Wisconsin High Risk Rural Roads (HRRR) GIS Data Integration and Risk Factor Analysis

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ABSTRACT

In order to address emerging federal reporting requirements, along with the need to more efficiently manage limited safety improvement resources, DOTs are continuing to expand capabilities for data driven approaches to supporting operations and planning decisions. A key component of this approach is the use of enterprise-wide Linear Referencing Systems (LRS) to integrate multiple data sources such as crashes, traffic volumes, and roadway inventory information. Within this context, the Wisconsin DOT (WisDOT) has recently completed a GIS-based crash map that was subsequently leveraged to develop an automated approach to identifying a statewide list of high risk rural roads (HRRR) for potential Highway Safety Improvement Program (HSIP) projects.

This paper describes the integration process and ranking methodology that were developed to generate the Wisconsin statewide HRRR list. The ranking process leveraged the Wisconsin Information System for Local Roads (WISLR) LRS along with the mapped crash and traffic volume data to compute corridor crash rates. Different ranking criteria were applied to produce a final "filtered K-A crash rate" ranking method. GIS maps and crash data details were provided for the top ten corridors as a basis to investigate potential HSIP projects. In addition to identifying specific high risk corridors, however, the automated approach and statewide list provides an opportunity to conduct systematic, aggregated analysis of the corridor rankings to identify HRRR risk factors. As a second component of this research, results are presented from an analysis of the 2012 HRRR list for a selected set of crash data attributes.

INTRODUCTION

In order to address emerging federal reporting requirements, along with the need to more efficiently manage limited safety improvement resources, DOTs are continuing to expand capabilities for data driven approaches to supporting operations and planning decisions. A key component of this approach is the use of enterprise-wide Linear Referencing Systems (LRS) to integrate multiple data sources such as crashes, traffic volumes, and roadway inventory information. Within this context, the Wisconsin DOT (WisDOT) has recently completed a project to geocode multiple years of state and non-state crashes to a single statewide network. The resulting LRS crash map was subsequently leveraged to develop an automated approach to identifying a statewide list of high risk rural roads (HRRR) for potential Highway Safety Improvement Program (HSIP) projects.

This paper describes the integration process and ranking methodology that were developed to generate the Wisconsin statewide HRRR list. The integration process leveraged WisDOT's Wisconsin Information System for Local Roads (WISLR) LRS network to compute corridor based crash rates for all county highways statewide. A network segmentation algorithm was also developed to define meaningful corridors from the WISLR county highway network. The ranking methodology applied a series of data validation filters and crash rate indices to produce a final "filtered K-A crash rate" ranking method. This method emphasizes severe injury crashes and represents a balanced approach to corridor ranking compared to other ranking methods that were investigated.

GIS maps and crash data details were provided for the top ten corridors as a basis to investigate potential HSIP projects. In addition to identifying specific high risk corridors, however, the automated approach and statewide list provides an opportunity to conduct systematic, aggregated analysis of the corridor rankings to identify HRRR risk factors. As a second component of this research, results are presented from an analysis of the 2012 HRRR list for a selected set of crash data attributes.

Although MAP-21 is expected to introduce changes to WisDOT's HSIP approach, developing automated system-wide safety identification and ranking procedures is certain to become an increasingly important component of this process. The Wisconsin HRRR ranking process is a successful implementation of an automated approach while identifying key challenges to address in the future.

Wisconsin HRRR Program Background

The High Risk Rural Roads (HRRR) Program was established under SAFETEA-LU in 2005 as a mandatory set-aside in the Highway Safety Improvement Program (HSIP) *(1, 2)*. The intent of the HRRR Program was to provide funding for construction and operational improvements on 1) rural major or minor collectors or rural local roads with 2) fatal or severe injury crash rates above the statewide average per functional classification. The HRRR Program represented a significant step towards recognizing the need to reduce fatalities on rural roads, which account for almost two-thirds of the over 43,000 roadway fatalities in the U.S. *(3)*.

The initial Wisconsin HRRR Program implementation focused on the local system, following the traditional HSIP application process with project specific applications submitted by the local level. Two questions quickly emerged: 1) Could the HRRR application process be turned from a "Reactive" to a "Proactive" one, and 2) could the focus of HRRR decision making be shifted away from "Hot Spot" to "Corridor" based project considerations. The essential idea was to develop a data driven approach at the statewide level to more effectively administer limited HRRR funds.

Two pilot projects were investigated to generate county-level HRRR analysis. The first project provided county-level corridor analysis based on functional classification and run-off-the-road type crashes and focused on low-cost safety countermeasures. The second project provided county rankings based on crash rate and urban versus rural classifications. Although the results of both pilot projects demonstrated the value of a data driven approach, they were considered too broad in their analysis to replace the existing reactive, application driven process. The major shift came with the completion of the WISLR Statewide GIS Crash Map *(4)*. This provided the first opportunity to generate an automated statewide corridor analysis.

