White Earth Tribal Area

As can be observed, while similar in size and coverage, the 15-minute Drive-time area for the White Earth Tribal Area more accurately reflects the area, and hence, roads, that are accessible than the 10-mile Distance (buffer). Accordingly, for each of the four Tribal Areas, 15-minute Drive-time analysis was performed and the crashes occurring within those areas were selected (Tables 3.3-3.5).

Table 3.3 Crashes Occurring on Tribal Areas

	Fatal		Incapcitating Injury		Non-Incapcitating Injury		Possible Injury		Total
Leech Lake	32	6.40%	65	13.00%	150	30.00%	253	50.60%	500
Mille Lacs	15	4.95%	24	7.92%	100	33.00%	164	54.13%	303
Red Lake	6	54.55%	1	9.09%	4	36.36%	0	0.00%	11
White Earth	22	6.61%	49	14.71%	113	33.93%	149	44.74%	333

Table 3.4 Crashes Occurring Adjacent to Tribal Areas (15-minute Drive time)

	Fatal		Incapcitating Injury		Non-Incapcitating Injury		Possible Injury		Total
Leech Lake	57	3.20%	117	6.58%	516	29.01%	1,089	61.21%	1,779
Mille Lacs	83	4.69%	128	7.24%	563	31.83%	995	56.25%	1,769
Red Lake	35	4.42%	61	7.70%	215	27.15%	481	60.73%	792
White Earth	44	3.99%	110	9.97%	346	31.37%	603	54.67%	1,103

Table 3.5 Crashes Occurring both on Tribal Areas and Adjacent Areas

	Fatal		Incapcitating Injury		Non-Incapcitating Injury		Possible Injury		Total
Leech Lake	89	3.91%	182	7.99%	666	29.22%	1,342	58.89%	2,279
Mille Lacs	98	4.73%	152	7.34%	663	32.00%	1,159	55.94%	2,072
Red Lake	41	5.11%	62	7.72%	219	27.27%	481	59.90%	803
White Earth	66	4.60%	159	11.07%	459	31.96%	752	52.37%	1,436

3.2.2 Hot Spot Analysis

Cluster analysis is used to identify the locations of statistically significant hot spots, cold spots, spatial outliers, and similar features. Isolating the location of spatial clusters is important when trying to identify the potential causes of the clustering; the location of clusters themselves can often provide clues about what might be causing the cluster. This type of analysis can help to answer questions such as, "Where are the clusters (hot spots/cold spots)?" , "Where are the spatial outliers?", and "Which features are most alike?".

In this study, various hot spot analyses were conducted on these four data sets. In this type of analysis, each crash is evaluated individually and the resultant output pinpoints those locations where unusual clusters of crash patterns occur. Specifically, Hot Spot Analysis calculates the Getis-Ord Gi* statistic for each feature in a dataset. The resultant z-scores and p-values indicate where features with either high or low values cluster spatially. This study was interested in identifying features that are statistically significant hot spots - a feature that has a high value and is surrounded by other features with high values. (By contrast, a cold spot is a feature that has a low value and is surrounded by other features with low values. That is, crashes have occurred at the cold spot location, but not with the same “intensity” as that of a hot spot.). The local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is very different from the expected local sum, and that difference is too large to be the result of random chance, a statistically significant z-score results. These values are typically displayed as illustrated in Figure 1.

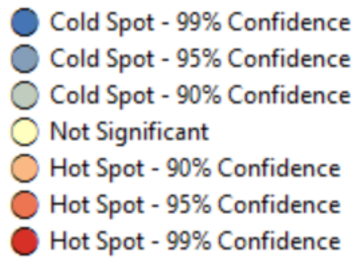


Figure 3.3 Legend Indicating Statistically Significant Hot Spots and Cold Spots

Very high (positive) or very low (negative) z-scores, associated with very small p-values, are found in the tails of the normal distribution. In the case of the output presented here, very high z-scores are indicative of "hot spots" while very low z-scores are indicative of "cold spots" (Figure 3.4).

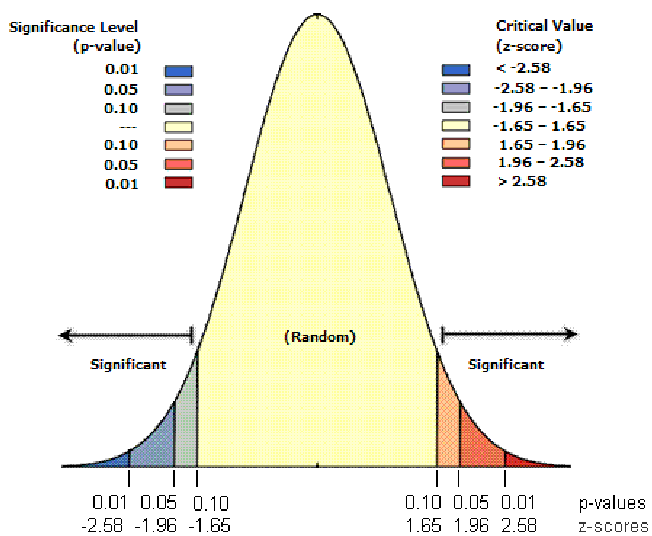


Figure 3.4 Standard Normal Distribution with associated z-scores and p-values

3.2.3 Analysis Question

In the analysis performed in this study, the research question was: "Where are there unexpectedly high spatial clusters of injuries, especially, clusters of fatal injuries, given all injuries?". This question was examined in relation to the Tribal Area, their Adjacent Area, and both areas combined (Figures 3.5-3.8).

