A Seven-Year Analysis of the Safety Impacts of Crossover Median Crashes in Wisconsin

Research/Special Report 2009-001

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16. Abstract
Over 37,000 crash reports were reviewed for the seven-year period, revealing 309 crossover median crashes. These crashes resulted in 184 injury crashes and 64 fatal crashes, yielding85 fatalities. A majority of the roadways examined have either 50 feet or 60 feet median widths. Current Wisconsin guidelines do not require a median barrier for a roadway with a median width greater than 60 feet, nor for sections with a median width less than 60 feet under certain ADT conditions. Data analysis revealed that there is limited correlation between median width and crossover median crash rate ascrossover median crash rates vary little with increasing median width. There was also limited correlation between ADT and crossover median crash rates, as crossover median crash ratesdid not significantly change with increasing traffic volumes. Other characteristics of crossover median crashes were examined, including total vehicles involved, crash vehicle type, crash severity, roadway geometry, initial causation of crash, age of driver, and the presence of alcohol. Crashes were plotted on a statewide highway map identifying 14 locations that exceeded the warrant for additional analysis. Safety improvements should be considered at each of the 14 sites.

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CHAPTER I
INTRODUCTION

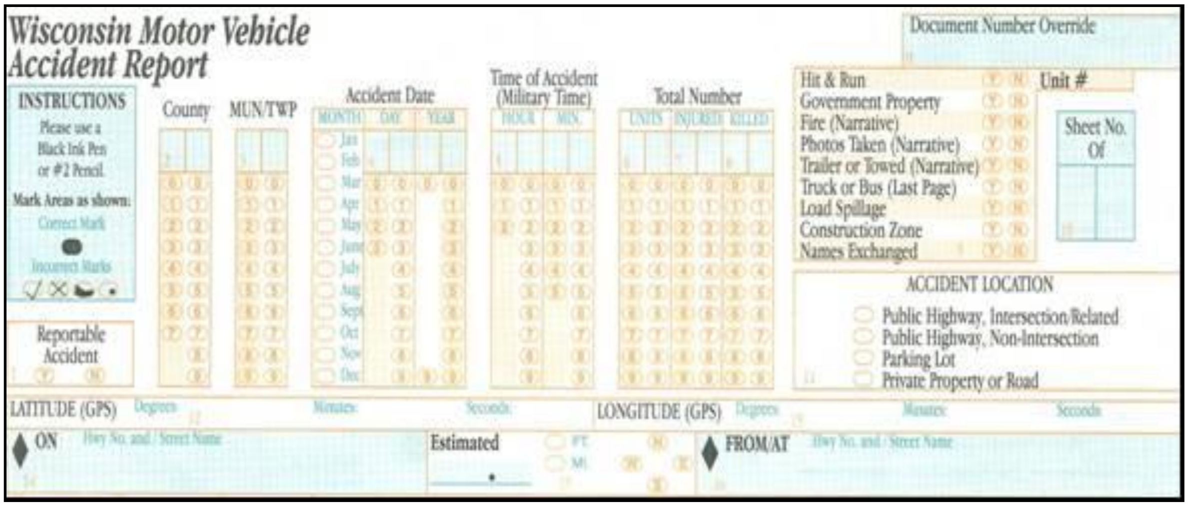
Over the seven year period from 2001 to 2007, 298,131 people lost their lives on America's roadways (1). In 2007 alone, 41,059 people were killed. Over 16,000 of these people died when their vehicle departed from their travel lane and crashed. Lane departure or run-off-road (ROR) crashes are associated with vehicles that leave the travel lane, encroach onto the shoulder and beyond, and hit one or more of any number of objects including opposing vehicles, bridge walls, poles, embankments, guardrails, parked vehicles, or trees (2). ROR crashes usually involve only a single vehicle, and consist of a vehicle encroaching onto the right shoulder and roadside, on the median side where the highway is separated, or on the opposite side when the vehicle crosses the opposing lanes of a highway. In recent years, approximately 55 percent of traffic fatalities were a result of ROR type crashes (3). Approximately 40 percent of fatal crashes were single-vehicle ROR crashes.

Over that same seven-year period, 5,470 people were killed in traffic crashes on Wisconsin's roadways, representing approximately 1.8 percent of the nation's total (4). In 2007 alone, Wisconsin experienced 756 fatalities. Wisconsin is also no exception to the high number of ROR crashes experienced nationally. A recent study found that approximately 54 percent of all non-intersection crashes on undivided roadways in Wisconsin were ROR type crashes (5). This number may be even higher on the divided roadway system.

Noyce and McKendry (6) and Witte et al. (7) documented research completed for the Wisconsin Department of Transportation (WisDOT) that identified the number and location of crossover median crashes that occurred in the state of Wisconsin for the three year period between 2001 and 2003 and five year period between 2001 and 2005, respectively. The research described in this report is an extension of the previous work to include seven years of crossover median crash history between 2001 and 2007. The additional two years of data are considered important in confirming trends identified in the five-year dataset and to allow a more robust analysis of locations with crossover median crash history.

In Wisconsin, County Sheriffs, local Police, or State Patrol troopers report crashes using the Wisconsin Motor Vehicle Accident Report (WMVAR), often referred to as MV4000, which is then scanned and archived into searchable databases that include: location and time of day, drivers and vehicles involved, weather and road conditions, presence of alcohol, and type of accident (6). FIGURE 1 through FIGURE 3display the relevant sections of the WMVAR that record these data.

The accident field of the WMVAR, displayed in FIGURE 4, divides crashes into three categories: collision with object not fixed, collision with fixed object, and non-collision, with various sub-categories. The form does not include a field to enter crashes in which the vehicle enters or crosses the median of a divided highway.



Wisconsin Motor Vehicle Accident Report

INSTRUCTIONS
Please use a Black Ink Pen or #2 Pencil.
Mark Areas as shown:
Correct Mark
Incorrect Marks

Reportable Accident

County
MUN/TWP
Accident Date
MONTH DAY YEAR
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
Time of Accident (Military Time)
HOUR MIN.
Total Number
UNITS INJURED KILLED

Document Number Override
Hit & Run
Government Property
Fire (Narrative)
Photos Taken (Narrative)
Trailer or Towed (Narrative)
Truck or Bus (Last Page)
Load Spillage
Construction Zone
Names Exchanged
Unit #
Sheet No. Of

ACCIDENT LOCATION
Public Highway, Intersection Related
Public Highway, Non-Intersection
Parking Lot
Private Property or Road

LATITUDE (GPS) Degrees Minutes Seconds
LONGITUDE (GPS) Degrees Minutes Seconds
ON Hwy No. and / Street Name
Estimated FT MI
FROM/AT Hwy No. and / Street Name

FIGURE 1WMVAR – Date, Time, and Location Data (6)

ACCESS CONTROL
1 No Control (Unlimited Access)
2 Full Control (Only Ramp Entry/Exit)
3 Partial Control

ROAD TERRAIN
Part A
1 Straight
2 Curve
Part B
3 Level/Flat
4 Hill

LIGHT CONDITION
1 Daylight
2 Dark–Not Lighted
3 Dark–Lighted
4 Dawn
5 Dusk
6 Unknown

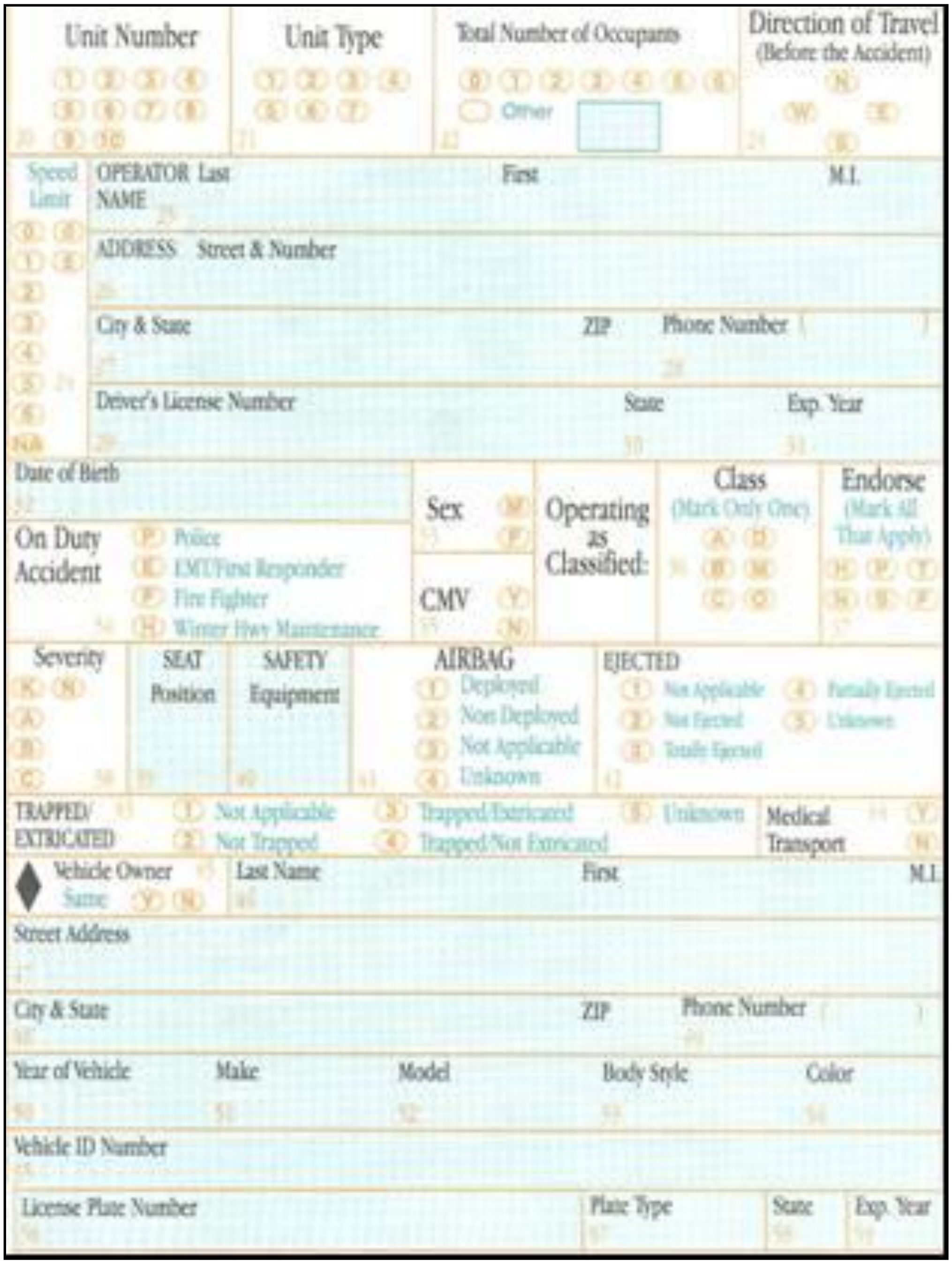
TRAFFIC WAY
1 Not Physically Divided (2-Way Traffic)
2 Divided Highway, Median Strip, without Traffic Barrier
3 Divided Highway, Median Strip, with Traffic Barrier
4 One-Way Traffic
5 Parking Lot or Private Property

