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High-Risk Rural Road Safety Study and Determining the Crash-Reduction Factors for High-Risk Rural-Road Usage

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Abstract

More than 32,000 motorists are killed on U.S. roads and streets annually, and approximately 54% of the accidents occur on rural roads. In an attempt to address and reduce these fatalities, the current transportation act, the Safe, Accountable, Flexible, Efficient Transportation Equality Act: A Legacy for Users (SAFETY-LU), elevated the Highway Safety Improvement Program (HSIP) to a core program and included a $90,000,000 High-Risk Rural Road Program (HRRRP) to address and significantly reduce traffic fatalities and incapacitating injuries on rural major or minor collectors, and/or rural local roads. While there were many challenges to properly implement the HRRRP in counties, this study provided important information that was needed to identify the predominant crash types on HRRRP-eligible roads and compiled a list of countermeasures for the predominant crash types that were identified on Kansas' high-risk rural roads. For the gathered countermeasures, crash reduction factors (CRFs) were also provided from the literature review, and their values were validated by conducting interviews with Kansas county engineers/officials. This study provided valuable information for the county engineers and local government officials while they worked on improving the safety of high-risk rural roads using HRRRP funds.

Keywords

HRRR, HSIP, Rural Road Safety, Crash Reduction Factors

1. Introduction

Rural roads are susceptible to a high rate of crashes, and the crash severities tend to be worse, leading to many

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fatalities and incapacitating-injury crashes [1]-[3]. The main reason for most of the rural-road crashes is due to the high speed that vehicles travel on rural roads [1]. According to a NHTSA report, among the total fatalities in the United States in 2012, 54% of them were recorded in rural areas even though only 19% of the U.S. population lived in rural areas [4].

To improve the safety of high-risk rural roads in the United States, the Federal Highway Administration (FHWA) has established the High-Risk Rural Road Program (HRRRP) under SAFETY-LU since 2005 as a mandatory set-aside in the highway-safety improvement program (HSIP) in order to provide funds to improve road deficiencies and to decrease the number of rural-road crashes [5]-[7]. The functional classes of roadways that are eligible for HRRRP funds are rural major or minor collectors, or rural local roads [6]. Further, the eligible roadways must have crash rates that exceed the statewide average for the respective roadway's functional classifications. Only fatal and incapacitating-injury crashes are considered, and their crash rates are determined by using exposure data, such as vehicle miles traveled (VMT), average daily traffic (ADT), lane miles, etc. However, other data-driven methods can be considered for determining the eligible roadways for HRRRP funds [6]. Projects that are eligible for HRRRP include construction and operational projects, and not projects dealing with data-system improvement, improving enforcement, and increasing educational efforts [8].

Using HRRRP to improve safety for high-risk rural roads can be challenging. Some common difficulties that state experience while improving the safety of rural roads by using HRRRP include gathering crash data and exposure data to identify locations for potential improvements; selection criteria for the best projects; and coordination among federal, state, and local transportation partners [8]. Gathering crash data can be a huge challenge because some counties do not maintain crash data. If the crash data are available, determining the accurate crash location and the availability of exposure data is questionable [8]. Therefore, providing useful information, such as identifying the significant crash types on the HRRRP-eligible roads, having guidelines to select an efficient project for maximum safety improvements, and providing the needed information to improve the usage of HRRRP funds, to county officials can lead to safe rural roads.

Rural-safety needs generally far outstrip the available HRRRP funds, along with the other funds that are available to many local jurisdictions; therefore, road deficiencies should be prioritized such that the limited funds that are available can provide the maximum, or most cost-effective, safety return per dollar spent. While funds and resources are available to improve the safety of rural roads, the county engineers and local jurisdictions need more information regarding the predominant crash types that are occurring on high-risk rural roads, all possible countermeasures for each crash type, and crash-reduction factors which are specific and appropriate for rural roads.