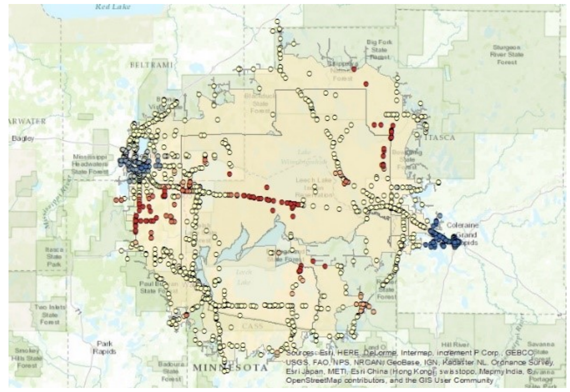
Hot Spot Analysis – Tribal Area	Hot Spot Analysis – Combined Areas
	

Figure 3.5 Hot Spot Analysis Leech Lake

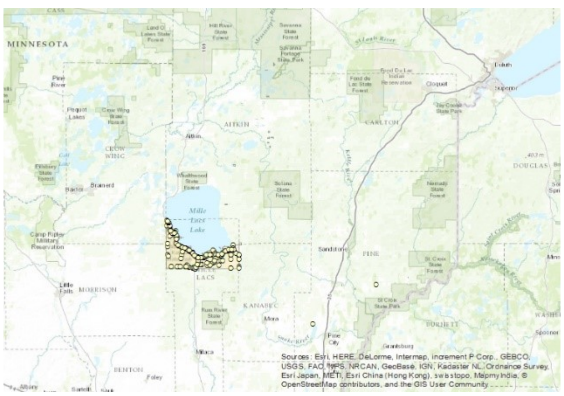
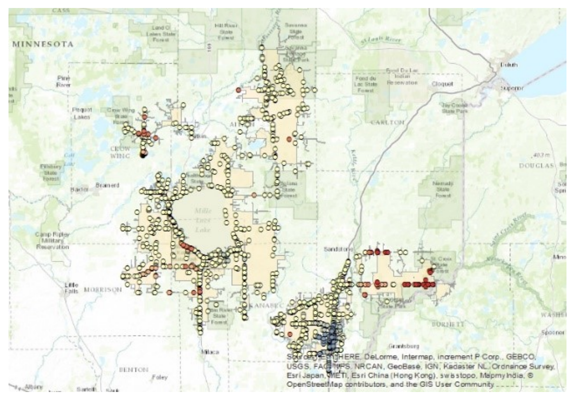
Hot Spot Analysis – Tribal Area	Hot Spot Analysis – Combined Areas
	

Figure 3.6 Hot Spot Analysis Mille Lacs

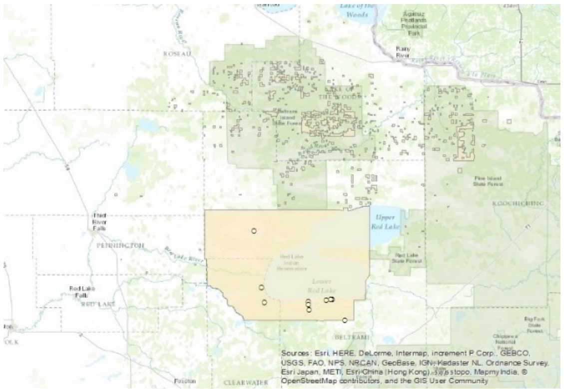
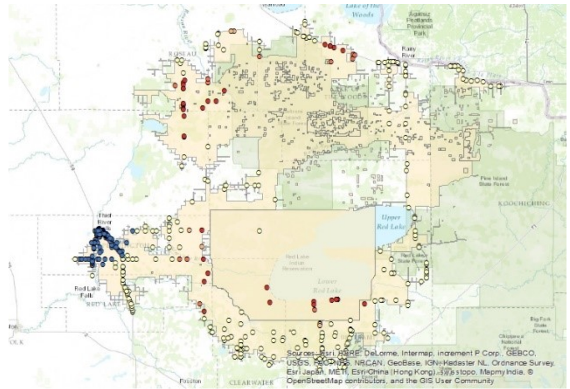
Hot Spot Analysis – Tribal Area	Hot Spot Analysis – Combined Areas
	

Figure 3.7 Hot Spot Analysis Red Lake

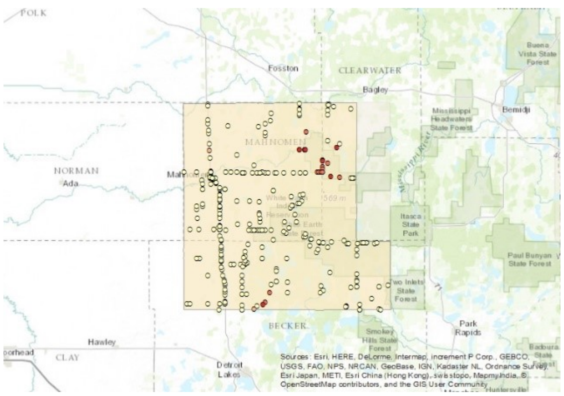
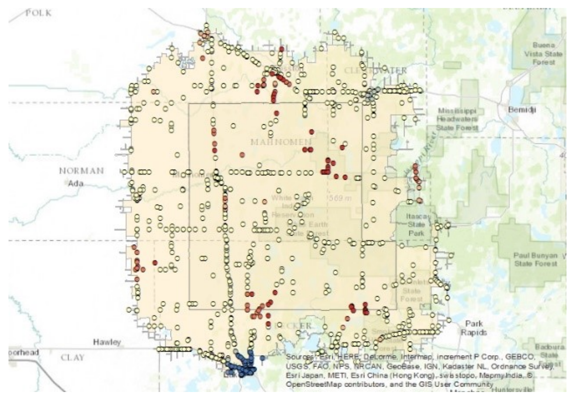
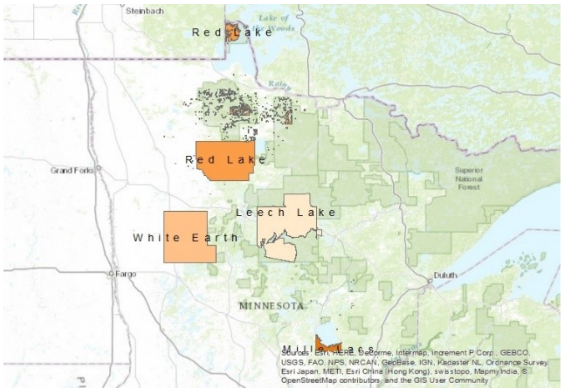
Hot Spot Analysis – Tribal Area	Hot Spot Analysis – Combined Areas
	

Figure 3.8 Hot Spot Analysis White Earth

3.2.4 Tribal Areas Hot Spots per Route Segment Mile

The next step in the analysis was to normalize the Hot Spot values (Avg-GiZScore) based on the total number of Route Segment Miles (road-miles) within the Tribal Areas. In this case, Mille Lacs had the highest proportion of Hot Spots per Route Segment Mile followed by Red Lake, White Earth, and Leech Lake (Figure 3.9).