ROAD SURFACE CONDITION
1 Dry
2 Wet
3 Snow/Slush
4 Ice
5 Sand, Mud, Dirt, Oil
6 Other
7 Unknown

WEATHER
1 Clear
2 Cloudy
3 Rain
4 Snow
5 Fog, Smog, Smoke
6 Sleet, Hail (Freezing Rain or Drizzle)
7 Blowing Sand, Soil, Dirt, Snow
8 Severe Crosswinds
9 Other
10 Unknown

RELATION TO ROADWAY
1 On Roadway
2 Parking Lot or Private Property
3 Shoulder (Other Than Shoulder within Median or Gore)
4 Median (Other Than Median within Gore)
5 Outside Shoulder—Left
6 Outside Shoulder—Right
7 Off Roadway—Location Unknown
8 Gore (Area between Ramp & Highway)
9 On Ramp
10 Unknown

FIGURE 2WMVAR – Weather and Road Conditions Data (6)



Unit Number
1 2 3 4 5 6 7 8 9 10

Unit Type
1 2 3 4 5 6 7

Total Number of Occupants
0 1 2 3 4 5 6
Other

Direction of Travel (Before the Accident)
N W E S

Speed Limit
0 0 1 2 3 4 5 6 N/A
OPERATOR Last NAME
First
M.I.
ADDRESS Street & Number
City & State
ZIP
Phone Number ( )
Driver's License Number
State
Exp. Year

Date of Birth
Sex M F
CMV Y N
Operating as Classified:
Class (Mark Only One)
A D B M C O
Endorse (Mark All That Apply)
H P T N S F

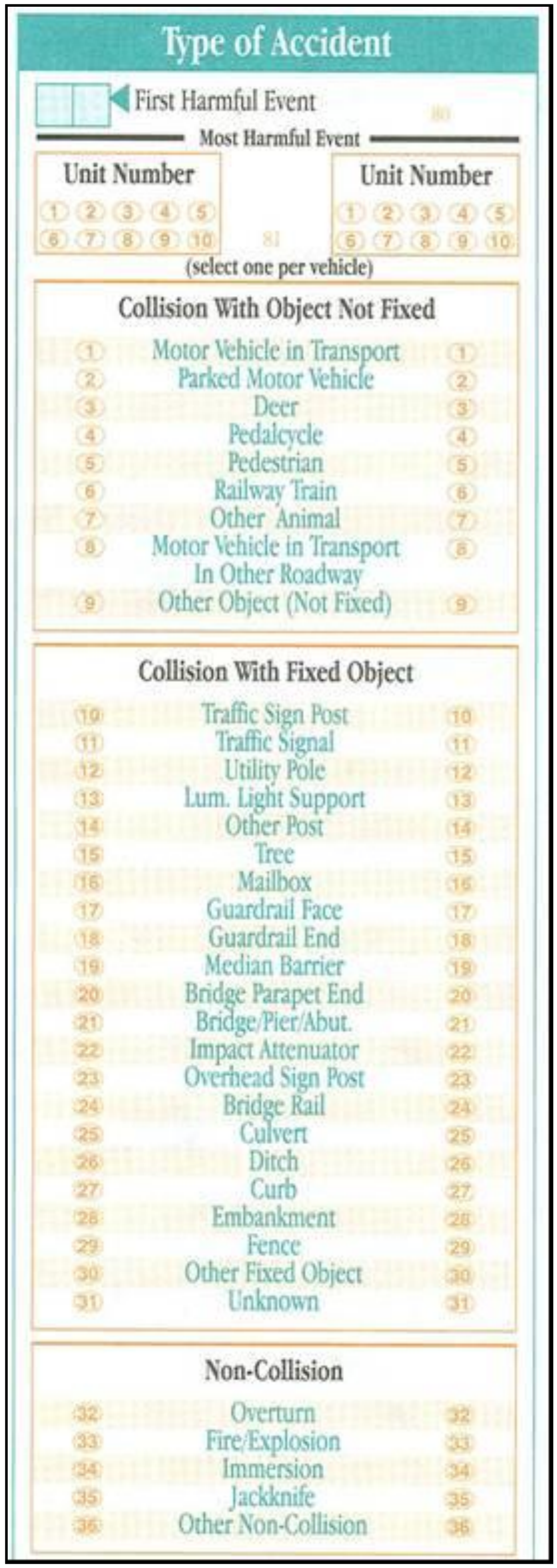
On Duty Accident
P Police
E EMT/First Responder
F Fire Fighter
H Winter Hwy Maintenance

Severity
K N A B C
SEAT Position
SAFETY Equipment
AIRBAG
1 Deployed
2 Non Deployed
3 Not Applicable
4 Unknown
EJECTED
1 Not Applicable
2 Not Ejected
3 Totally Ejected
4 Partially Ejected
5 Unknown

TRAPPED/EXTRICATED
1 Not Applicable
2 Not Trapped
3 Trapped/Extricated
4 Trapped/Not Extricated
5 Unknown
Medical Transport Y N

Vehicle Owner Same Y N
Last Name
First
M.I.
Street Address
City & State
ZIP
Phone Number ( )
Year of Vehicle
Make
Model
Body Style
Color
Vehicle ID Number
License Plate Number
Plate Type
State
Exp. Year

FIGURE 3WMVAR – Driver and Vehicle Data (6)



Type of Accident

First Harmful Event

Most Harmful Event

Unit Number	Unit Number
① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩	① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

(select one per vehicle)

Collision With Object Not Fixed

1	Motor Vehicle in Transport	1
2	Parked Motor Vehicle	2
3	Deer	3
4	Pedalcycle	4
5	Pedestrian	5
6	Railway Train	6
7	Other Animal	7
8	Motor Vehicle in Transport In Other Roadway	8
9	Other Object (Not Fixed)	9

Collision With Fixed Object

10	Traffic Sign Post	10
11	Traffic Signal	11
12	Utility Pole	12
13	Lum. Light Support	13
14	Other Post	14
15	Tree	15
16	Mailbox	16
17	Guardrail Face	17
18	Guardrail End	18
19	Median Barrier	19
20	Bridge Parapet End	20
21	Bridge/Pier/Abut.	21
22	Impact Attenuator	22
23	Overhead Sign Post	23
24	Bridge Rail	24
25	Culvert	25
26	Ditch	26
27	Curb	27
28	Embankment	28
29	Fence	29
30	Other Fixed Object	30
31	Unknown	31

Non-Collision

32	Overturn	32
33	Fire/Explosion	33
34	Immersion	34
35	Jackknife	35
36	Other Non-Collision	36

FIGURE 4WMVAR – Type of Crash (6)

The American Association of State Highway & Transportation Officials (AASHTO) defines a median as the "portion of a highway separating directions of the traveled way" and includes the vegetated area of land and the interior shoulders located between travel lanes. AASHTO's *A Policy on Geometric Design of Highways and Streets,* published in 2004, states that "medians are highly desirable on arterials carrying four or more lanes" of traffic (8). The separation of opposing volumes attempts to prevent head-on collisions. Medians also serve numerous other purposes including providing a drainage outlet for roadway runoff, providing an area for vehicles to stop and regain control in an emergency, allowing space for turning lanes, minimizing headlight glare, and providing space for the addition of future lanes (8).

AASHTO has design guidelines but no specific standards regarding median width. For medians 40 feet or wider, AASHTO states that drivers are given a "sense of separation from opposing traffic" and a "desirable ease and freedom of operation" (8). WisDOT's *Facilities Development Manual* (FDM) specifies a minimum median width of 60 feet for all Design Class A3 freeways and Design Class A3 expressways with a speed limit greater than 55 miles per hour (mph); and a minimum median width of 50 feet for all Design Class A3 expressways with speed limits of 50 or 55 mph (9). A Design Class A3 highway is an arterial with a minimum volume of 7,000 vehicles per day (vpd) and a minimum design speed of 65 mph (*10*). Typical medians used on Wisconsin highways are depicted in FIGURE 5 and FIGURE 6.