Therefore, the study's objectives are as follows:

1) Describe a procedure to select an efficient project/countermeasure for an identified high-risk rural-road location;
2) Identify the predominant crash types for high-risk rural roads;
3) Compile countermeasures for all the predominant crash types;
4) Gather the crash-reduction factors for each countermeasure, and validate them by interviewing county engineers.

These objectives are achieved by studying Kansas' crash database and by contacting Kansas' county engineers to validate the crash-reduction factors.

2. Study Methodology

The state of Kansas was considered for this study and for demonstrating the study methodologies. The study's initial objective was to identify the predominant crash types for high-risk rural roads. To determine the crash types that were predominant on high-risk rural roads, an analysis of the available crash database should be conducted. Kansas' crash database was studied to determine the predominant crash types for high-risk rural roads. Later, the crash reduction factors (CRFs) of all possible countermeasures for the predominant crash types were gathered from the literature. These CRFs were validated and modified by conducting interviews with county engineers in Kansas.

The functional classes of roads that are eligible for operational improvements through HRRRP funding include rural major or minor collectors, or rural local roads. Further, the fatal or incapacitating-injury crash rate for these roads should be higher than the statewide average per functional classification in order to be eligible for HRRRP funding to improve the eligible rural roads' safety. Therefore, fatal and incapacitating-injury crashes in Kansas were analyzed for the functional road classes, such as rural major collectors, rural minor collectors, and rural local roads, to identify the most significant crash types.

Improving a High-Risk Rural-Road Location Using HRRRP

To determine that a rural road was eligible for HRRRP funds, the crash (fatal or incapacitating) rate for a segment of an eligible rural road should be more than the statewide average. When a section of rural road had a crash rate higher than the statewide average, all the crashes that occurred at that location were studied to determine the predominant crash types for the road segment. If a certain crash type was predominant, then the segment's safety could be improved by adopting suitable countermeasures. Various countermeasures were available for each crash type, and every countermeasure was assigned a CRF which was derived from research and case studies that determined how much of a crash reduction can be expected after installing a countermeasure at a location with prior accidents. CRFs are expressed as a percentage or decimal which adds up to 100% or 1.00. The CRF gives the number of crashes that can be reduced by the countermeasure by multiplying the factor by the "before" number of crashes. As shown in **Figure 1**, an effective countermeasure, among the many available countermeasures for a crash type, can be determined by knowing each countermeasure's CRF value and then conducting a cost-benefit analysis.

3. Kansas Crash Data Analysis

The Kansas Crash Analysis Reporting System (KCARS) database was used to analyze the crashes on rural roads that were eligible for HRRRP in the state of Kansas [9]. The KCARS database included crash records reported by law-enforcement agencies following the state's reporting threshold, *i.e.*, an accident involving a fatality, an injury, or property damage of at least $1000 in aggregate. The KCARS database was analyzed for the years of 2002 to 2006 to identify the crash types for the following functional classes of roads: rural major collectors, rural minor collectors, and rural local roads. Only crash-severity classifications of fatal and incapacitating injuries were considered for the analysis. Together, these crashes were considered serious crashes.

From the 5-year (2002-2006) crash-data analysis in Kansas, a total of 2533 crashes with fatalities or incapacitating injuries were identified for the functional roadway classes of rural major collectors, rural minor collectors, and rural local roads. Among these crashes, most of them occurred on rural major collectors (1364 crashes) and rural local roads (1023 crashes), and very few occurred on rural minor collectors (146 crashes). These crashes were analyzed and categorized based on accident severity, accident class, manner of collision, fixed-object type, and accident location. Categorizing the crash data can help understand the predominant crash types on the rural roads that are eligible for HRRRP.