Tribal Areas Hot Spots per Route Segment Mile



Avg_GiZScore / road_miles
- -0.0001208
- -0.0001207 - 0.000007451
- 0.000007452 - 0.0001390
- 0.0001391 - 0.001556

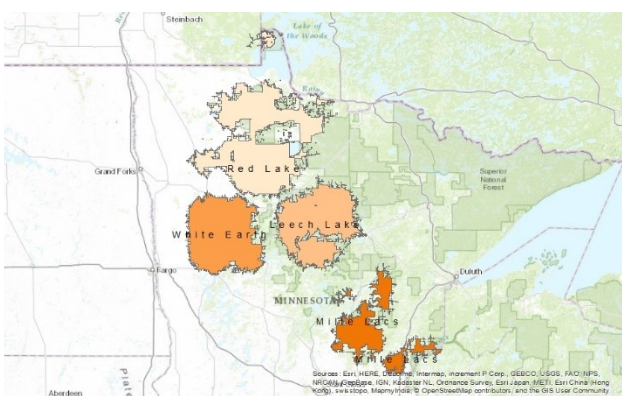
Figure 3.9 Tribal Areas Hot Spots per Route Segment Mile

3.2.5 Combined Tribal Areas and Adjacent Areas Hot Spots per Route Segment Mile

Following this, the next step in the analysis was to normalize the Hot Spot values (Avg-GiZScore) based on the total number of Route Segment Miles (road-miles) within the Combined Tribal Areas and Adjacent Areas. In this case, Mille Lacs has the highest proportion of Hot Spots per Route Segment Mile followed by White Earth, Leech Lake, and Red Lake (Figure 3.10).

Combined Tribal Areas and Adjacent Areas

Hot Spots per Route Segment Mile



Avg_GiZScore / road_miles
- -0.0005568
- -0.0005567 - -0.0002099
- -0.0002098 - -0.0001467
- -0.0001466 - -0.0001097

Figure 3.10 Combined Tribal Areas and Adjacent Areas Hot Spots per Route Segment Mile

Comparing Tribal Areas (road-mile normalized z-score) with their Adjacent Areas (road-mile normalized z-score) indicates the following (Table 3.6):

1 - All Tribal Areas have z-scores greater than their Adjacent Areas, that is, they are worse off.

2 - Ranking these in terms of severity (greatest difference between z-scores) indicates that Mille Lacs is the worst Tribal Area followed by Red Lake, White Earth, and Leech Lake.

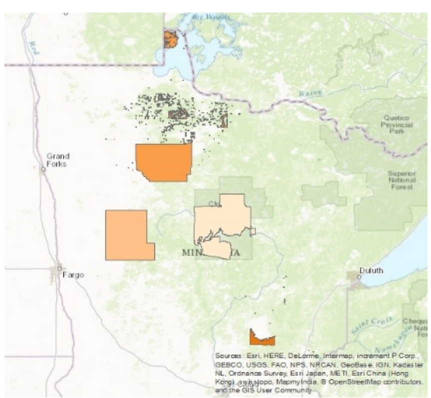
Table 3.6 z-score Comparison and Ranking for Route Segment Miles (road-miles)

	Tribal Area Avg Z Score	Adjacent Area Avg Z Score	Absolute Value Z Score	Rank in Terms of Severity
Leech Lake	-0.000121	-0.000342	0.000221	4
Mille Lacs	0.001556	-0.000151	0.001707	1
Red Lake	0.000139	-0.000474	0.000613	2
White Earth	0.000007	-0.000276	0.000283	3

3.2.6 Tribal Areas Hot Spots per AADT

The next step in the analysis was to normalize the Hot Spot values (Avg-GiZScore) based on the total Annual Average Daily Traffic (total AADT) within the Tribal Areas (the AADT data values for the years 2004, 2006, 2008, 2010, and 2012 were averaged to arrive at an Average AADT Value). In this case, Mille Lacs has the highest proportion of Hot Spots per AADT followed by Red Lake, White Earth, and Leech Lake (Figure 3.11).

Tribal Areas Hot Spots per AADT



Avg_GiZScore / total AADT
- -0.000001292
- -0.000001291 - 0.000000123
- 0.000000123 - 0.000002281
- 0.000002282 - 0.000002897

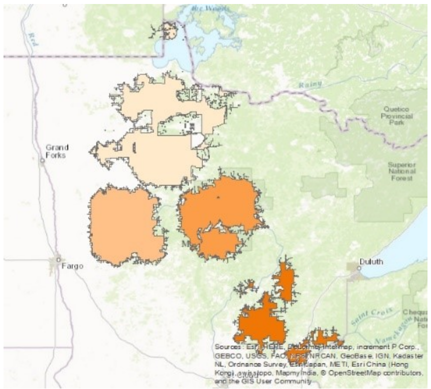
Figure 3.11 Tribal Areas Hot Spots per AADT

3.2.7 Combined Tribal Areas and Adjacent Areas Hot Spots per AADT

Following this, the next step in the analysis was to normalize the Hot Spot values (Avg-GiZScore) based on the total Annual Average Daily Traffic (total AADT) within the Combined Tribal Areas and Adjacent Areas. In this case, Mille Lacs had the highest proportion of Hot Spots per AADT followed by Leech Lake, White Earth, and Red Lake (Figure 3.12).