Historically, these median standards have been deemed adequate in providing sufficient vehicle recovery space to maximize safety and in preventing vehicles from traveling across the median into opposing lanes of traffic. However, there are numerous roadways throughout the state that do not meet these standards (i.e., a narrower median width) and do not provide any additional safety features such as median barriers.

Median barrier systems are designed to reduce the chance of a vehicle crossing over the median and into the opposing direction travel lanes (8). Examples of median barrier systems are displayed in FIGURE 7 (6). The Wisconsin median barrier guidelines are depicted in FIGURE 8, and show that median barriers are only warranted based on a highway's specific combination of Average Daily Traffic (ADT) and median width. A barrier is not warranted for median widths greater than 60 feet, nor for medians widths as narrow as 20 feet when ADT is less than 20,000 vpd. It is not well understood whether the current median barrier warrant guidelines are sufficient in maximizing the safety of divided highways in Wisconsin. A number of other states have moved to include crossover median crash rate warrants to identify highway segments that require additional median safety analysis in supplement to traffic volume and median width relationships. In many cases, locations qualifying for additional analysis are also selected for the installation of median safety treatments such as median barrier.

FIGURE 5Typical Wisconsin Highway Median (I-39 Rock County – 60 feet) (6)

FIGURE 6Typical Wisconsin Highway Median (USH 14 Dane County – 68 feet) (6)

FIGURE 7Typical Median Barriers(6).

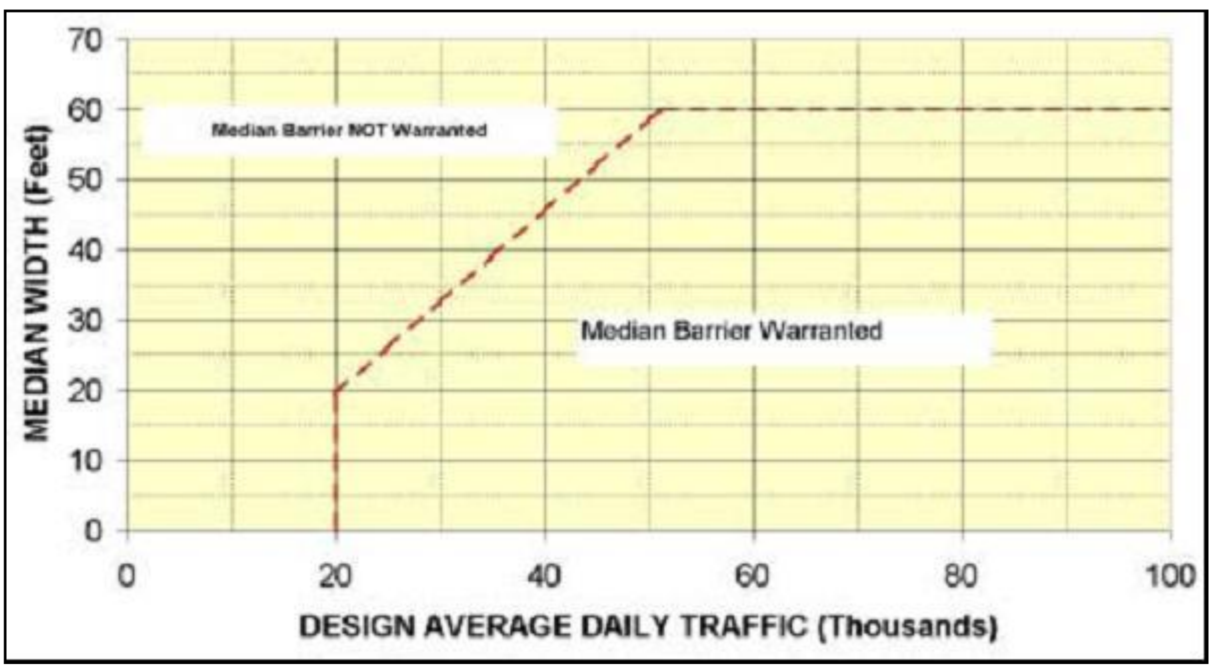


FIGURE 8Wisconsin Median Barrier Warrant Guidelines(8)

Problem Statement

The number of crossover median crashes is growing across the United States, and Wisconsin is no exception to this trend. Noyce and McKendry (6) quantified the magnitude of the crossover median crash problem in Wisconsin and found 631 median crossover crashes that occurred between 2001 and 2003 in locations where no median barrier currently exists, an average of approximately 210 crossover median crashes per year. In this analysis, median crossover crashes were defined as any reported single or multi-vehicle crash in which the vehicle traversed the median and penetrated or past through the opposing lanes of traffic. This research also examined the characteristics and causes of these crashes and concluded that the current traffic volume/median width guidelines may no longer be adequate for today's traffic conditions. Studies have suggested that wider median widths are safer, but it is not well understood what median width is necessary to maximize the safety of a roadway.

Additionally, the definition of a crossover median crash varies amongst state transportation agencies, which makes the application and comparison of crossover median crash rate warrants difficult. Some agencies do not include in their definition single vehicle crossover median crashes in which the crossing vehicle only partially enters the opposing direction travel lane and/or crossover median crashes in which the crossing vehicle stops or passes through the opposing lanes of traffic without striking a vehicle. These variations in definitions may have a significant effect on the number and length of highway segments identified for additional analysis.

To overcome this problem, Wisconsin has identified and selected a definition of crossover median crashes to be used in all current and future analysis. Specifically, WisDOT is using a definition originally developed by Caltrans. The Wisconsin definition of a fatal crossover median crash is all crashes that traversed the median, entered or went beyond the opposing lanes of traffic, involved multiple vehicle, and the accident caused a fatality. Wisconsin's definition of an injury crossover median crash includes all crashes that traversed the median, and enter or went beyond the opposing lanes, had multiple vehicles involved, and there was at least property damage associate with the crash. In both definitions, a segment of roadway was required to have at least three crashes within a five year period. The Caltrans methodology was selected by WisDOT because:

- Caltrans performed a Benefit-Cost Analysis to generate their methodology;
- Caltrans has had this cross median crash methodology since 1978;
- Caltrans has reviewed their methodology twice (1991 and 1997) and performed only minor changes;
- Other states have adopted the Caltrans's methodology; and
- When this research was started, there was no other rigorously defined methodology to use to study crossover median crashes.

An analysis of crossover median crashes using this definition continues to be needed in Wisconsin with the incorporation of the most recent crash data available.

Research Objectives

The objective of this research was to investigate and evaluate the present state of crossover median crashes on Wisconsin freeways and expressways. Specific objectives were to:

- Quantify the magnitude of crossover median crashes in Wisconsin between 2001 and 2007;
- Establish a relationship between median width, traffic volumes, and crossover median crashes;
- Identify the most critical factors affecting crossover median crashes;
- Update the research described in previous reports (6,7);
- Evaluate the impact of varying the definition of a crossover median crash on the number and length of highway segments identified for additional analysis, and
- Evaluate the median barrier guidelines.

Scope

The scope of this research was limited to reported crossover median crashes on Wisconsin freeways and expressways for the period between 2001 and 2007. Most, but not all, divided highway sections in Wisconsin were considered. Highway sections with an existing median barrier were not considered. Crashes that occurred where a vehicle broke through or vaulted over a median barrier, where a vehicle intentionally crossed over the median, or where an object crossed over the median that a barrier would not have prevented, were excluded from the analysis. Only data available through the Wisconsin crash records system were considered.

Organization of Report

This report is separated into six chapters as presented. Chapter 1 has presented an introduction to the relationship between median width and crossover crashes. Chapter 2 presents past research on median width and crossover crashes, state median barrier policy, and a review of different median barrier types. Chapter 3 presents the experimental design of the research. Chapter 4 presents the data analysis and research results while Chapter 5 presents a review of the impact of varying definitions of crossover median crashes. Information in Chapter 5 can be used to identify sites that should be monitored as potential sites for additional safety analysis. Chapter 6 presents the conclusions and recommendations.