Figure 2 summarizes the crash categorization based on accident class for the three functional road classes that were studied. It can be understood, from **Figure 2**, that overturned crash, a crash involving a collision with another motor vehicle, and a crash involving a collision with a fixed object are major contributors. It has also been observed that 21% of the total overturned crashes and 20% of the total crashes involving a collision with a fixed object are further categorized as run-off-road crashes in the KCARS database. Crashes involving a col-

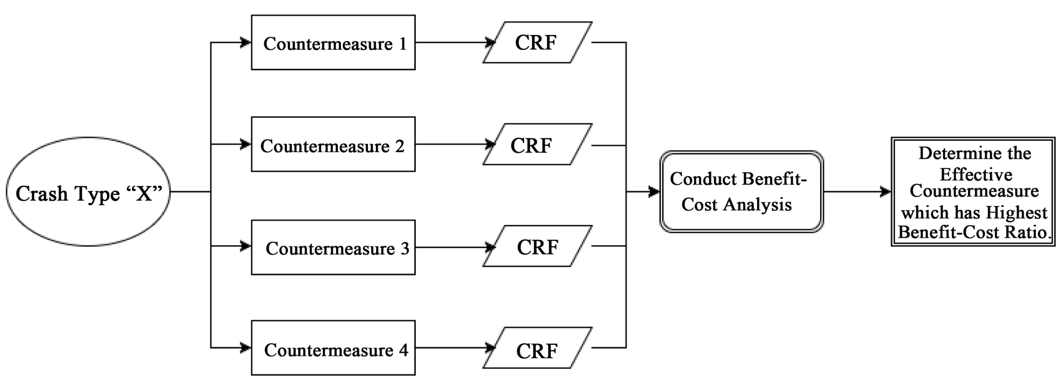

Figure 1. Procedure for determining an effective countermeasure for maximum safety benefits.

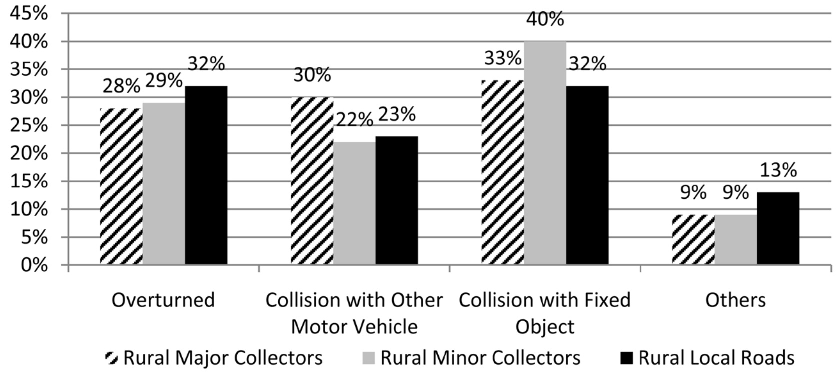

Figure 2. Crash categorization based on accident class.

lision with another motor vehicle are further categorized and summarized in **Figure 3**. It can be observed from **Figure 3** that angle-side impact crashes are a major share of the collision-with-another-motor-vehicle crashes. The other two major types of crashes involving a collision with another motor vehicle are head-on crashes and rear-end crashes. While most angle-side impact crashes occur at rural intersections, this crash type is not in the study's scope.

This study primarily focuses on improving the safety for a segment of rural roads excluding the intersections because rural-intersection safety can be an entirely different kind of study and has been well researched. More information about intersection safety, various possible countermeasures available to enhance the intersection safety, and crash-reduction factors can be found in a FHWA document, "Safety at Unsignalized Intersections", and a Kansas Department of Transportation report, "Mitigating Crashes at High-Risk Rural Intersections with Two-Way Stop Control" [10] [11]. Crashes involving a collision with a fixed object are further categorized and presented in **Figure 4**. It can be understood, from **Figure 4**, that fixed-object crash types, such as ditch and tree, are comparatively higher among many fixed-object crashes. While there are many kinds of fixed-object crashes identified, the common reason for these crashes is running off the road. Therefore, from the five-year crash analysis of HRRRP-eligible roads in Kansas, the predominant crash types are fixed-object crashes, run-off-road crashes, overturned crashes, rear-end crashes, and head-on crashes.