Combined Tribal Areas and Adjacent Areas

Hot Spots per AADT



Avg_GiZScore / total AADT

- -0.000004911
- -0.000004910 - -0.000001180
- -0.000001179 - -0.000000843
- -0.000000843 - -0.000000413

Figure 3.12 Combined Tribal Areas and Adjacent Areas Hot Spots per AADT

Comparing Tribal Areas (total AADT normalized z-score) with their Adjacent Areas (total AADT normalized z-score) indicates the following (Table 3.7):

1 - Three Tribal Areas have z-scores greater than their Adjacent Areas, that is, they are worse off (in the case if Leech Lake the z-scores are equal).

2 - Ranking these in terms of severity (greatest difference between z-scores) indicates that Red Lake is the worst Tribal Area followed by, Mille Lacs, White Earth, and Leech Lake.

Table 3.7 z-score Comparison and Ranking for Annual Average Daily Traffic (total AADT)

	Tribal Area Avg Z Score	Adjacent Area Avg Z Score	Absolute Value Z Score	Rank in Terms of Severity
Leech Lake	-0.000001	-0.000001	0	4
Mille Lacs	0.000003	-0.000001	0.000004	2
Red Lake	0.000002	-0.000004	0.000006	1
White Earth	0	-0.000002	0.000002	3

The above analysis indicates that there are localized "hot spot" areas within the Tribal Areas where crashes are occurring at a statistically significant rate that is higher than would be normally expected. In addition, when controlling for both Route Segment Miles (road-miles) and Annual Average Daily Traffic (total AADT), all Tribal Areas (specifically, seven of eight possible outcomes) had z-scores greater than their Adjacent Areas, that is, they were all worse off in terms of hot spots than in the areas surrounding each Tribal Area. Thus, when answering the research question, "Where are there unexpectedly high spatial clusters of injuries, especially, fatal injuries, given all injuries?" unfortunately, the answer to this question is that for the Tribal Areas analyzed, these clusters lie within their territory.

3.3 SUMMARY AND DISCUSSION

This phase of the research sought find the answer to the question of identifying locations where there were unexpectedly high spatial clusters of injuries, especially, clusters of fatal injuries, given all injuries.

The spatial analysis revealed that all Tribal Areas have z-scores greater than their Adjacent Areas, that is, they are worse off in terms of traffic safety. Some Tribes were more severe than then others. Ranking these in terms of severity (greatest difference between z-scores) indicates that Mille Lacs has the highest z-score followed by Red Lake, White Earth, and Leech Lake.

Given that the adjacent areas were generally similar (e.g., rural), this suggests that there are conditions distinct within tribal boundaries that contribute to this difference. Future research should link this form of spatial analysis with other exposure, conditions, and behavioral data to fine-tune the explanation of the differences especially as they may vary by Reservation location.

CHAPTER 4: TRIBAL IMPLEMENTATION CONSIDERATIONS

4.1 INTRODUCTION

Beginning in 2017, the research team began considering a broader scope for considering Tribal GIS implementation to improve transportation safety. This work builds the concept of Tribal Data Sovereignty that is being investigated by Tribal member (and report co-author) J. Robertson[2]. As such, the scope of this chapter is to consider a tribal governance framework using data sovereignty as a mechanism for promoting appropriate data collection and practice in tribal traffic safety.

The concept of sovereignty has been well documented and established through more than a century of United States Federal Indian Law and Policy (Robertson, 2017). Recently, Kessler-Mata's (2014) *A Constitutive Theory of Tribal Sovereignty: The Possibilities of Federalism* explained:

Claims by tribes in the United States for the rights to exercise self-determination and self-governance are most often made through an appeal to the concept of tribal sovereignty. Tribal sovereignty is supposed to serve as both a justification for these rights (i.e. 'as tribes, we are sovereign entities and, therefore, ought to be able to exercise these rights'), as well as a guiding principle that enables tribes to delineate boundaries and authorities between themselves and other polities (i.e. 'as sovereigns, we are empowered with these unencumbered rights of governance').

To claim that tribal sovereignty embodies a right to self-determination or a right to self-governance is to put forward a concept that does much more in theory that it does in practice. The concept of tribal sovereignty is one that promotes intergovernmental relations with non-tribal governments and which takes the principles of equitable interaction and political coordination as central to its operation.

This analysis extends tribal sovereignty to the issue of a recent development of data sovereignty and is intended illustrate this concept through the issues of tribal transportation safety. Presently, there is no precedent that effectively addresses the current state of how tribes aggregate, maintain, or share data as an act of sovereignty. Since every tribal, federal, state, and local governments are trying to contend with the exponential growth of data as it relates to strategic decision-making; tribes are in a unique position to provide their own data and analysis to strengthen their position in data driven decision-making using this framework. Transportation Safety and the use of GIS therein is one element of this decision-making.

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[2] Member of the Sisseton Wahpeton Oyate Tribe and a doctoral student at the South Dakota State University who recently completed his dissertation on tribal data sovereignty (Robertson, 2018).

4.2 FRAMEWORK OBJECTIVES

The goal of this analysis was to design a framework with a set of diagnostic tools to better understand how tribal traffic safety can be managed consistent with tribal sovereignty principles. The framework includes global ideas of self-governance but also examines methods practical implementation of diagnostic tools to measure success for each unique Tribe through key indicator development. Furthermore, the framework was designed with ease of implementation in mind to provide more flexibility than previous and well-documented top-down models of governance and management strategies.

The key to effective framework design is to allow for a multidimensional approach that provides depth in evaluating a set of key indicators aimed at not only understanding data management, policy analysis, and any number of associated data domains; but how this applies to the diversity of social, economic, and political structures on American Indian reservations.

The goal was to orient the values and opinions of tribal stakeholders that represent the contingency of individuals doing the work. Effective design strategies that provide an administrative way to incorporate all global and local stakeholders in all levels of governance further adds dimension in negotiating data-driven decisions. It is important to account for all levels of interaction and to build sensible policy from information gathered and analyzed for the benefit of the Tribal community, not necessarily the individual.

The basis for this proof of concept framework was to align to objectives aimed at testing the validity of the diagnostic tools by acquiring appropriate tribal and non-tribal stakeholder feedback concerning the design. The key to applying multidimensionality was to understand the depth of knowledge of the stakeholders at each phase of any analysis and to appropriate an effective design strategy to unify this information strategically and in this case, to address transportation safety in tribal communities.