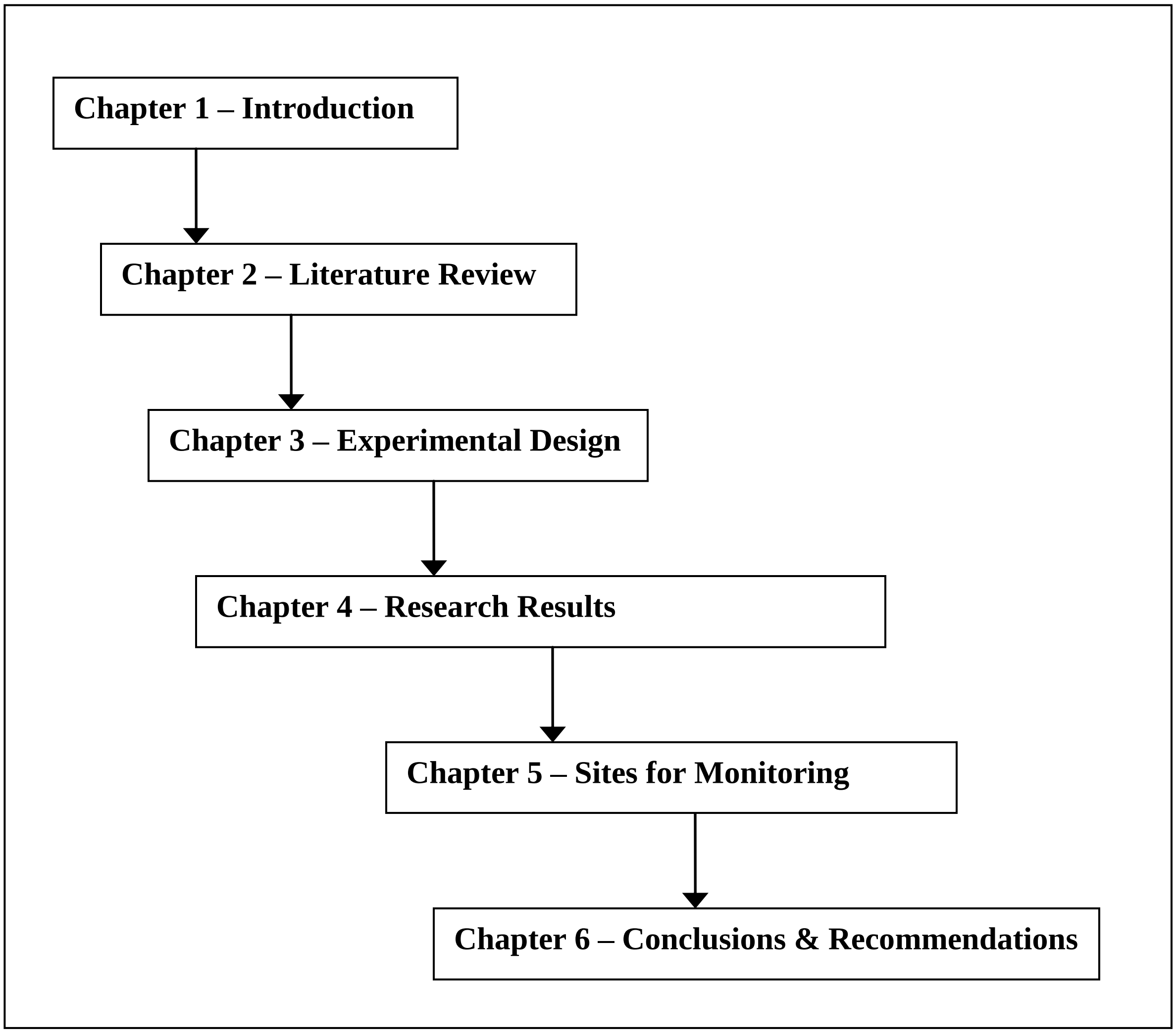


FIGURE 9Organization of Report

CHAPTER II
LITERATURE REVIEW

As previously described, this research is an extension of the research conducted by Witte et al. in 2007 for WisDOT (7). A detailed literature review was conducted as part of this comprehensive research study in 2007 and has been summarized in the following sections. Additionally, literature identified since the 2007 report is included. These sections summarize historical research into a number of median safety characteristics; describe state median barrier policies and in particular focuses on some of the median safety warrants applied in different states; and describes the different types of median barrier systems commonly employed.

Summary of Median Safety Characteristics Literature

Median Width and Cross Section Design

Hutchinson and Kennedy determined from field studies conducted in Illinois in the 1950's and 1960's that a minimum median width of 30 feet should be used on all rural highways and that the median should be obstacle-free with a mild (24:1 or greater) cross-slope (*11*). Similarly, computer simulations performed at the Georgia Institute of Technology in 1970 demonstrated that while median widths of 30 feet had a positive effect in reducing the severity of crossover crashes compared to narrower or no medians, they were still inadequate at providing an acceptable level of safety (*12*).

Median Width and Overall Crash Improvement

Garner and Deen (*13*) and Knuiman et al. (*14*) demonstrated that the presence of a traversable median that can be used as a place of refuge has a beneficial effect on all crashes, not just median crossover crashes. Garner and Deen found that as median width increased, the crash rate and crash severity decreased, with benefits diminishing at median widths between 30 and 40 feet. Knuiman et al. advised that a minimum median width of 30 feet was necessary to have an affect on crash rates and that any reduction in width beyond 30 feet would be marked by a decrease in safety. This research also found that overall crash rate reduction due to increasing median width continued until a width of approximately 60 to 80 feet, at which point no improvement in safety was realized.

Garner and Deen further supported the need for a clear, traversable median by showing that raised or depressed medians led to an increase in vehicles that either lost control or rolled-over. Macedo (*15*) concurred with Garner and Dean on the need for a clear median, if the width was large enough to prevent a crossover crash. However for narrower median widths, Macedo suggested that a steep raised median may be preferable, citing that a single-vehicle rollover crash was favorable to a crossover or barrier crash.

Crossover Crash Survey

The Pennsylvania Department of Transportation (PennDOT) undertook a comprehensive review of crossover median crashes in 2002. An assembled expert panel listed the top four factors affecting median safety as: horizontal curvature, operating speed, median cross-slopes, and driver behavior (*16*). The inside shoulder width was considered the most important geometric cross-section feature affecting whether a vehicle crossed the median. The panel also made median width recommendations for the application of the three different types of median barrier systems:

- Median widths less than 20 feet: concrete safety barrier;
- Median widths between 20 and 33 feet: strong post W-beam guardrails; and
- Median widths greater than 33 feet: three-strand cable barrier.

Donnell et al. (*16*) identified 267 cross-median crashes, defined as crashes "in which a driver traversed the entire width of the median, entered the opposing roadway, and collided with a vehicle traveling on the opposing roadway", on Pennsylvania Interstates and expressways between 1994 and 1998. The majority of crashes were a result of drivers losing control of the vehicle (71 percent). Twenty percent occurred as a result of a same-direction vehicle collision and eight percent occurred as a result of a driver trying to avoid a same-direction vehicle. Sixtythree percent occurred during daylight (vs. 58 percent of all crashes), 32 percent while dark (vs. 37 percent of all crashes), and four percent during dawn or dusk (vs. five percent of all crashes). The weather conditions varied amongst the cross-median crashes with 43 percent of cross-median crashes occurring under dry conditions (vs. 61 percent of all crashes), 32 percent under wet conditions (vs. 19 percent of all crashes), and 25 percent under snow and ice (vs. 21 percent of all crashes). Twelve percent of cross-median crashes involved alcohol and/or drugs (vs. six percent of total crashes). A comparison of crash rates (crashes per hundred million vehicle miles traveled) showed that, although not significant, as median width increased the crash rate decreased.

Donnell and Hughes conducted a survey of 37 state transportation agencies (STAs) to ascertain median design and safety practices. Responses showed that mitigation measures employed in response to median-related crashes included the installation of median barrier, flattening median side slopes, installing rumble strips on the median shoulder, and general geometric improvements (*17*). The responding STAs indicated that "traveling too fast for conditions" was by far the most reported causation of median-related crashes, followed by "driver lost control", "driver inattention", "avoidance maneuver", "adverse weather conditions", and "driver under the influence of drugs or alcohol" (*17*).

Crossover Median Crash Costs

Noyce and McKendry (6) developed a crash cost based on information held in the Wisconsin Crash Outcome Data Evaluation System (CODES) database and the National Highway Traffic Safety Administration (NHTSA) model. The CODES analysis found that crossover crashes, in terms of medical costs, exceed median barrier impact crashes by approximately $19 million per year. Although the full cost of installing median barrier could not be evaluated, the research concluded that the potential medical and societal cost savings of median barrier installation at high frequency crossover crash locations is significant.

Crossover Median Crash Modeling

A number of recent studies have used ordinal logistic regression to relate crash severity, classified as fatal, injury, or property damage, to various geometric, traffic operation, and environmental conditions. Donnell and Mason (*18*) used roadway inventory and crash record information collected on Pennsylvania Interstate highways for the five-year period between 1994 and 1998 to develop cross-median and median barrier crash logistic regression models. The researchers found that modeling crash severity as an ordinal response produced appropriate results for cross-median crashes and that the use of drugs and the presence of a curvilinear alignment increased the odds of a fatal cross-median crash when compared to injury or property damage crashes. The predicted severity probability models developed by Donnell and Mason (*18*) are described in equations 1 through 3.

$$p_{fatal} = e^{\text{Equation 4}}/(1 + e^{\text{Equation 4}}) \quad (1)$$

$$p_{injury} = [e^{\text{Equation 5}}/(1 + e^{\text{Equation 5}})] - p_{fatal} \quad (2)$$

$$p_{PDO} = 1 - (p_{fatal} + p_{injury}) \quad (3)$$

From the regression modeling results:

$$-2.2212 + 0.6552X_1 + 1.3694X_2 - 1.0591X_3 - 1.1884X_4 + 1.3088X_5 \quad (4)$$
$$1.4074 + 0.6552X_1 + 1.3694X_2 - 1.0591X_3 - 1.1884X_4 + 1.3088X_5 \quad (5)$$

Where:
X_1 = drug or alcohol use indicator (1 if not using, 0 otherwise);
X_2 = horizontal alignment indicator (1 if tangent, 0 otherwise);
X_3 = horizontal alignment indicator (1 if curve to right, 0 otherwise);
X_4 = interaction between drug use and horizontal alignment indicator (1 if no drug use and tangent section, 0 otherwise); and
X_5 = interaction between drug use and horizontal alignment indicator (1 if no drug use and curved section to the right, 0 otherwise).