HRRR Identification Objectives and Source Data

The objectives for the Wisconsin statewide HRRR corridor analysis were as follows:

- Generate a list of the top 10 statewide HRRR corridors for project consideration
- Focus on:
  - Rural major and minor collectors
  - Run-off-the-road crashes
  - Five years of crash data
- Develop a corridor ranking based on crash rates
- Leverage the WISLR LRS network for the data integration process
- Develop an automated and repeatable process

Additional considerations included emphasizing corridor wide problem identification over intersections and other hotspots and arriving at a final list that was reasonably balanced across the state. Whereas the run-off-the-road definition (discussed below) helped satisfy the first consideration, the second consideration was highly dependent on the ability of the ranking methodology to normalize the risk criteria across counties and regions.

The following discussion provides a description of the data sources used in the integration and analysis process.

Wisconsin Information System for Local Roads (WISLR)

The Wisconsin Information System for Local Roads (WISLR) contains a complete GIS network of all publically maintained roadways in Wisconsin, with specific detail given to local roads. Individual municipalities are responsible for submitting updates to their local road networks and business data. GTA funding decisions are based on WISLR, hence there is a high degree of participation by local authorities. The WISLR LRS network serves as an integrating framework for WisDOT business data including crash data, traffic volumes, and roadway inventory information. It also contains a highly accurate cartographic representation of the highway and local road system in Wisconsin. A subset of WISLR geospatial and relational database files are provided by WisDOT to the Wisconsin Traffic Operations and Safety (TOPS) Laboratory on an annual basis.

Wisconsin Crash Database

The TOPS Lab WisTransPortal system contains a complete database of Wisconsin MV4000 Traffic Accident Extract data from 1994 through the current year. *(5).* This database contains information on all police reported crashes in Wisconsin, including the location of each crash, vehicles involved, and general crash attributes. This database is updated on a monthly basis through coordination with WisDOT Division of Motor Vehicles. The TOPS Lab maintains this database for research purposes and as a service to WisDOT. The recently completed statewide GIS crash map combines multiple years of state and non-state MV4000 crashes onto the WISLR LRS network. Crash locations are assigned to the WISLR network in terms of link and link-offset locations, which facilitates integration with other WISLR network data. The WISLR crash map and GIS database is hosted at TOPS Lab on the WisTransPortal system.

WisDOT Traffic Data System

The WisDOT "TRADAS" database contains all continuous and short duration volume, speed, classification, and Weigh in Motion (WIM) traffic data collected by the WisDOT Bureau of State

Highway Programs for planning purposes and federal HPMS reporting. Principal Arterials, HPMS Sections, National Highway System (NHS), and minor arterials with an Annual Average Daily Traffic (AADT) greater than 5,000 have counts taken on a three year cycle. Minor arterials with an AADT less than 5,000 and collectors with an AADT greater than 5,000 are on a six-year cycle and low volume collectors have counts taken on a ten-year cycle. *(6).* All TRADAS count sites are located to WISLR links and are available as an ESRI point shapefile. A subset of the TRADAS database and geospatial files are available at TOPS Lab and are updated on a regular basis.

DATA INTEGRATION

As described, three primary data sources were used for the data integration and HRRR corridor ranking process. The WISLR linear referencing system provided roadway network cartography and link-based functional classifications. It also served as the underlying data integration platform. The WisDOT MV4000 crash database provided crash report attributes and WISLR link crash locations. The WisDOT TRADAS database provided point AADT values on WISLR links. Given these data sources, the initial task was to extract relevant information from each dataset prior to the data integration and corridor crash rate assignment process.

Crash Data Selection

In order to identify corridor-wide safety issues, as opposed to hot spots which are addressed through other HSIP funding mechanisms, it was desirable to restrict the HRRR crash rates to run-of-the-road (ROR) type crashes. The Wisconsin MV4000 crash report form, however, does not have a designated category for ROR crashes. As such, the definition given below was used to select ROR crashes from the WisTransPortal crash database for the five year period 2007-2011. This definition has been previously applied by the WisDOT "Meta-Manager" system for highway ROR crash analysis.

Meta-Manager Definition for ROR Crashes:
1. Non-intersection crashes (ACCDLOC=N)
2. Satisfies one of the following:

TABLE 1 Definition for ROR Crashes

Accident Type			Manner of Collision
MOTOR VEH TRANS OTHER RDWY	BRIDGE RAIL	MAILBOX	HEAD ON
OTHER OBJECT NOT FIXED	OTHER POST	FENCE	SIDESWIPE/SAME DIR
OVERHEAD SIGN POST	EMBANKMENT	CULVERT	SIDESWIPE/OPPOSITE DIR
OTHER FIXED OBJECT	TRAFFIC SIGNAL	TREE	
BRIDGE PARAPET END	GUARDRAIL FACE	OVERTURN	
LUM LIGHT SUPPORT	GUARDRAIL END	UNKNOWN	
IMPACT ATTENUATOR	MEDIAN BARRIER	JACKKNIFE	
TRAFFIC SIGN POST	UTILITY POLE	DITCH	
BRIDGE/PIER/ABUT	CURB		

Roadway Definition

The candidate HRRR corridors were limited to rural major and minor collectors. The WISLR Overlay feature class was used to obtain the Functional Class type:

- 30 = MAC – Other (Rural) (57.3%)
- 40 = MIC – Other (Rural) (42.7%)

The initial selection resulted in 90303 total WISLR links (both directions) for the rural area of the state of which 57% were major collectors and 43% were minor collectors. A corridor identification process, described in the next section, was developed to combine segments with similar roadway properties to form corridors. After the segmentation process, 5850 corridors were finalized for analysis.