4.3 DATA SOVEREIGNTY FRAMEWORK DEVELOPMENT

Data sovereignty can be thought of as an initiative to provide a set of tools or smart solutions that when constructed as a collective framework can empower Tribal governments to use data as matter of self-determination. Collectively, this idea can encompass any number of data driven decision-making tools such as designing and implementing a Tribal census, managing natural resources and sacred sites, or developing data collection through statistical analysis to further a tribe’s ability to make effective planning decisions. The outline of this exploratory process is organized around four key dimensions. In addition, key descriptors are an extension of the four key indicators provided by the data sovereignty framework.

4.3.1 Analysis Steps

Step 1: Developing a Preliminary Framework

First, based on a review of the pertinent literature, four dimensions were devised to capture critical elements of the Data Sovereignty Framework: Tribal Community and Culture, Tribal Governance, Data Management, and Data Domain Structures. Within each of these dimensions, key indicators were identified, and a series of questions devised to guide development of tribal specific framework metrics. Thus, the framework was intended to inductively generate a number of Tribal specific issues for data sovereignty and how this relates to the data domain of transportation safety.

Step 2: Diagnostic Evaluation of Key Descriptors

Once identification of key indicators has been established, an examination of the key descriptors can begin. Every key indicator's descriptors remain constant to provide a way to uniformly assess the interaction of governance, community and data practices. The next step is to evaluate the level of fulfillment each descriptor plays in contributing to the selected data domain. For instance, if the tribal government has an existing agreement with a stakeholder in analyzing traffic data, then not only is nation to nation communique fulfilled, but data ownership, security and privacy may also have been established. Thus, evaluating and goal setting of the key indicator descriptors is the priority.

Step 3: Analysis of the Targeted Data Domain

Once the key descriptors have been examined, a more in-depth analysis of the tribal traffic safety domain can begin. In design theory, an exploratory analysis will provide an assessment of information already collected or need to be collected, design options, looking at operational capacity, or how to unify existing structures with the purpose of creating a unified set of practices to produce specific data driven outcomes. After examining the specific metrics of interest, a comprehensive plan can be produced to specifically address data sovereignty infrastructure as it pertains to transportation safety.

4.4 PRELIMINARY DATA SOVEREIGNTY FRAMEWORK

4.4.1 Key Indicators of Data Sovereignty Framework

The framework design outlined has four indicators:

1. Tribal Community and Culture
2. Tribal Governance
3. Data Management
4. Data Domain

Each dimension drives a decision-making process to allow for specific framework diagnostic questions to be developed using the paired key descriptors in Table 4.1.

Table 4.1 Data Sovereignty Framework Indicators with Key Descriptors

Data Sovereignty Key Descriptors with Each Respective Key Indicator			
Tribal Community and Culture	Tribal Governance	Data Management	Data Domain: Tribal Transportation Safety
History	Federal Indian Law and Policy	Data Collection and Practice	Quantitative Transportation Data
Culture	Nation to Nation Communique	Data Analysis	Qualitative Transportation Data
Cultural Values	Sovereignty	Data Ownership	GIS and Analytical Infrastructure
Citizenry	Self-Determination	Security and Privacy	Tribal Plans and Priorities

The design templates developed for the diagnostic tools (see Appendix 1) rely on the key indicators and descriptors to remain fixed except for data domain; which can be regarded as the indicator that can encompass any task a tribe needs to analyze. This maintains the integrity of the framework design.

In addition, it is important to prioritize the cultural design metrics first. Allowing tribal citizens to contribute in an overall governance strategy is an important aspect in indigenous nation building: to be stable and effective in self-governing, governmental systems must fit with the way a particular culture answers questions of who, what, where, and how. This is called cultural match: a fit with the shared norms of the community. In addition, cultural grounding is a critical element in legitimacy that makes wielding governmental authority a sacred trust, a sacred responsibility to serve the people and their interest in an appropriate way.

Although most organizations stress the importance of data driven metrics, too often analyses are compiled by organizations outside of the tribal community and the disconnect from what is perceived to be important in tribal communities may be much different than what the actual needs of tribal citizenry are. The next section defines this cultural and data relationship in broader terms.

4.4.2 The Four Key Indicator Definitions

These indicators are aligned to adhere to the research objectives and provide theoretical background information that is the basis of the diagnostic tool constructs in the next section. These definitions are a set of guidelines establishing past or current work in each respective field, whether it is federal Indian law, governance strategies, or understanding research design principles.

Key Indicator 1: Tribal Community and Culture

Conceptually, the reason many projects fail to deliver in many Tribal communities is the one-size-fits-all model of governance is inappropriate given the diverse and complex nature of each tribal groups' history, culture, and identity. Ignoring this critical aspect in Indian country has had devastating effects and decentralizes important power structures defined by each tribe in their everyday affairs.

More broadly, the importance of *cultural match* maintains a necessity with consonance (match) between the structure of a society's formal institutions of governance and economic development and its underlying norms of political power and authority (culture) for those institutions to function and serve effectively. For this concept to "work", institutions must meet two tests: legitimacy in eyes of the citizens and practical efficacy (State of Native Nations, 2008)

The citizens of tribal nations often have the daunting task of compiling information for any number of things happening in day to day operations. The roles these individuals undertake can be complex and sometimes one individual is solely responsible for multiple jobs involving GIS analysis, IT, data analysis; thus, human capital often gets stretched thin.

The framework was designed with tribal citizenry at its center for several purposes:

- To honor tribal cultural capital
- To obtain information from citizens at the ground level
- Through citizen science, information can be provided to aid in reducing workload

Thus, the unification of tribal voices may seem cliché; however, history has shown that the exclusion of citizens at any level creates fragmentation and the aim here is to study the quantitative effect of inclusion through these key indicators.