Ordinal logistic regression was also employed by Lu et al. (*19*) to model the crash severity of crossover median crashes that occurred in Wisconsin during the three year period between 2001 and 2003. The researchers found that season has an effect on crossover median crash severity, likely due to deteriorated weather and roadway conditions prevalent in Wisconsin during the winter months. Additional statistical analysis showed that as well as seasonal effects (i.e., weather and roadway conditions), driver age affects the severity of crossover median crashes when the traffic volume is relatively high. However, road condition was the only significant variable identified under low traffic volumes. Under inadequate median width conditions, weather condition and emergency vehicle response time were found to be significant explanatory variables. The general severity probability prediction models developed as part of the research conducted by Lu et al. are described in equations 6 through 8.

$$p_{PDO} = e^{\text{Equation 9}}/(1 + e^{\text{Equation 9}}) \quad (6)$$
$$p_{injury} = [e^{\text{Equation 10}}/(1 + e^{\text{Equation 10}})] - p_{PDO} \quad (7)$$
$$p_{fatal} = 1 - (p_{PDO} + p_{injury}) \quad (8)$$

From the regression modeling results:

$$-3.6578 + 3.0082X_1 - 1.9333X_2 - 0.0356X_3 \quad (9)$$
$$-0.4945 + 3.0082X_1 - 1.9333X_2 - 0.0356X_3 \quad (10)$$

Where:
X_1 = clear weather indicator (1 if yes, 0 otherwise);
X_2 = sleety weather indicator (1 if yes, 0 otherwise); and
X_3 = reaction time predictor.

The modeling results of Donnell and Mason (*18*) and Lu et al. (*19*) were found to be statistically significant and may be useful to practitioners in determining the probability of fatal, injury, and property damage only crashes based on a given set of geometric and environmental variables.

Donnell and Mason (*20*) also developed crash frequency models that related the number of median barrier crashes to a number of geometric and cross-section elements using a negative binomial distribution. Median barrier crash frequency was found to be influenced by speed limit, traffic volumes, horizontal alignment, the distance the barrier was offset from the travel lanes, and the presence of interchange entrance ramps (*18*, *20*).

Shankar et al, used random effects negative binomial (RENB) and the cross-sectional negative binomial models (NB) to develop predictive models of cross-median crash frequencies in road sections without median barriers (*21*). Five year crash data from 1990 through 1994 was used. The negative binomial distribution was chosen as it can model the nonnegative integer nature of crashes as well as their overdispersion. Although accounting for overdispersion, the NB model does not account for location-specific effects or serial correlation over time. The authors compare the NB and RENB models developed.

The negative binomial (NB) model specifies the probability of n_{it} cross-median crashes for a section *i* in year *t* as

$$P(n_{it}) = \frac{\Gamma(\theta + n_{it})}{\Gamma(\theta) n_{it}!} u_{it}^{\theta} (1 - u_{it})^{n_{it}} \quad (11)$$

Where $u_{it} = \frac{\theta}{\theta + \lambda_{it}}$ and $= \frac{1}{\alpha}$, $\Gamma(.)$ is a gamma function and λ_{it} is given by

$$ln\lambda_{it} = X_{it}\beta + \varepsilon_{it} \quad (12)$$

Where X_{it} is a vector of geometric, traffic and weather data for roadway section I in year t, and β is a vector of estimable coefficients and $\exp(\varepsilon_{it})$ is a gamma distributed error term with mean one and variance α.

Standard maximum likelihood procedures were used to estimate λ_{it}. This model considers the yearly frequencies of each location as independent observations and does not allow for serial correlation in the crash data. The RENB model, however assumes that the overdispersion parameter is randomly distributed across groups; thereby letting the variance-mean ratio to vary across locations.

$$ln\lambda_{ij} = X_{ij}\beta + u_i$$

Where $u_i$is a random effect for the i[th] location group such that $\exp(u_i)$ is gamma-distributed with mean one and variance α. The joint density function is obtained by using $\frac{\theta_i}{1+\theta_i}$ to be B(a,b) where B(.) is the beta distribution.

$$P(n_{il}, \cdots n_{iT}) = \frac{\Gamma(a+b)\Gamma\left(a+\sum_T \lambda_{it}\right)\Gamma\left(b+\sum_T n_{it}\right)}{\Gamma(a)\Gamma(b)\Gamma\left(a+b+\sum_T \lambda_{it}+\sum_T n_{it}\right)} \prod_T \frac{\Gamma(\lambda_{it}+n_{it})}{(\lambda_{it})n_{it}!}$$

The parameters a, b and β vector are estimated using standard maximum likelihood procedures.

Five years of annual median crossover counts for 275 sections were used. The panel was balanced with all the sections containing data for 5 years. Four specifications: basic nonlocation and nontime-specific regression, a location effects model, a location and time effects model and a loation, time and location-time interaction model were considered and run under both NB and RENB distributions. The authors reported that the relative effectiveness of the RENB model diminished as more spatial and temporal effects were included. However the authors found location and time-specific variables to be significant and state that the RENB model offers an alternative where those effects are captured indirectly rather than by direct specification as indicator variables. Significant improvement in the likelihood was reported when the spatial effects were included indicating that significant unobserved heterogeneity occurs from roadside effects.

Ulfarsson and Shankar examined using negative multinomial (NM) model that accounts for section specific serial correlation across time, to predict the median crossover frequencies on sections without median barriers (*22*). This study used the same data and same model variables as Shankar et al. The temporal serial correlation in the median crossover data violates the assumption of independent error terms and if not accounted for properly, can cause the coefficient estimates to be inefficient and the estimated standard errors to be biased. The unconditional joint density function for NM distribution is given by

$$P(Y_{i1} = y_{i1}, \ldots, Y_{it_i} = y_{it_i}) =$$

$$\frac{\Gamma(y_i + \theta)}{\Gamma(\theta) y_{i1}! \ldots y_{it_i}!} \left(\frac{\theta}{\eta_i + \theta}\right)^{\theta} \left(\frac{\eta_{i1}}{\eta_i + \theta}\right)^{y_{i1}} \ldots \left(\frac{\eta_{it_i}}{\eta_i + \theta}\right)^{y_{it_i}}$$

Where
$\Gamma(.)$ is a gamma function,

$\eta_i = \eta_{i1} + \cdots + \eta_{it_i}$, and
$y_i = y_{i1} + \cdots + y_{it_i}$
$\eta_{it} = e^{x_{it}}.\beta$
Variance of $\exp(\varepsilon_i)$ is α and is equal to $1/\theta$. When there is no section specific correlation, in other words when each section has only one observation this formulation yields the negative binomial distribution. Maximum likelihood procedures are used to estimate coefficients β and α. The authors report that the coefficient values estimated using NM, NB and RENB models were similar but not identical. Statistical comparison of the log likelihood led the authors to conclude that the NM model outperforms the NB model even with temporal and spatial effects and the RENB model. Divided highways with low traffic volumes (i.e., less than 5,000 vehicles per lane per day) were found to experience fewer cross-median crashes than higher volume roadways. Increasing the number of horizontal curves per mile of road was found to decrease the expected number of cross-median crashes. Finally, increasing the roadway segment length was found to be associated with an increase in the expected number of cross-median crashes.

Miaou et al. used roadway inventory and crash data from Texas to develop a predictive model of cross-median crashes along divided highways (*23*). In the model, the expected number cross-median crashes decreased as the median width increased. Additionally, the expected number of cross-median crashes decreased as the number of through travel lanes per direction increased. Roadways with posted speed limits of 65 and 70 mph were found to experience more cross-median crashes than roadways with posted speed limits of 60 mph. No roadway geometric design features or traffic volume data were found to be statistically significant in a model of cross-median crash severity.

Harkey et al. recently used roadway inventory and crash data from California to develop predictive models of cross-median crashes (*24*). Separate models were specified for rural and urban roadways with and without full-access control. Additionally, separate models were specified for four- and five-or-more lane divided highways. In all models it was found that the expected cross-median crash frequency decreases as the median width increases and that the presence of an interchange entrance ramp is associated with an increase in the expected number of cross-median crashes. The magnitude of the interchange ramp influence indicator was greater on urban roadways than on rural roadways. This suggests that interchange entrance ramps may be a more important contributory factor on urban than on rural roadways.

State Median Barrier Policies

AASHTO
The AASHTO *Roadside Design Guide* (*25*) established guidelines to evaluate the need for median barrier installation under specific combinations of median width and ADT as shown inFIGURE 10. Several selected state median barrier policies/programs are presented below.

Wisconsin
The median barrier warrant criteria outlined in the WisDOT FDM(9) are based on median width and ADT, however are more conservative than the AASHTO recommendations. Median barrier is warranted for selected ADTs up to a median width of 60 feet.

South Carolina
Cable guard median barriers were installed on all freeway sections with a median width less than 60 feet (*26*). Crossover median crash fatalities dropped from over 70 during the two-year period between 1999 and 2000, to eight fatalities during the three year period subsequent to the barrier implementation. The median barrier system averages three hits per mile per year, resulting in repair costs that average approximately $1,000 per hit. Only 15 vehicles have traveled through or over the barrier during the three year analysis period (*26*).

Connecticut
The Connecticut Highway Design Manual warrants median barriers for all freeway median widths up to 66 feet and on wider medians if crash history indicates a need (*27*). At sections where median width varies, the median barrier should extend for 100 feet into the section where width no longer requires a barrier (*27*).