Traffic Volume Determination

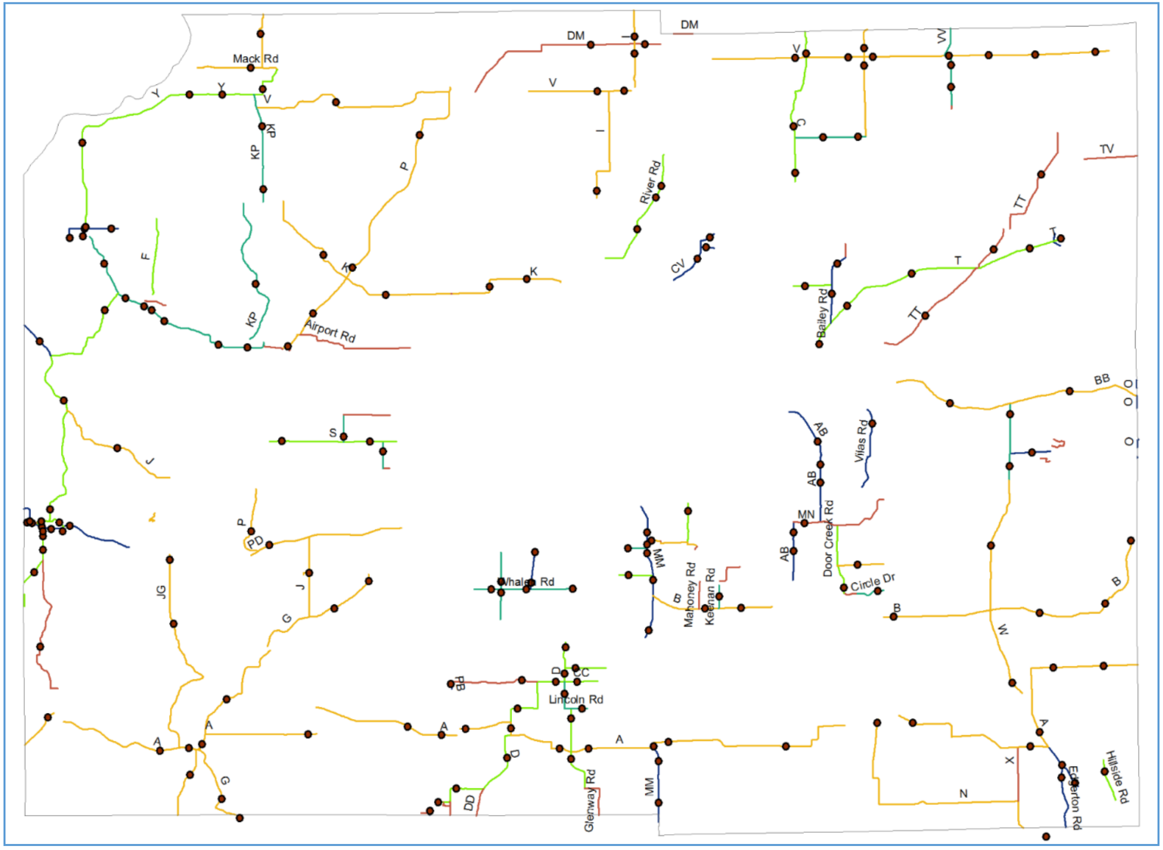
The TRADAS AADT data is represented in terms of point values along the WISLR link network. For rural MAC/MIC roadways, which are typically undivided, a single AADT is given for both directions at the same location. There were several considerations to overcome the sparseness of the TRADAS dataset in terms of temporal and spatial coverage. First, the best available volume data was taken from the extended 2000-2011 date range. Second, TRADAS point volumes were averaged over corridors to obtain a corridor wide AADT. It is important to note that approximately 22% (200041 out of 90303) of the initialWISLR links were not assigned an AADT. However for the selected corridors after basic filtering processes (described below), only 1.5% (16 out of 1057) were missing volume information. As such, it was concluded that the TRADAS database was sufficient for this analysis and that is was unnecessary to undertake additional traffic count data collection on specific corridors.

Data Integration

A data integration process between ROR crashes, traffic volumes, and roadway network segments was conducted by using the WISLR linear referencing system link network. This processes was carried out largely in a relational database environment (Oracle) by merging data attributes assigned to common WISLR roadway network links and link offsets values. Corridor crash rates were then computed by aggregating over all network links for a given corridor.

A preliminary investigation was conducted using Dane County data to confirm data availability and integration capabilities. Figure 1 shows the Dane County rural major/minor collector network, ROR crashes (points), and AADT count sites per mile (color coded segments).