Key Indicator 2: Tribal Governance

Undoubtedly, matters of governance and culture in tribal communities relies on a careful assessment of "the process by which a community or nation improves its economic ability to sustain its citizens, achieve its sociocultural goals, and support its sovereignty and governance processes" (Rebuilding Native Nations, 36). One strategy is to allow self-determination to be the vehicle that drives economic development that reflects a unique tribe's agenda in achieving those goals.

The scope of governance is functionally diverse and developing priorities that support development are not always achievable, so it is important to understand what strategies exist in each tribal government that maximizes the relationship between tribal governance policy and the community driving the work that reflects this dynamic.

Thus, this indicator is designed with understanding the scope of each individual tribe's system of governance. As mentioned in the first section, the delicate balance between the theory and practice in asserting sovereignty through self-determination is no easy task. But what is most important is this notion of equitable interaction, which is conceptually asserting sovereignty through agreements made with non-Indian entities and maintaining a more powerful position of negotiation through data collection and practice.

Key Indicator 3: Data Management

The descriptors in Data Management key indicator are a direct result of governance strategies that regard data and Data Sovereignty as the next step in providing safeguards for tribes in pursuing data ownership, security, and privacy. These framework inter-dependencies are the result of Native-centric design principles geared towards assisting Tribes with understanding the power of data analysis to bolster government to government communication, written agreements, and sustainable economic development. Data sovereignty represents the highest quantifiable standard to which governance reflects native nation building. Data management is a hierarchy of processes that utilize the foundations of statistical design theory in managing the overall framework stability. Since data collection often begins with the need for situated, qualitative, and collaboratively produced data, the natural order of pursuing more advanced data techniques such as survey design, statistical modeling is an example of how key descriptors in this key indicator add dimensional structure as the framework continues to advance beyond simply an exploratory process.

Thus, data management is defined to be more than just information collection; it is the cornerstone of providing crucial data driven metrics important in asserting sovereignty through governance and economic development.

Key Indicator 4: Data Domain

Data domains are defined as any data collection process that occurs in Tribal communities that can be understood to have specific meaning in the context of governance, economic development, or operational capacity. Domains such as health care, transportation, education, enrollment, historic preservation, and census are all considered data domains. Since data domains can represent any project a tribe is interested in, it is implied that the four key descriptors will change depending on the choice of data domain. The dimensionalities of these domains are vast and can encompass any level of analysis from descriptive to analytical. The choice of descriptors is then a matter of assessing each indicator as it pertains to the domain. In this context, transportation safety and the use of GIS for spatial data analysis is the spatial domain.

4.4.3 Diagnostic Tool Development Templates for Evaluation

The construction of diagnostic tools to accompany the data sovereignty framework is to put theory into practice. The set of tools that have been designed are to understand the collective nature of the connectedness of tribal cultural values, the importance of governance, and the impact quantifying information as a matter of sovereignty: making data driven decisions a strategic measure in how a tribe asserts its authority is no different than any organization wishing to use to analytics as the foundation of providing irrefutable evidence governing their decision making for sound policy decisions.

Diagnostic tools were developed for the key indicator definitions presented in the previous, and they are contained and detailed in Appendix 1. As part of their development, interviews were conducted with two experts, a representative for Mille Lacs Tribe in Minnesota[3] and Sisseton Wahpeton Oyate Tribe in South Dakota[4] using these tools as guides. What follows is a summary of these two interviews relative to the framework elements.

1: Tribal Community and Culture

According to the Mille Lacs representative, one needs to understand variations in the size of tribal communities. Since tribes are often small scale, some tools are cost prohibitive and some off the shelf solutions are hard to scale. Minnesota counties are large enough to customize their own GIS software, scalability and capabilities while tribes sometimes cannot**.** There are also various goals to be reconciled, such as economic development and infrastructure safety. Projects are identified by public participation and that allows for grassroots opinions and values.

According the Sisseton Wahpeton Oyate representative, the history of the infrastructure in the community is important. A lot of their roads on the reservation were built in the 1960’s, so members are driving on roads that have engineering standards of those times. Because of this history the community is in need paved roads, wider roads, bridges, not just for the tribe but for the county as well. Moreover, local bridges were built back in the 1950’s, and having these be brought up to date is a critical issue.

2: Tribal Governance

According the Mille Lacs representative, one fundamental challenge comes from not only from different levels of tribal government, but land ownership whether it be commercial versus trust land versus allotted. Also, one needs to take into account five additional counties and townships means the work processes and systems tend to be spread out in not only the land base in these scenarios but Minnesota in general. Interaction with state and federal officials was viewed as fairly cooperative. Joint committees meet quarterly with MNDOT. Locally, some tribal and counties get along well, but there are also counties that some tribes find very different to deal with and that can impede cooperation across the governance entities.

According the Sisseton Wahpeton Oyate representative, it does not seem that tribal governance that gets in the way. It could be the county itself seems to hinder the tribe. That seems to be a factor in days gone past; the real barrier is lack of funds and making the roads up to standards.

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[3] Interview conducted on February 8, 2018
[4] Interview conducted on February 14, 2018

3. Data Management

According the Mille Lacs representative, access to data is fairly easy in Minnesota since the portal the state provides allows for state level downloading of data sets and tribes do use GIS in varying degrees. However, help is needed in how to report crashes and how that relates to digital infrastructure addressing small organizations since many simply have no concept of what digital infrastructure looks like. This challenge is building professionalism and capacity in data management at the tribes. Quarterly reports go to 'everybody' but not every tribe does anything with this information. Many time others need to relearn and adapt to already established modes of addressing the issues at hand.

According the Sisseton Wahpeton Oyate representative, there are competing interests and need for data. For example, there is this intersection in town, and the state DOT has proposed to put roundabouts in and it seems no one has even asked the tribal community. This leads to questions about what data they are using. There is a need for some type of improvement but wouldn't a traffic light be a better than roundabout. It is a state highway and with big trucks and such, they will have to drive through this roundabout. They are taking a European mentality and applying it to a rural farming community. If the Tribe had our own data, we could advise them what needs to be done.