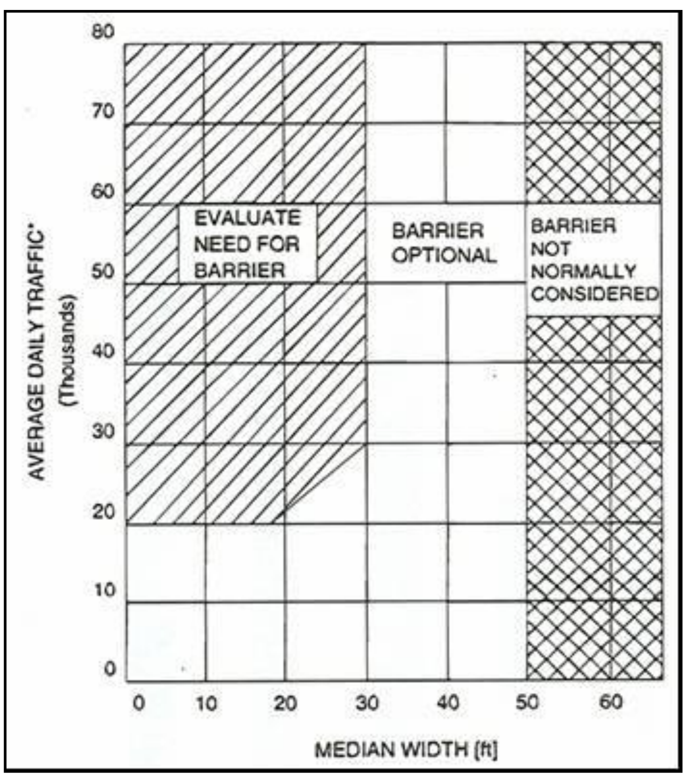


FIGURE 10AASHTO Median Barrier Guidelines (25)

North Carolina

North Carolina installed cable guard median barriers for all freeway sections with a median width less than 70 feet (*28*). The program included installation of cable guard barriers on over 1,000 miles of freeway between 1999 and 2004 and resulted in an estimated 90 percent reduction in the amount of crossover crashes and an average of 25 to 30 lives saved per year (*28*). The installation cost of approximately $55,000 per mile (~$55 million total), including material and labor costs, is estimated to have saved more than $290 million in crash costs, based on NHTSA's estimate of fatality and injury costs (*29*).

Washington

Approximately 25 miles of test sites were installed with cable median barriers for median widths ranging between 40 and 82 feet (*30*). The annual crossover crash rate for these sites decreased from 16 crashes per year before installation to 3.8 crashes per year afterwards. The rate of disabling and fatal crashes decreased from 3.8 crashes per year to 0.33 crashes per year, with no fatal crashes reported since the installation of cable median barrier (*30*). Installation of the cable barrier cost $44,000 per mile with an annual maintenance cost of $2,570 per mile. Although the overall median crash rate doubled from 49 crashes per year before installation to 100 crashes per year afterwards, the decrease in fatal and disabling injury crashes resulted in a net benefit of $420,000 annually per mile (*30*). Cable median barrier was found to be the most cost effective system, with a benefit cost ratio ranging from 2.7 to 5.5 for median widths up to 50 feet; however, beam guardrail and concrete median barriers were also found to be cost effective for median widths up to 50 feet (*31*).

Florida

The Florida Department of Transportation (FDOT) requires median barriers be installed on all highways with a median width less than 64 feet. A five year review of crossover median crashes from 1995 to 1999 conducted by FDOT (*32*) showed that 19 percent of crashes involved, or were suspected to involve alcohol; two percent involved a truck as the crossing vehicle; 78 percent of crashes occurred when the crossing vehicle's speed was within five mph of the posted speed limit; 75 percent of crashes occurred in "good" weather conditions, with 83 percent of these crashes being the result of driver error and avoidance maneuvers; 62 percent and 82 percent of all crossover median crashes occurred within one-half mile and one mile of interchange ramp termini, respectively.

Maryland

The Maryland State Highway Administration determines the need for a median barrier based on median width and ADT. On high speed highways, defined as highways with a design speed greater than 45 mph (*17*), median barriers are required for: median widths up to 30 feet for all traffic volumes; median widths up to 50 feet with an ADT of at least 40,000 vpd; and median widths up to 75 feet with traffic volumes greater than 80,000 ADT.

A number of states including Pennsylvania and Texas have recently sponsored studies to review their guidelines for the application of median safety improvements. In both cases, a benefit/cost (B/C) analysis procedure was used to determine at what median width and ADT combination is the installation of median barrier economically beneficial.

Pennsylvania

Donnell and Mason (*33*) investigated current median barrier warrant practices in the state of Pennsylvania using a safety and economic evaluation of cross-median and median barrier crashes. The researchers found that the AASHTO guidelines currently adopted by the state did not accurately reflect "increasing traffic volume trends or the improved performance capabilities of the modern vehicle." Similar to Noyce and McKendry (6) and the results of this study, Donnell and Mason found that there were a number of divided interstate highways that experienced a high frequency of crossover median crashes but did not warrant evaluation for median barrier under the current AASHTO guidelines.

Alternative median barrier warrant criteria were developed using crash prediction and severity models developed by the researchers from geometric and cross-section data and crash records collected on Interstate highways in Pennsylvania for the five year period between 1994 and 1998. For the study period, 138 crossover median crashes, defined as a crash in which a vehicle "leaves the roadway to the left, enters and crosses the median, and collides with a vehicle traveling in the opposite direction", were identified along with 4,416 median barrier crashes. Revised warrants for the implementation of concrete median barrier and W-Beam guardrail median barrier are shown in FIGURE 11and FIGURE 12, respectively.

The number within each cell in FIGURE 11and FIGURE 12 is the benefit/cost (B/C) ratio for each condition based on the assumptions of a 20-year service life analysis, benefits and costs as summarized inTABLE 1, a negligible salvage value, and an interest rate ranging between 3.20 and 5.40 percent. The expected number of crossover median crashes of each severity was determined by multiplying the predicted probability of each severity category by the expected crash frequency for both crossover median and median barrier crashes. The shaded portion of each warrant represents scenarios where the barrier system was found to be economically beneficial in preventing cross-median crashes, that is, where the benefit of the barrier is two to 19 times the cost of implementation. The outlined portion of each warrant represents scenarios where, although found to be economically beneficial, additional evaluation based on a crash rate analysis is recommended due to the reduction in exposure and low crash rate observed at highway sections with median widths greater than 70 feet.

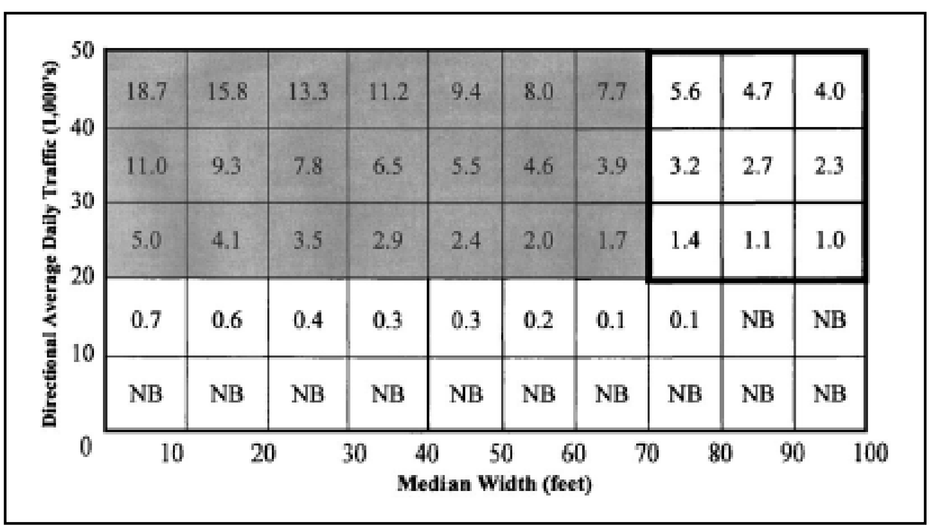


FIGURE 11Pennsylvania Concrete Median Barrier Placement Guidelines(33)

Notes: *Values represent the benefit/cost ratio of installing barrier along the centre of the median.*
NB = No calculated benefits.

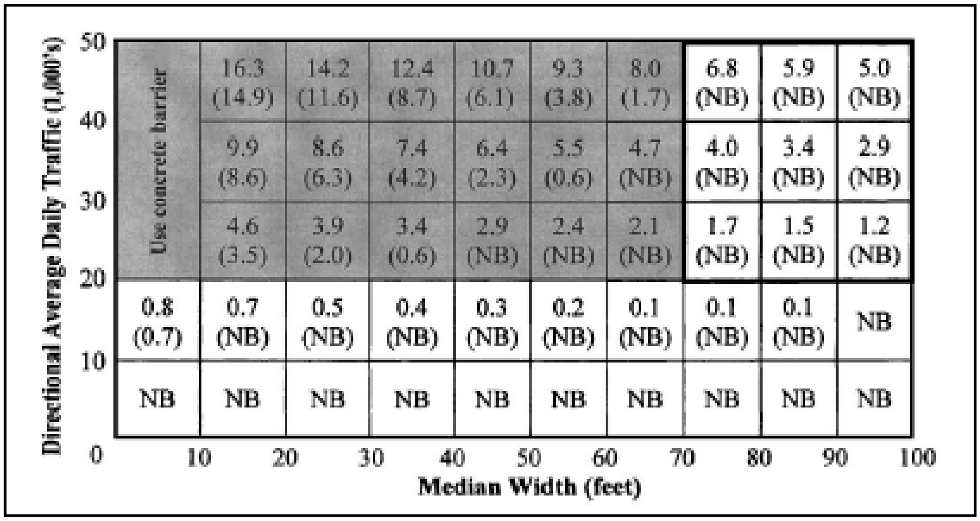


FIGURE 12Pennsylvania W-Beam Guardrail Median Barrier Placement Guidelines(33)

Notes: *Values represent the benefit/cost ratio of installing barrier along the centre of the median.*
Values in parentheses represent the benefit/cost ratio of installing barrier offset 4 feet from the travel lane.
NB = No calculated benefits.