FIGURE 1 Data Integration for Dane County



HRRR RANKING METHODOLOGY

Corridor Identification

The WISLR Overlay shape file contains detailed roadway inventory information for all public local roads in Wisconsin including surface type, curb type, median type, functional class, primary roadway name, and so on. This information is represented at the WISLR network level in terms of starting and ending links and link offset values, and therefore captures changes in linear roadway features with high granularity. Of these, functional class and primary roadway name were used for the HRRR segmentation algorithm. Specifically, the HRRR corridor identification algorithm is based on the following processing steps:

Step 1. Network Segmentation:

This step derives an initial segmentation from the statewide WISLR MAC/MIC roadway network. Starting with an initial set (90303 network links) of all WISLR rural major / minor collectors, grouped by roadway name (e.g., CTH E), we break the set into roadway segments based on three criteria:

- **Primary Roadway Name Change** Changes in the primary roadway name are typically characterized by a corresponding change in roadway features or traffic patterns (such as concurrency with a highway or reduced speeds and signalization through a municipality or town). Name changes often span short segments of the roadway, but are removed from the analysis and provide initial break points for the segmentation algorithm.
- **Functional Class Change** This refers to the case where a rural collector corridor spans multiple function classifications, generally due to a highway crossing or when the corridor is divided by a community or local road. In these cases, there are usually significant traffic volume gaps for different segments of the roadway. The segmentation algorithms breaks to preserve consistent traffic characteristics along the roadway.
- **Change of County** The Wisconsin HRRR program is oriented towards county level corridors. Although it is uncommon, there are a few cases whereby a county highway crosses into two counties and preserves the same name in both counties. In these cases, the corridor will be split at the boundary. A more common situation is for different counties to have different county highways with the same name (e.g., CTH A in Dane, Rock, and Taylor Counties).

Step 2. Corridor Synthesis:

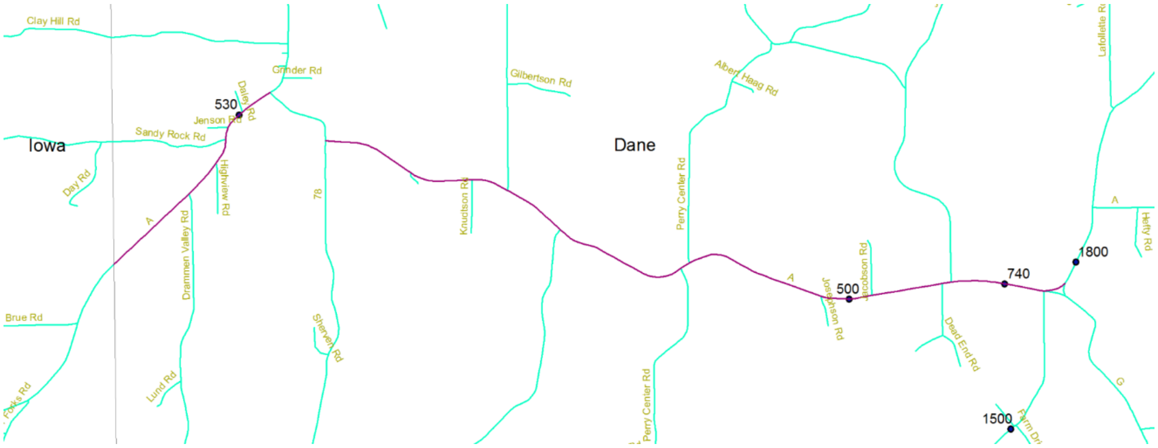
This step generates MAC/MIC corridors by combining segments from Step 1. Although most of the roadways broken by change in functional class have corresponding changes in volume, there are some roadways that do not. Table 1 shows an example of CTH A in Dane County broken by HWY 78 due to functional class change. The two segments still have close AADT values. For these segments, we do a combining process after the initial segmentation.

1. Compute the standard deviation over all AADT values for each roadway segment with same road name in the same county. Since the average AADT of different pairs of segments may differ significantly we use the "Coefficient of Variance" to evaluate the average AADT values:

$$\text{CV\% (Coefficient of Variance)} = \frac{\text{standard deviation}}{\text{mean average AADT}}$$

2. Use CV% > 40% as a break point. After this process, about 10 percent of the segments are recombined.

FIGURE 2 CTH A in Dane County



Note: Numerical values represent point AADTs obtained from the TRADAS database. The two segments are recombined into a single corridor that is nevertheless non-contiguous due to a short span where CTH A is concurrent with Hwy 78.

"Filtered KA Crash Rate" Ranking

Basic Filters

After the segmentation process, 5850 corridors are finalized across the state. This includes all corridors even if it is a short connection between two roadways. Thus, we applied a basic filter process to exclude corridors that were less than 3 miles in length or had less than 5 crashes over the five year study period. The objective was to develop an analysis that was truly corridor based and to eliminate corridors with insufficient data to produce stable results. There were 1057 corridors remaining after the basic filter process

Above Average Crash Rate

Crash rates, expressed as "Total Crashes per Million Vehicle Miles Traveled" (MVMT), is the combination of crash frequency (crashes per year) and vehicle exposure (traffic volumes or miles traveled) along a give corridor. It serves as a 'first brush' tool to compare the safety performance of the roadway to state average. We used the following formula to compute the corridor crash rate and filtered all roadway corridors that are below average:

$$R = \frac{\mathrm{C} * 1{,}000{,}000}{365 * \mathrm{T} * \mathrm{V} * \mathrm{L}}$$

Where:

R = Crash rate of the corridor in crashes per million vehicle miles of travel.
C = Total number of crashes on the corridor for the study period
T = Time period of the study (in years or fraction of years).
V = Average Annual Daily Traffic (AADT) during the study period.
L = Length of the corridor in miles.