4. Traffic Safety Data Domain

According to the Mille Lacs representative, residents often point to road safety issues such as pedestrian safety. Many tribal members are taught to walk on different sides of the road. These observations have led to more formal studies. The state had done some pedestrian counts but cameras monitoring a "hole in a fence" found about 150 people were using a cut hole in the fence designed to route foot traffic to a controlled intersection. Less than 3% of residents use the actual controlled intersection that was designed. Spatial analyses such as these have helped inform safety priorities.

According to the Sisseton Wahpeton Oyate, there are numerous safety issues for analysis including pedestrian safety. The problem is the Lake Traverse district has those eleven units (tribal housing) alongside county highway seven and safety issues if they are trying to access the lake. There is just a highway where people have to go through the ditch, go on top of the highway, then go on the other side through the ditch, then walk out to the lake.

4.5 SUMMARY AND DISCUSSION

This phase of the research sought explore an implementation framework for Tribal Transportation Safety and the role of GIS therein. It takes as its departure point the concept of Tribal Sovereignty and within that notes items such as culture, governance, data management and safety data access need to be considered with crafting a means to use GIS spatial analysis to improve tribal safety. As the study was approaching a conclusion when these dimensions were designed, only a very preliminary investigation could be conducted. However, the interviews provided a preliminary indication of how the four dimensions were operative in terms of explaining traffic safety issues, and the role of GIS therein. Future research should more systematically examine the role of the four indicators in helping to manage traffic safety analysis using GIS.

Taken together, the findings suggest that GIS can be a useful tool to assist tribal communities in addressing tribal safety issues. The spatial analysis further demonstrates the need to take innovative approaches to improve safety, as rates of traffic fatalities inside tribal communities exceeds the rates outside the communities. However, there remain a number implementation dimensions that need to be considered.

CHAPTER 5: CONCLUSIONS AND DIRECTIONS

5.1 SUMMARY OF FINDINGS

The first objective was to design and test tribal safety GIS prototypes. Drawing on a literature review and stakeholder outreach, a series of prototype applications were devised that could be used by Tribes to assist in their transportation safety planning, assessment and implementation. Feedback from Tribal representatives provided confirmation that easy to interpret maps of safety trends and conditions could assist in focusing safety information gathering and improvement efforts as well as information sharing of best practices among Tribes. Subsequent interviews with Tribal representatives (e.g. Chapter 4) provided additional insight into implementation barriers faced by Tribes, such as limited staff resources that could be devoted to such GIS usage despite their perceived value.

The second objective was to use one of these applications (hot spot analysis) to analyze traffic safety to investigate tribal safety issues using traffic fatality data. The resultant z-scores revealed that all Tribal Areas had z-scores greater than their adjacent areas; that is, they are worse off in terms of traffic safety. Given that the adjacent areas were generally similar (e.g., rural), this suggests that there are conditions distinct within tribal boundaries that contribute to this difference.

A third objective was to examine implementation paths for GIS. Drawing on the concept of Tribal Sovereignty, this analysis developed a framework for considering GIS Based Traffic Safety Analysis within the context of Tribal governance and management. The multi-level nature of the implementation framework highlighted the need to think through the unique context of tribal management. Further, Tribes have multiple data needs for economic development, natural resource management and so forth.

5.2 FUTURE DIRECTIONS

Future analysis and research can build on these findings. As efforts continue to move GIS and business analytics into online cloud environments, the availability of off-the-shelf applications (such as the one designed in Chapter 2) will only increase. Tribal communities that already have been using GIS can play a leadership role in demonstrating these next generation of applications. Further, Bureau of Indian Affairs does provide a variety of training opportunities for GIS and these could be expanding to include these online elements.

In terms of analysis, while the spatial analysis revealed differential traffic safety conditions within versus outside the tribal lands, a more detailed analysis of these differential rates is needed. This would include, for example, integrating both exposure, behavioral, and roadway physical design factors into the analysis. As was noted in Chapter 2, this is perhaps the most complex of applications, yet the findings have implications for tribal improvements. Turning to the implementation issues discussed in Chapter 4, there is a need to understand variations in tribal size and resources and how they affect the capacity to conduct such analysis.

Finally, the concept of data sovereignty is offered as an organizing concept not just for GIS but for Tribal data management more generally. It has as its foundation a number of dimensions that can affect implementation success. Moreover, GIS implementation needs to be considered across a range of domains (e.g. transportation, economic development) and that would provide synergies, as suggested in the recent *Tribal GIS: Supporting Native American Decision-Making* publication (Esri Press, 2017). Future research could explore its value for traffic safety more systematically as well as consider the data sovereignty concept for other tribal data management domains.

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APPENDIX A

Key Indicator 1: *Tribal Community and Culture*

Key Descriptors:

History	Culture	Cultural Values	Citizenry

Why is it important? Culture Does Matter

Cultural values play an important in decision making. The importance of consulting elders, stakeholders, and citizens is to be Native. The history of excluding voices that speak for local clans, districts, or inter-tribal groups is a product of assimilation and acculturation. To understand the voices of the community requires a commitment to knowing each tribe as unique entities with a set of cultural values and citizenry that when given a proper voice would contribute to a betterment of their community if given the opportunity. Each unique history provides context to decision making.

Communities still face issues of historical trauma, lack of stable governments, poverty, and lack of representation. This framework aims to provide this opportunity through a well-developed process of data collection and practice aimed at collecting information from tribal citizens that do the work of the community in addition to providing input to tribal officials.

Descriptors:

History

What particular tribal history is important to understand when developing a data domain?

How do non-Indian stakeholders hold themselves accountable to understanding cultural history and context in working with tribes?

How do tribes maintain the context of relevant historical record when making planning decisions?

Current Culture

What cultural beliefs should be understood when making decisions?

What is current state of community culture and perceptions?

How can we support these stakeholders through data-driven initiatives using cultural capital?

Cultural Values

Who are the elders you think can contribute most effectively injecting additional cultural values in decision making?

Key Indicator 2: *Tribal Governance*

Key Descriptors:

Federal Indian Law & Policy	Nation to Nation Communique	Tribal Sovereignty	Self-Determination

Why is it Important? Sovereignty Matters.