TABLE 1 Benefits and Costs Considered in the Pennsylvania B/C Analysis (33)

	Concrete Barrier	**W-Beam Guardrail**
Benefits		
Reduction in Crash Severity Reduction in Crash Frequency	PDO = $2,350/crash Injury = $627,000/crash Fatal = $3,060,000/crash	PDO = $2,350/crash Injury = $627,000/crash Fatal = $3,060,000/crash
Costs		
Site Preparation	$0 – 50,000/mi	$0 – 50,000/mile
Unit Cost	$35/linear foot	$24/linear foot
Installation	Included above	Included above
User Costs and Delays	$1,500/day/mi (low volume) - $16,000/day/mi (high volume) Included in Site Preparation	$1,500/day/mi (low volume) - $16,000/day/mi (high volume) Included in Site Preparation
Maintenance	Negligible	$5/linear foot

Two approaches for implementing the revised median barrier warrants were recommended. The first involved fitting median barrier at all highway sections that meet the warrants. This method would deliver immediate safety advantages but would likely prove cost prohibitive. An alternative procedure was also presented to prioritize the implementation of median barrier at warranted highway segments. The procedure, although not described in detail, would consider crash frequency, crash severity, median width, traffic volumes, posted speed limits, and other geometric elements in the development of a severity index for each warranted highway segment. A B/C assessment would then be conducted using the severity index to determine the worth of installing median barrier at each location and a prioritized list of implementation sites developed (*33*).

Texas

Research conducted by Bligh et al. at the Texas Transportation Institute also employed a B/C analysis to develop improved median barrier guidelines for application in the Texas Department of Transportation (TxDOT) *Roadway Design Manual* (*34*). Crash frequency and severity prediction models were developed using a Poisson model applied under a full Bayes approach from 3,672 median-related crashes identified in the Dallas-Fort Worth area between 1998 and 1999. These crashes included 346 cross-median crashes, defined as crashes in which a vehicle crossed the median, entered the opposing travel lanes, and collided with a vehicle in the opposing travel lanes. A B/C analysis was then conducted using the frequency and severity prediction models, information provided by TxDOT and summarized in TABLE 2 regarding crash costs, and the cost and analysis assumptions presented in TABLE 3 for each combination of ADT and median width. A sensitivity analysis was also conducted to determine the effects of changes in the assumptions adopted in the analysis. The results of the sensitivity analysis were reflected in the revised guidelines (*34*).

TABLE 2Summary of Texas Crash Cost Assumptions(34)

Crash Severity Type	Estimated Crash Costs for AllState Highways (2000 $)[1,2]	Number of Persons Involved with the Maximum Severity Incurred per Crash 1998-1999[3]			Adjusted Crash Costs (2000 $)[4]		
		No Median Barrier		With Median Barrier	No Median Barrier		With Median Barrier
		Cross Median Crashes	Other Median-Related Crashes	All Median Related Crashes	Cross Median Crashes	Other Median-Related Crashes	All Median Related Crashes
Fatal (K)	1,191, 887	1.43	1.12	1.17	1,482,086	1,160,794	1,212,615
Incapacitating (A)	69,199	1.57	1.32	1.21	82,933	69,727	63,917
Non-Incapacitating (B)	25,218	1.79	1.26	1.21	32,475	22,859	21,952
Possible Injury (C)	14,198	1.88	1.36	1.36	17,001	12,299	12,299
Property Damage Only (O)	1,969	2.18	1.10	1.13	2,411	1,217	1,250

Notes:
[1] *The cost was estimated by TxDOT Traffic Operations Division, based on the National Safety Council's estimate of societal cost (not the comprehensive cost) for crashes which occurred on all state-maintained highways. The estimated crash costs will roughly triple if comprehensive costs are used.*
[2] *2000 $ = Value in year 2000 dollars.*
[3] *Obtained from Texas traffic crash records. For example, on average, 1.15 persons were killed per crash in all state system fatal crashes; while 1.43 persons were killed in a fatal cross-median crash. For PDO crashes, 1.78 vehicles were involved in each PDO crash for all state highways; while 1.1 vehicles were involved, on average, in a PDO median-related (non-cross-median) crash with no longitudinal barrier present.*
[4] *These adjusted costs were developed by the authors of this study. For example, the adjusted cost for a cross-median fatal crash is calculated as $1,191,887*(1.43/1.15)=$1,482,086 and as $69,199*(1.57/1.31)=$82,933 for cross-median incapacitating crashes.*

A revised median barrier guideline that relates median width and ADT was developed by Bligh et al. and is presented on FIGURE 13. The guidelines are split into four distinct "priority zones" depending on the magnitude of the B/C ratio. These zones range from Zone 4, which includes scenarios with the lowest B/C ratio and in which median barrier is not generally considered, through to Zone 1, in which a median barrier is normally required and provides the highest B/C ratio. Within the same figure, Bligh et al. also developed median barrier crash rate guidelines by calculating the mean expected number of cross-median crashes for each of the B/C priority zones from the cross-median frequency model (*34*).

Practitioners can apply the guidelines by determining the priority zone in which the ADT/median width combination and/or average cross-over crash rate lies. Barriers are normally required for highway segments in which the ADT/median width combination falls within Zone 1, or if the average crash rate is greater than 0.7 cross-over crashes per mile per year. For ADT/median width combinations falling within Zone 2 or observing a crash rate greater than 0.4 cross-over crashes per mile per year, median barrier is "cost effective and should be considered." Barriers are considered optional for Zone 3 and are not normally considered at all for Zone 4.

TABLE 3Summary of Texas Transportation Institute B/C Analysis Assumptions(34)

	Mean B/C Estimate		**Low B/C Estimate**	
	Concrete Barrier	**Cable Barrier (High Tension)**	**Concrete Barrier**	**Cable Barrier (High Tension)**
Project Life (years)	20	20	20	20
Interest Rate (%)	5	5	5	5
AADT Annual Growth Rate (%)	3	3	1	1
Estimate of Cross-Median Crash Frequency	Mean	Mean	2.5th Percentile	2.5th Percentile
Installation Cost per Mile[1] ($1,000)	(190+370)/2	(65+100)/2	370	100
Site Preparation and Grading Cost[1] ($1,000)	(Median Width in feet – 20)*100/80	0	(Median Width in feet – 20)*100/80	0
Barrier Breaching Crash Rate as a Percentage of Estimated Barrier Hits[2] or Crashes	0.3% of estimated number of reported crashes	3% of estimated number of barrier-hits[2]	0.3% of estimated number of reported crashes	3% of estimated number of barrier-hits[2]
Repair Cost per Hit[2] ($1,000)	0	(0.35+0.70)/2	0	0.70
Salvage Value at End of Project Life	0	0	0	0

Notes

[1] It is assumed that barriers are placed near the center of the median. Installation costs include material, labor, and equipment costs. The site preparation cost for concrete barriers is assumed to be a linear function of median width (excluding existing shoulder width of 20 ft), with an estimate of $100,000 at a median width of 100 ft. This assumes a relatively mild slope of 6:1 or flatter without a lot of earthwork to flatten the slope to a 10:1. These costs do not include user costs due to travel delay, and traffic control and engineering costs during constructions.

[2] To estimate the number of hits on cable barriers that require repair, the estimated number of hit-barrier crashes from the model is multiplied by a factor of two to account for unreported crashes and crashes that do not meet the reporting and coding threshold. Since July 1, 1995, Texas DPS stopped coding those PDO crashes for which vehicles did not have to be towed away.

In terms of barrier choice, the research concludes that high-tensioned cable barriers are "generally more cost-effective than concrete barriers for the range of median widths for which they are applicable." Depending on the deflection standards for the barrier system being considered, it is recommended that the use of high-tensioned cable barriers be limited to median widths greater than 20 feet.