Above Average Crash Density

Crash Density is a useful measure for corridors where traffic volume data is not available. It is also used in this study to balance concerns about the overall data quality of the corridor volume assignments and potential bias of the crash rate ranking towards lower volume roadways. We used the following formula to compute the corridor crash density and filtered all roadway corridors that are below average:

$$D = \frac{\mathrm{C}}{\mathrm{L}}$$

Where

D = Crash density of the corridor in crashes per mile.

C = Total number of crashes on the corridor for the study period.

L = length of the corridor in miles.

Taken together, the crash rate and crash density filters ensure that all corridors in the final top 10 HRRR list satisfy minimum requirements in terms of exceeding the statewide averages.

Minimum Fatal and Severe Injury (K+A) Crash Counts

Since an important goal of the HRRR program is to achieve a significant reduction in fatalities ("K") and serious injury ("A") crashes on public roads, we set up a minimum threshold of at least two "K+A" crashes over the five year period. After applying the three filters described above, 59 corridors were left.

Sort by K+A Crash Rates

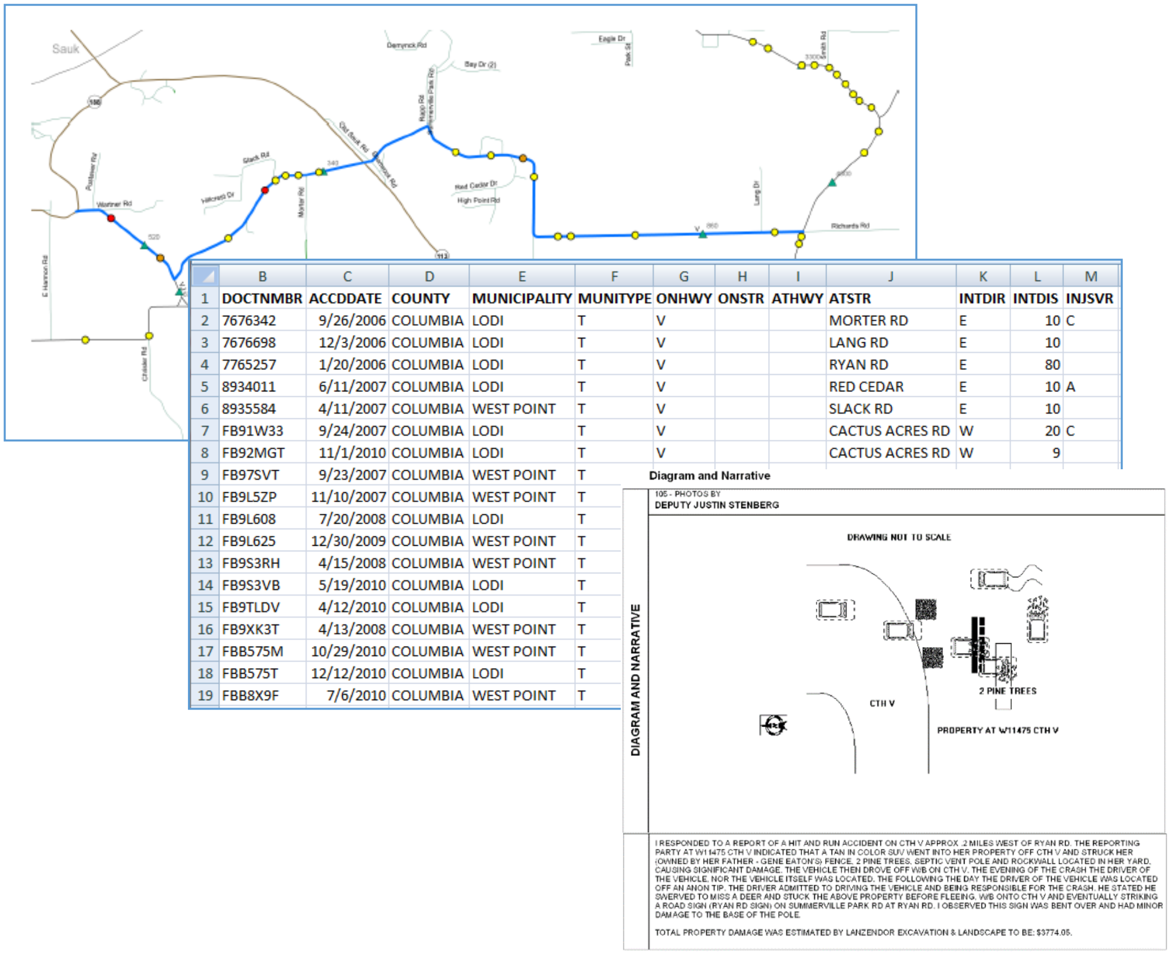
The "KA crash rate" is calculated by restricting the total number of corridor crashes (C) to the number of fatal and severe injury crashes.