The Federal Highway Administration (FHWA) has compiled various countermeasures and the crash-reduction factors (CRFs) for each crash type from all known, reliable sources into a desktop reference [12]. The CRF determines how much of a crash reduction can be expected after installing some countermeasure at a location with prior accidents. All possible countermeasures and their CRFs for the five predominant crash types that are identified above are gathered from the FHWA report "Desktop Reference for Crash Reduction Factors" and listed in **Table 1** and **Table 2** [12].

The CRFs gathered from the FHWA report [12] are average estimates based on numerous studies; however, they can be of value when estimating the cost effectiveness and/or ranking, as well as prioritizing, for a group of countermeasures. Further, the CRFs gathered from the FHWA report [12] are based mostly on the expected accident reductions for state highways, hence these CRFs may or may not be highly reliable for low-volume county roads. It would be best for a given county to keep track of all accidents before and after various safety countermeasures are implemented and to develop its own CRFs.

This study attempted to determine the CRFs for Kansas' high-risk rural roads by interviewing the county engineers to obtain the county's unique CRF values and also to inquire about if the CRFs are closer to the CRFs compiled in the FHWA report [12]. A total of 50 counties in the state of Kansas were contacted and given survey forms to gather the CRF values from Kansas' county engineers for all the countermeasures regarding the five predominant crash types that were identified for HRRRP-eligible roads. Among the 50 counties contacted, 11 counties responded, making the response rate 22%. A few more county officials responded by e-mail saying that they did not have any accurate CRFs. Results from the returned survey forms are summarized in **Table 1** and **Table 2**. About 50% of the countermeasures had CRFs that matched the FHWA's reference report, and the other half of the countermeasures had different CRF values. Also, when the CRFs from the survey results matched the CRFs from the FHWA report, it was mainly due to the fact the FHWA repot had a wide range of CRF values. Further, having a range of CRF values for a countermeasure might lead to inaccurate safety-benefit

Table 1. Countermeasures and CRFs for fixed-object, run-off-road, and overturned crashes.

Countermeasure	CRFs			
	Average CRF from county engineer's survey (%)	CRF from FHWA report (%) [12]	% of survey responses matching the FHWA CRFs	CRF from the surveys in the FHWA's CRF range? (Yes/No)
Fixed-object crash type				
Widen shoulder (paved)	34.8	15 - 62	90%	Yes
Widen shoulder (unpaved)	23.1	13 - 43	80%	Yes
Remove or relocate fixed objects outside the clear zone	67.6	40 - 100	60%	Yes
Widen the clear zone	28.4	13 - 44	50%	Yes
Improve pavement friction (grooving)	22	19 - 36	77%	Yes
Install edge-line markings	59.6	59 - 66	100%	Yes
Improve guardrail	16.17	18 - 21	67%	No
Install guardrail (as shield for rocks and posts)	81.1	100	80%	No
Install impact attenuators	46.1	69	50%	No
Flatten horizontal curve	61.5	68 - 87	77%	No
Flatten side slopes	50.7	62	80%	No
Improve pavement friction (overlay)	35	43	80%	No
Improve pavement friction (resurface with open-graded mix)	75	93	80%	No
Install or upgrade curbing	39.6	50	67%	No
Run-off-road crash type				
Install guardrail (at embankment)	22.8	7 - 47	67%	Yes
Flatten horizontal curve	75.2	79 - 90	89%	Yes
Flatten side slopes	17	10 - 24	70%	Yes
Widen lane	25.6	12 - 49	80%	Yes
Widen shoulder (paved)	35.4	60 - 16	73%	Yes
Widen shoulder (unpaved)	23.7	13 - 43	70%	Yes
Improve pavement friction (groove shoulder)	27.8	27 - 41	80%	Yes
Install shoulder rumble strips	23.1	7 - 41	77%	Yes
Install edge-line markings	25.3	25 - 30	100%	Yes
Improve guardrail	26.7	28 - 41	67%	No
Improve super-elevation	44.6	50	89%	No
Remove or relocate fixed objects outside the clear zone	64.2	71	77%	No
Install curve advance-warning signs	28.1	30	80%	No
Install delineators (general)	33.7	34	80%	No
Improve pavement friction (overlay)	23	28	80%	No
Overturned crash type				
Improve guardrail	31.2	27 - 41	80%	Yes
Install guardrail (at bridge)	32.8	32 - 41	90%	Yes
Flatten horizontal curve	43.6	24 - 73	90%	Yes
Remove or relocate fixed objects outside the clear zone	35.1	42 - 44	77%	No
Improve pavement friction (grooving)	35.2	35 - 54	77%	No