Tribal governments who assert sovereignty through self-determination face innumerable challenges that can strengthen or weaken their position in negotiations. Tribes do have inherent rights to manage their affairs as they see fit, but in the era of forced federalism, the need for equitable interaction and political capital is an absolute necessity when making agreements with non-Indian stakeholders.

In the modern era, sovereignty and self-determination are tools tribes utilize to maintain their unique nationhood directly from the body of Federal Indian Law established from two centuries of negotiation, sacrifice, and cultural identity. This historical precedence is why tribal governments fight so hard for their nationhood.

Tribes who assert sovereignty in nation to nation communications by forming compacts, memoranda of understanding, or informal agreements must fully understand there are policy tools non-Indian policymakers use that have a direct effect on not only policy, but political capital as well. The two types of policy tools that have a direct effect on negotiations are regulatory and capacity-building.

Regulatory policies are used when policymakers view emerging contenders as a threat to economic or political well-being; while in contrast capacity-building tools are intended to strengthen communities by enhancing tribal powers of self-determination. Capacity-building tools are the cornerstone of the data sovereignty framework because it comes the closest to describing Indigenous nation building strategies.

Descriptors:

Federal Indian Law and Policy

Is there appropriate Federal Indian Law precedence in exploring the current data domain?

What is the position the tribal government takes in data-driven policy initiatives?

Nation to Nation Communique

Are their existing MOA/MOU/Compact agreements that the tribe has used in the past?

<u>Key Indicator 3: *Data Management*</u>

Key Descriptors:

Data Collection Practices | Data Analysis | Data Ownership | Security and Privacy

Why is it Important? Unifying Data in Indian Country is Paramount

Data management is crucial in organizing information so meaningful outcomes can be achieved. The framework was designed with the intent of organizing data uniformly through these sets of indicators with the expected outcome of creating a structured look at data in developmental stages of capacity. The key descriptors can be divided into two groups: quality of data practices as it relates to the data domain and management of the data as for security purposes. In addition, this indicator also attempts to identify the types of technologies that are used in a tribe's data collection process which could be data storage systems or software related to analysis such as ArcGIS, SAS, or R. The importance of these baseline metrics provides informational capacity so when an exploratory process is designed, it aligns to the best possible outcome for the not only the project, but governance strategies as well.

At every level tribes are collecting data. Some the data is structured some it is unstructured. This framework seeks to understand a tribe's operational capacity of data collection, practice, as well as security and privacy. In addition, all tribes have some sort of technological infrastructures in place, and so the purpose of this indicator is to understand the strengths and weaknesses as it relates to the data domain. Thus, much of data management revolves around structuring data based on a tribe's current infrastructure to investigate which stage of development is appropriate from the analysis processes described in the last section (i.e. descriptive, exploratory or advanced analysis).

Learning how to create strategic solutions from either descriptive or inferential topics in strategic planning will help tribes implement data solutions to minimize errors in measurement, or to invest software platforms capable of making data collection or analysis easier. Data sovereignty conceptually is creating platforms to utilize data as an Indigenous nation building tool for equitable interaction.

Descriptors:

Data Collection Practices

What are the current data collection practices (i.e. manual or digital data collection)?

Who collects the data?

Where is the data stored?

Descriptors:

Data Analysis

What is the quality of tribal data analyses?

Do tribes rely on consultants or in-house personnel for analyzing data?

Does the tribe have any software platforms for data collection, analysis, or reporting?

Data Ownership

Do tribes have a policies governing data ownership, whether it is with existing or future data collection?

Is there Federal Indian Law precedence that prevents tribes from taking full ownership of data when engaged in federal, state or local jurisdictional agreements?

Who uses and reports specific data to the tribe?

Security and Privacy

Are there privacy policies in place?

Are their data sharing policies in place?

Are there data encryption protocols in place?

Privacy: Who is sharing what?

Are there protocols in place in regard to theft of data through cyber-attacks?

Key Indicator 4: Specified Data Domain

Key Descriptors: Tribal Transportation Safety

Quantitative Transportation Data	Qualitative Transportation Data	GIS and Analytical Infrastructure	Tribal Plans and Priorities

Why is it Important? Data Ownership and Management Matters

An accompanying report, *Using GIS to Improve Tribal Traffic Safety: A Statistical Evaluation of Hot Spots on Minnesota Tribal Reservation Areas* was the basis for developing these descriptors. Hot spot analysis was a prototype application developed as a matter of assessing the Tribes interest in implementing GIS applications for planning, analysis, and programming in transportation safety. The report also provided additional inferential topics to strengthen further development of not just tribal traffic analysis, but point process model development and network analysis in current transportation safety literature.

The American Indian reservation system is not entirely disjoint from the regular business that occurs in areas within a reasonable distance to Tribal affairs, and traffic related accidents are very relevant to the location of services within the immediate vicinity of townships that border the reservation. Development of this data domain into a proof of concept was the purpose of the report and to aggregate any number of considerations that create a unified framework in order to work with Tribal governments in developing GIS analysis as a practical and efficient way to improve transportation safety through equitable interaction with state and local officials.

Descriptors:

Quantitative Transportation Data

What is the source of data used for Tribal safety planning and analysis?

Do Tribes have ready access and capacity to analyze this data?

Qualitative Transportation Data

What qualitative data is available for understanding transportation safety issues?

Do Tribes have read access and capacity to analyze this data?

Key Indicator 4: Specified Data Domain

Key Descriptors: Tribal Transportation Safety

Quantitative Transportation Data	Qualitative Transportation Data	GIS and Analytical Infrastructure	Tribal Plans and Priorities

Descriptors:

GIS and Analytical Infrastructure

In developing traffic safety, what tools are necessary?

Does the tribe have a GIS department?

Do tribal stakeholders have access to MnCMAT should data sharing?

Has there been on-going data collection on traffic issues within the reservation boundaries?

How can tribes use hot spot analysis as a potential prototype for tribes to provide input?

Tribal Plans and Priorities

What priorities do tribes have for traffic safety?

How well has the data been used to inform these priorities?

Have traffic safety plans and programs been developed using this data?