STATEWIDE CORRIDOR ANALYSIS RESULTS

Data Validation

The top twenty high ranking corridors were manually reviewed against individual crash database records and crash reports for the purpose of validating the results of the automated process. Figure 3 shows one of the high ranking corridors, CTH V in Columbia County. In the zoomed in corridor view, each red dot represents a fatal crash, orange dots represent severe injury crashes, and yellow dots represent all other crashes (B and C injury crashes and property damage crashes). A spreadsheet of attribute data for each crash along the corridor and a sample crash report diagram and narrative are also shown. The manual verification process reviews the individual crash records for ROR criteria, mapping accuracy, and segmentation logic.

FIGURE 3 Data Validation Example for Columbia CTH V



	B	C	D	E	F	G	H	I	J	K	L	M
1	DOCTNMBR	ACCDDATE	COUNTY	MUNICIPALITY	MUNITYPE	ONHWY	ONSTR	ATHWY	ATSTR	INTDIR	INTDIS	INJSVR
2	7676342	9/26/2006	COLUMBIA	LODI	T	V			MORTER RD	E	10	C
3	7676698	12/3/2006	COLUMBIA	LODI	T	V			LANG RD	E	10	
4	7765257	1/20/2006	COLUMBIA	LODI	T	V			RYAN RD	E	80	
5	8934011	6/11/2007	COLUMBIA	LODI	T	V			RED CEDAR	E	10	A
6	8935584	4/11/2007	COLUMBIA	WEST POINT	T	V			SLACK RD	E	10	
7	FB91W33	9/24/2007	COLUMBIA	LODI	T	V			CACTUS ACRES RD	W	20	C
8	FB92MGT	11/1/2010	COLUMBIA	LODI	T	V			CACTUS ACRES RD	W	9	
9	FB97SVT	9/23/2007	COLUMBIA	WEST POINT	T							
10	FB9L5ZP	11/10/2007	COLUMBIA	WEST POINT	T							
11	FB9L608	7/20/2008	COLUMBIA	LODI	T							
12	FB9L625	12/30/2009	COLUMBIA	WEST POINT	T							
13	FB9S3RH	4/15/2008	COLUMBIA	WEST POINT	T							
14	FB9S3VB	5/19/2010	COLUMBIA	LODI	T							
15	FB9TLDV	4/12/2010	COLUMBIA	LODI	T							
16	FB9XK3T	4/13/2008	COLUMBIA	WEST POINT	T							
17	FBB575M	10/29/2010	COLUMBIA	WEST POINT	T							
18	FBB575T	12/12/2010	COLUMBIA	LODI	T							
19	FBB8X9F	7/6/2010	COLUMBIA	WEST POINT	T							

Diagram and Narrative

105 - PHOTOS BY
DEPUTY JUSTIN STENBERG

I RESPONDED TO A REPORT OF A HIT AND RUN ACCIDENT ON CTH V APPROX .2 MILES WEST OF RYAN RD. THE REPORTING PARTY AT W11475 CTH V INDICATED THAT A TAN IN COLOR SUV WENT INTO HER PROPERTY OFF CTH V AND STRUCK HER (OWNED BY HER FATHER - GENE EATON'S) FENCE, 2 PINE TREES, SEPTIC VENT POLE AND ROCKWALL LOCATED IN HER YARD, CAUSING SIGNIFICANT DAMAGE. THE VEHICLE THEN DROVE OFF WB ON CTH V. THE EVENING OF THE CRASH THE DRIVER OF THE VEHICLE, NOR THE VEHICLE ITSELF WAS LOCATED. THE FOLLOWING THE DAY THE DRIVER OF THE VEHICLE WAS LOCATED OFF AN ANON TIP. THE DRIVER ADMITTED TO DRIVING THE VEHICLE AND BEING RESPONSIBLE FOR THE CRASH. HE STATED HE SWERVED TO MISS A DEER AND STUCK THE ABOVE PROPERTY BEFORE FLEEING, WB ONTO CTH V AND EVENTUALLY STRIKING A ROAD SIGN (RYAN RD SIGN) ON SUMMERVILLE PARK RD AT RYAN RD. I OBSERVED THIS SIGN WAS BENT OVER AND HAD MINOR DAMAGE TO THE BASE OF THE POLE.

TOTAL PROPERTY DAMAGE WAS ESTIMATED BY LANZENDOR EXCAVATION & LANDSCAPE TO BE: $3774.05.