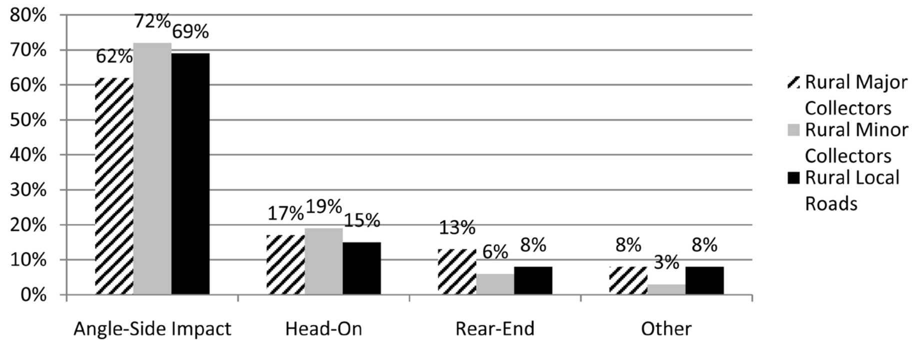

Figure 3. Crash categorization based on the manner of colliding with another motor vehicle.

Table 2. Countermeasures and CRFs for rear-end and head-on crashes.

Countermeasure	CRFs			
	Average CRF from the county engineers' survey (%)	CRF from the FHWA report (%) [12]	% of survey responses matching the FHWA CRFs	CRF from the surveys in the FHWA's CRF range? (Yes/No)
Rear-end crash type				
Flatten horizontal curve	37	24 - 73	75%	Yes
Increase the number of lanes	32.5	32 - 53	75%	Yes
Improve pavement friction (grooving)	35	35 - 54	63%	Yes
Install acceleration/deceleration lanes	64.5	75	77%	No
Install channelized lane	70.4	93	75%	No
Install lane-assignment signs	8.1	10	77%	No
Improve pavement friction (overlay)	11.4	12	70%	No
Install edge-line markings	35.3	45 - 50	67%	No
Implement maintenance and bituminous overlay	18.5	21	60%	No
Head-on crash type				
Widen lane	36.2	5 - 70	70%	Yes
Widen shoulder (paved)	41.7	15 - 75	70%	Yes
Improve pavement friction (overlay)	31.5	19 - 61	70%	Yes
Install centerline rumble strips	41.3	21 - 68	77%	Yes
Widen bridge	37	40 - 50	80%	No
Flatten horizontal curve	47.8	64 - 67	70%	No
Increase the number of lanes	36	38 - 53	77%	No
Install shoulder bus lanes	38.9	50	77%	No
Install curve advance-warning signs	24.2	29	80%	No
Install delineators (general)	58.6	67	80%	No
Improve pavement friction (curve overlay)	68	86	70%	No
Improve pavement friction (resurface with deicing additives)	21.8	31	67%	No
Improve pavement friction (resurface with open-graded mix)	71.1	90	77%	No
Pave shoulder	61.6	86	56%	No
Install no-passing line	37.7	40	77%	No