Data Analysis

Although the immediate goal of the statewide corridor analysis was to identify specific HRRR corridors for project identification, the final ranking provides an opportunity to conduct a comparative analysis against the statewide list to better understand the outstanding risk factors on rural county highways. For purposes of this analysis, aggregate statistics were generated with respect to several crash data variables for the following groups:

1. HRRR crashes for the top 20 HRRR corridors based on filtered KA crash rate ranking
2. HRRR crashes for the top 50 HRRR corridors based on filtered KA crash rate ranking

3. All HRRR crashes (i.e., ROR crashes on MIC/MAC roadways, before filtering)
4. All crashes statewide

The study period for this analysis was based on the five year period 2007-2011. All crashes are taken from the Wisconsin MV4000 crash database of police reported crashes.

The results of the data analysis include some general conclusions which well match previous research. For example, it shows that compared to all general crashes, HRRR crashes are more likely to occur in dark / unlit conditions (41.66% vs. 11.17%), snow (24.97% vs. 13.13%) or ice (12.27% vs. 4.91%), or when a driver fails to keep the vehicle under control (36.66% vs. 16.91%).

Table 2 shows the percentage of crashes by "curve" or "straight" horizontal terrain features at the point of impact. We observe an increasing trend in roadway "curvature" related crashes as we progress to the ‘top’ HRRR corridors (39.83% to 54.47% to 58.13%) with 18.31% difference between all HRRR and the TOP 20 HRRR (shown by the %DIFF column).

TABLE 2 Horizontal Road Terrain at the **Point of Impact**

HORIZONTAL TERRAIN	*TOP 20 HRRR*		*TOP 50 HRRR*		*ALL HRRR*		*ALL CRASHES*		
	COUNT	*PCT*	*COUNT*	*PCT*	*COUNT*	*PCT*	*COUNT*	*PCT*	*% DIFF*
STRAIGHT	121	*41.869*	453	*45.528*	10699	*60.174*	575049	*89.461*	-18.31
CURVE	168	*58.131*	542	*54.472*	7081	*39.826*	67745	*10.539*	18.31

In terms of contributing Highway Factors noted on the police crash reports, "soft shoulder", "loose gravel" and "visibility obscured" are observed to have the highest significance for rural collector crash risk. For example, there are 3.00% HRRR crashes on all rural collectors related to loose gravel, but the number increases to 4.11% for the TOP 50 HRRR corridors and doubles to 6.93% for the TOP 20 HRRR corridors.

TABLE 3 Highway Factors Being a Possibly Contributing Circumstance to a Crash

HIGHWAY FACTORS ATTRIBUTE	*TOP 20 HRRR*		*TOP 50 HRRR*		*ALL HRRR*		*ALL CRASHES*		
	COUNT	*PCT*	*COUNT*	*PCT*	*COUNT*	*PCT*	*COUNT*	*PCT*	*% DIFF*
SNOW / ICE / WET	83	82.178	379	86.530	7157	87.601	128542	83.755	-5.42
NARROW SHOULDER	2	1.980	9	2.055	138	1.689	1010	0.658	0.29
LOW SHOULDER	2	1.980	6	1.370	118	1.444	531	0.346	0.54
SOFT SHOULDER	**3**	**2.970**	**8**	**1.826**	**104**	**1.273**	**581**	**0.379**	**1.70**
LOOSE GRAVEL	**7**	**6.931**	**18**	**4.110**	**245**	**2.999**	**2723**	**1.774**	**3.93**
ROUGH PAVEMENT	0	0.000	4	0.913	39	0.477	542	0.353	-0.48
DEBRIS PRIOR TO CRASH	0	0.000	0	0.000	7	0.086	317	0.207	-0.09
OTHER DEBRIS	1	0.990	2	0.457	103	1.261	1996	1.301	-0.27
SIGN OBSCURED / MISSED	0	0.000	0	0.000	3	0.037	308	0.201	-0.04
NARROW BRIDGE	0	0.000	0	0.000	9	0.110	88	0.057	-0.11
CONSTRUCTION ZONE	0	0.000	0	0.000	21	0.257	3858	2.514	-0.26
VISIBILITY OBSCURED	**2**	**1.980**	**4**	**0.913**	**78**	**0.955**	**9078**	**5.915**	**1.03**
OTHER	1	0.990	8	1.826	148	1.812	3900	2.541	-0.82

Another interesting result is that alcohol and motorcycle crashes are over-represented in the higher risk road categories. Table 4 shows that 1.578% of all HRRR crashes are motorcycle related whereas 4.488% of TOP 20 location crashes are motorcycle related. On the other hand, speed related crashes do not exhibit any significant change in representation across HRRR categories.

TABLE 4 Other Factors Being a Possibly Contributing Circumstance to a Crash

CRASH FLAGS ATTRIBUTE	*TOP 20 HRRR*		*TOP 50 HRRR*		*ALL HRRR*		*ALL CRASHES*		
	COUNT	*PCT*	*COUNT*	*PCT*	*COUNT*	*PCT*	*COUNT*	*PCT*	*% DIFF*
ALCOHOL	**59**	**6.789**	**162**	**5.702**	**2539**	**5.365**	**35516**	**2.116**	**1.42**
AUTO	191	21.979	709	24.956	13005	27.479	560420	33.387	-5.50
BIKE	0	0.000	1	0.035	25	0.053	5785	0.345	-0.05
BUS	1	0.115	1	0.035	18	0.038	3279	0.195	0.08
CITATION	146	16.801	474	16.684	8220	17.369	296856	17.685	-0.57
COMMERCIAL	6	0.690	14	0.493	430	0.909	35712	2.128	-0.22
CONSTRUCTION	3	0.345	3	0.106	59	0.125	8118	0.484	0.22
MOTORCYCLE	**39**	**4.488**	**74**	**2.605**	**747**	**1.578**	**13271**	**0.791**	**2.91**
DEER	0	0.000	0	0.000	1	0.002	85284	5.081	0.00
DRUG	2	0.230	9	0.317	146	0.308	3127	0.186	-0.08
FIRE	5	0.575	9	0.317	80	0.169	3159	0.188	0.41
GOVERNMENT	56	6.444	233	8.201	3002	6.343	73767	4.395	0.10
HIT AND RUN	18	2.071	67	2.358	1331	2.812	80692	4.807	-0.74
INJURY TRANSPORTED	115	13.234	287	10.102	3705	7.829	81109	4.832	5.41
LARGE TRUCK	8	0.921	19	0.669	561	1.185	37758	2.249	-0.26
MATERIAL SPILLED	3	0.345	9	0.317	149	0.315	2326	0.139	0.03
MOPED	0	0.000	1	0.035	44	0.093	1432	0.085	-0.09
PEDESTRIAN	0	0.000	0	0.000	9	0.019	8194	0.488	-0.02
SPEEDING	**136**	**15.650**	**473**	**16.649**	**7461**	**15.765**	**107938**	**6.430**	**-0.11**
TRAIN	0	0.000	0	0.000	1	0.002	228	0.014	0.00
TRUCK	65	7.480	248	8.729	4713	9.958	178713	10.647	-2.48
TOWING A TRAILER	8	0.921	23	0.810	509	1.075	28202	1.680	-0.15
TRAILER	8	0.921	25	0.880	572	1.209	27671	1.648	-0.29

As a final result, it is interesting to note that Inattentive Driving is slightly under-represented in the highest risk categories whereas 'Too Fast for Conditions' is relatively unchanged. These results suggest that (with the exception of alcohol and impaired driving) engineering and geometric factors may be more significant than behavioral ones for HRRR program safety improvements.

TABLE 5 Driver Factors Being a Possibly Contributing Circumstance to a Crash

DRIVER FACTOR ATTRIBUTE	*TOP 20 HRRR*		*TOP 50 HRRR*		*ALL HRRR*		*ALL CRASHES*		
	COUNT	*PCT*	*COUNT*	*PCT*	*COUNT*	*PCT*	*COUNT*	*PCT*	*% DIFF*
EXCEED SPEED LIMIT	20	4.630	59	4.117	853	3.627	15052	2.374	1.00
TOO FAST FOR CONDITIONS	**107**	**24.769**	**371**	**25.890**	**5941**	**25.259**	**80590**	**12.708**	**-0.49**
FAILURE TO YIELD	1	0.231	8	0.558	246	1.046	95012	14.982	-0.81
INATTENTIVE DRIVING	**47**	**10.880**	**179**	**12.491**	**3180**	**13.520**	**128093**	**20.199**	**-2.64**
FOLLOWING TOO CLOSE	1	0.231	3	0.209	62	0.264	45838	7.228	-0.03
IMPROPER TURN	1	0.231	3	0.209	119	0.506	17849	2.815	-0.27
LEFT OF CENTER	26	6.019	84	5.862	1216	5.170	10339	1.630	0.85
DISREGARD TRAFFIC CONTROL	2	0.463	3	0.209	53	0.225	24462	3.857	0.24
IMPROPER OVERTAKE	1	0.231	12	0.837	245	1.042	8646	1.363	-0.81
UNSAFE BACKING	2	0.463	2	0.140	81	0.344	34729	5.476	0.12
FAILURE TO KEEP VEHICLE UNDER CONTROL	160	37.037	529	36.916	8617	36.637	107257	16.913	0.40
DRIVER CONDITION	55	12.731	159	11.096	2504	10.646	36810	5.804	2.09
PHYSICALLY DISABLED	0	0.000	2	0.140	16	0.068	828	0.131	-0.07
OTHER	9	2.083	19	1.326	387	1.645	28660	4.519	0.44

CONCLUSION

This paper describes the data integration and ranking methodologies that are proposed to automate the procedures of identification, ranking, as well as risk factor analysis for rural county highways. The process of the methodology is validated by using the crash records and police reports from the Wisconsin crash database. The initial data analysis results suggest some outstanding risk factors on high risk rural collectors such as horizontal curvature, soft shoulder, loose gravel, motorcycle, etc. On the other hand, the results also indicates that some factors, such as speeding, are less significant to high risk rural collectors.

Although MAP-21 is expected to introduce changes to WisDOT's HSIP approach, developing automated system-wide safety identification and ranking procedures is certain to become an increasingly important component of this process. The Wisconsin HRRR ranking process is a successful implementation of an automated approach while identifying key challenges to address in the future. Future work will focus on improving the stability of the ranking methodology, refining the segmentation algorithm, and streamlining updates to crash and volume data.

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