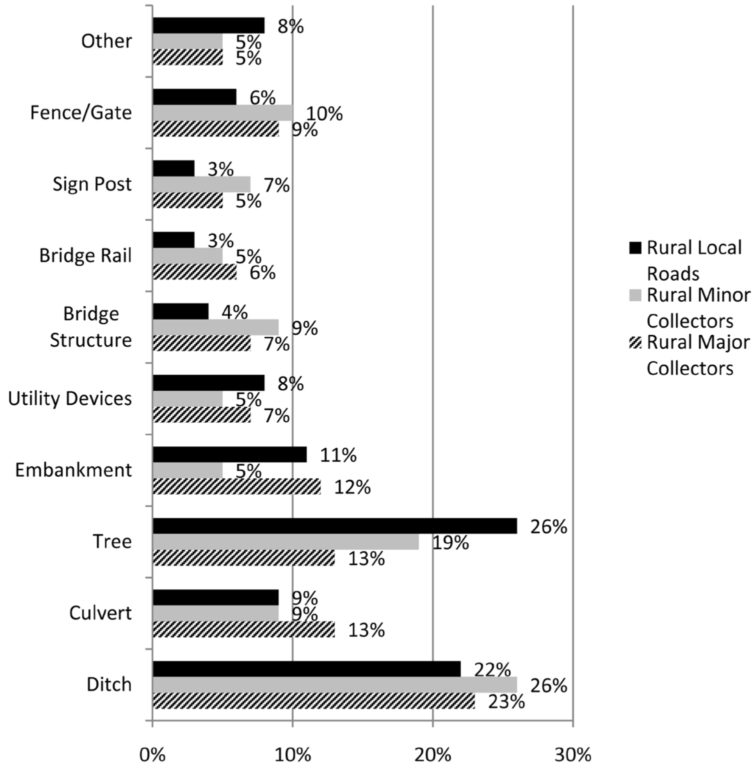

Figure 4. Crash categorization based on a fixed-object type.

prediction for high-risk rural roads. Therefore, it would be very efficient to have a precise CRF value for efficient safety benefit prediction of countermeasures on high-risk rural roads. This study presents precise CRF values for various countermeasures that can be readily applicable for HRRRP-eligible roads because these CRF values are derived by the crash reduction observed by implementing the countermeasures on high-risk rural roads. Therefore, the CRFs gathered by surveying the Kansas county engineers can be more reliable and accurate when predicting the safety effectiveness of the compiled countermeasures with high-risk rural roads.

4. Conclusions and Recommendations

This study analyzed the crashes on high-risk rural roads and focused on improving these roads' safety by providing more information and tools for the FHWA High-Risk Rural Road Program (HRRRP). The state of Kansas was selected for analyzing and demonstrating the study methodologies. Fatal and incapacitating-injury crashes on Kansas' rural major collectors, rural minor collectors, and rural local roads were analyzed for five-year crash data, and the predominant crashes types that were identified were fixed-object crash, run-off-road crash, overturned crash, rear-end crash, and head-on crash. Various possible countermeasures and the CRFs for each predominant crash type were gathered from the literature, and the CRF values were validated for high-risk rural-road usage by conducting interviews with Kansas county engineers/officials. The predominant crash types might be different for high-risk rural roads in other U.S. states, but basic crash-data analysis for the rural roads would be sufficient to identify the predominant crash types.

From the 50 Kansas counties contacted, only 12 counties responded, making the response rate 22%. The CRF values obtained by Kansas county interviews were different from the CRF values available through the FHWA's report [12] for most of the countermeasures, proving that the countermeasures' crash-reduction factors could be different for rural major collectors, rural minor collectors, and rural local roads. Some counties officials who did not respond with their CRF values, provided feedback that, they did not have any accurate CRFs because they did not maintain a record of accidents over time. However, if before-after crash results are recorded by county engineers when various countermeasures are installed, then, over time, reliable CRFs could be developed for any given county or U.S. state. Reliable CRFs can be a valuable tool when setting priorities for needed safety improvements. The authors believe that, although CRFs should not be considered as an absolute, accurate value, they are better than not having any idea what safety benefit will result from a given improvement and have a value in prioritizing several possible improvements.

Updated countermeasure CRFs for this study's identified predominant crash types can be useful for county engineers and local government officials to improve the safety of high-risk rural roads with available funding programs, particularly HRRRP.

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