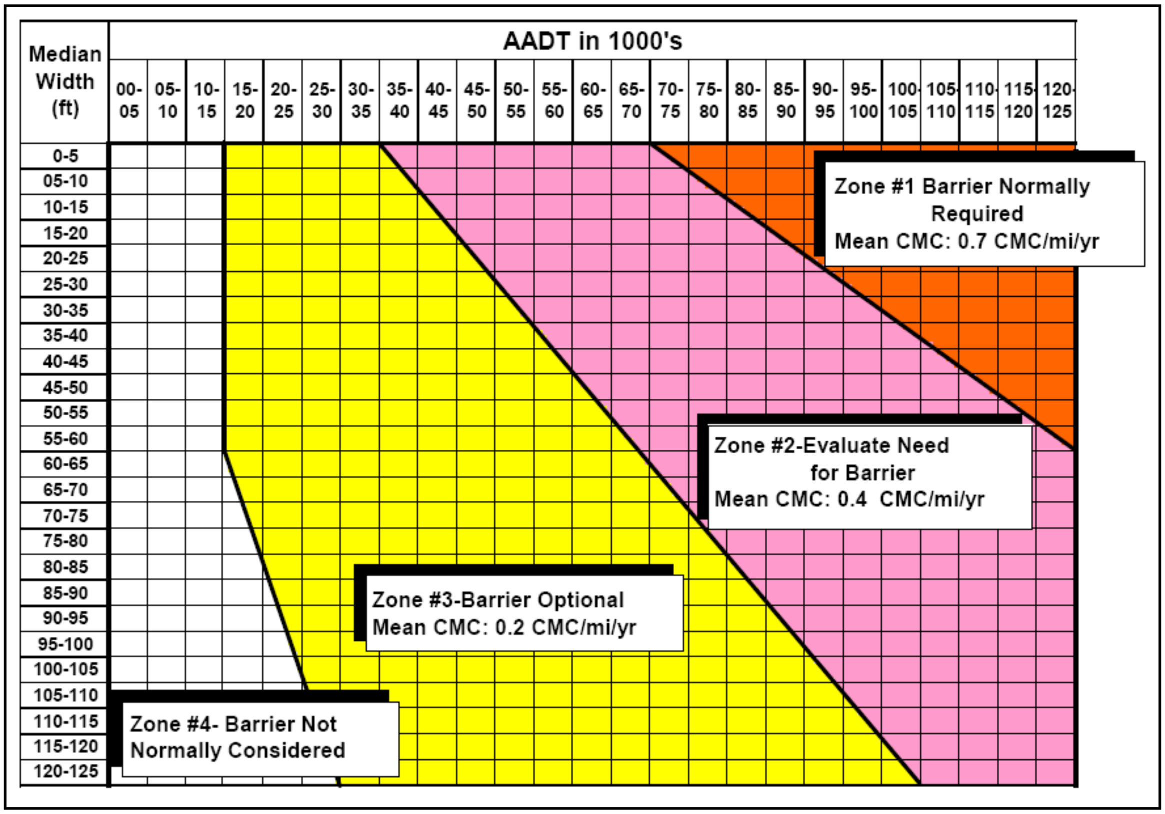


FIGURE 13Recommended Guidelines for Installing Median Barrier on Texas Interstates and Freeways (34)

California

A relationship between ADT and median width is one of the primary criteria used by the California Department of Transportation (Caltrans) in determining the need for additional median safety analysis. FIGURE 14shows the median width and ADT combinations selected to warrant additional analysis.

California also used crash history as a factor in identifying sites requiring additional analysis. In 1978, Caltrans adopted the crash rate warrants of 0.5 crossover median crashes per mile per year and 0.12 fatal crossover median crashes per mile per year, with at least three crossover median crashes over a five year period, to determine sites that warrant additional analysis on the basis of crash history. A crossover median crash in California is defined as a crash in which a vehicle crosses the median and strikes or is struck by a vehicle from the opposite direction.

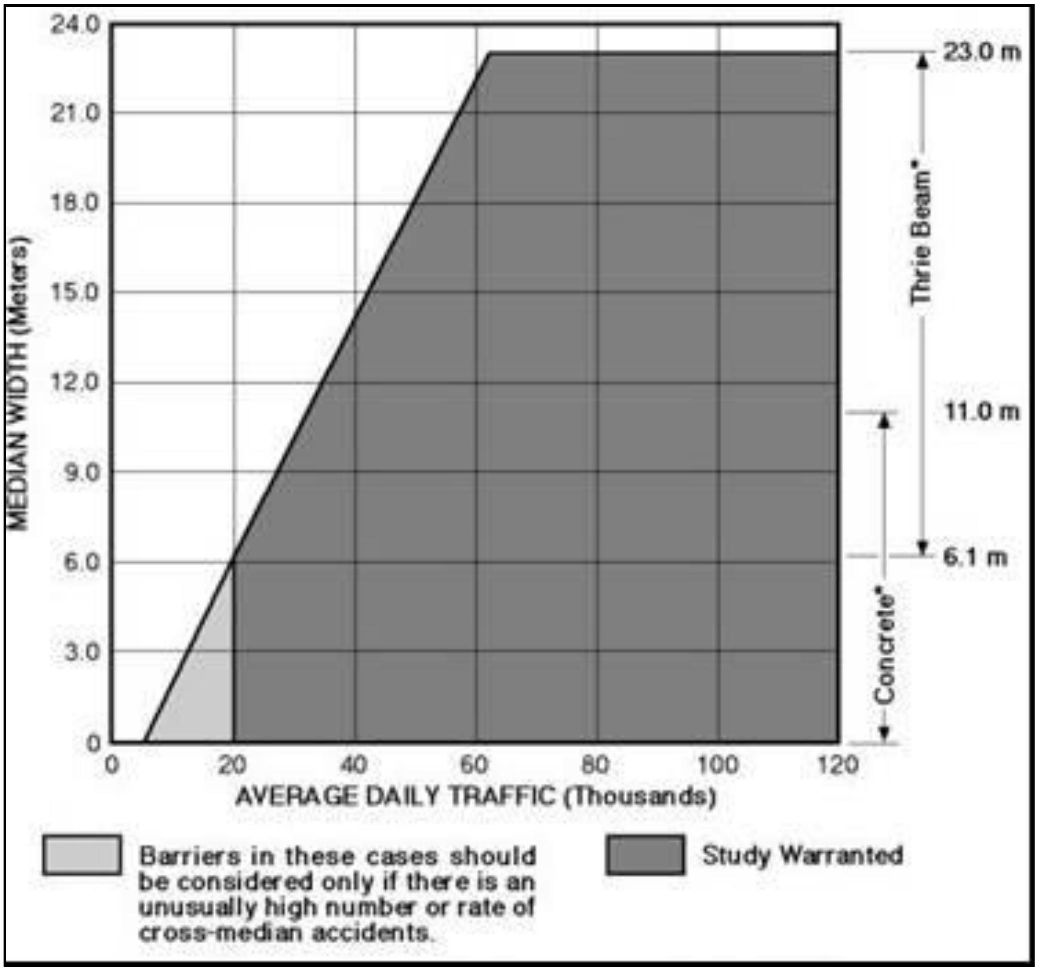


FIGURE 14Caltrans Additional Analysis Warrant Guidelines(35)

Both the median width/traffic volume and crash rate warrants were reviewed in 1991 by Seamons and Smith (*35*) and again in 1997 by Nystrom et al. (*36*). Seamons and Smith concluded that the median width/traffic volume warrant and the crash rate warrants (identified above) be retained as guidelines for identifying sites requiring additional analysis (*35*). Sites meeting the warrant with three to four crashes over a five year period "frequently lost their warrants before construction" due to the random nature of crashes. Although it was suggested that the warrant be increased to require five rather than three crashes observed in a five year period, the crash frequency requirement was not changed so as not to "preclude valid projects from being identified and constructed."

Nystrom et al. used a B/C procedure to review the traffic volume/median width and crash rate warrants (*36*). The study employed cross-median and struck-barrier crash information along with geometric and operational data for divided, multi-lane freeways for the five year period between 1991 and 1995. The B/C analysis employed a human capital approach that incorporated all measurable direct and indirect economic costs associated with a crash and a service life of 20 years. Under this methodology, fatal crashes were valued at $850,000 per crash (in 1997 dollars), injury crashes at $17,200 per crash, and property damage crashes at $3,700 per crash. The cost of installing either concrete or metal beam median barrier was estimated at $270,000 per mile (in 1997 dollars). Nystrom et al. concluded that an economic benefit would result for an "increase in the existing traffic volume/median width guidelines up to a median width of 75 feet (*36*)." This is reflected in the current warrant presented in FIGURE 14. However, for median widths greater than 75 feet, no net reduction in fatal crashes was reported with the installation of median barrier, further offset by an increase in the frequency of property damage and injury crashes as a result of the barrier being in place. The crash rate warrant was deemed appropriate. A comparison of the Caltrans and WisDOT median width/traffic volume warrants is presented inFIGURE 15.

Median Barrier Types

Rigid Barriers

Concrete, or Jersey barriers, are the most rigid type of median barrier and have several shapes, each with the purpose of minimizing the severity of a crash upon collision and maximizing the ability of a driver to regain control of their vehicle. For these reasons, in addition to their minimal lateral displacement upon impact, concrete barriers are recommended for narrow median widths, often found in urban areas or corridors with minimal right of way. Concrete barriers are the most costly type of median barrier ranging from approximately $130,000 to $1.4 million per mile for materials and labor, depending on the associated earthwork and/or paving needed (*26*, *37*). FIGURE 16displays a typical concrete barrier design (9).

Semi-Rigid Barriers

Semi-rigid barriers, often referred to as guardrail, consist of connected segments of metal rail supported by heavy posts and blocks. Support posts are made of either steel or metal, and usually placed 6 feet - 3 inches apart from each other (*38*). There are two common types of metal rail: W-Beam and Thrie-Beam.

W-Beam guardrail is the most common type of semi-rigid barrier and contains two protrusions in the rail. The rail is typically 12 inches from top to bottom when mounted parallel with the roadway. Thrie-Beam guardrail contains three protrusions and is typically 20 inches tall (*39*, *40*). The added width of the Thrie-Beam makes it a better choice for areas with a narrower median where a more rigid barrier is required and at connection points to rigid barriers. Guardrail is more cost effective than concrete barrier with the cost of installation of a W-Beam guardrail estimated at approximately $72,000 per mile (although costs vary widely) (*39*). W-Beam and Thrie-Beam guardrail can be used for a variety of surface conditions including natural earth. For narrow medians, it may be necessary to double-stripe the guardrail, i.e., run two rails back-to-back for increased strength.

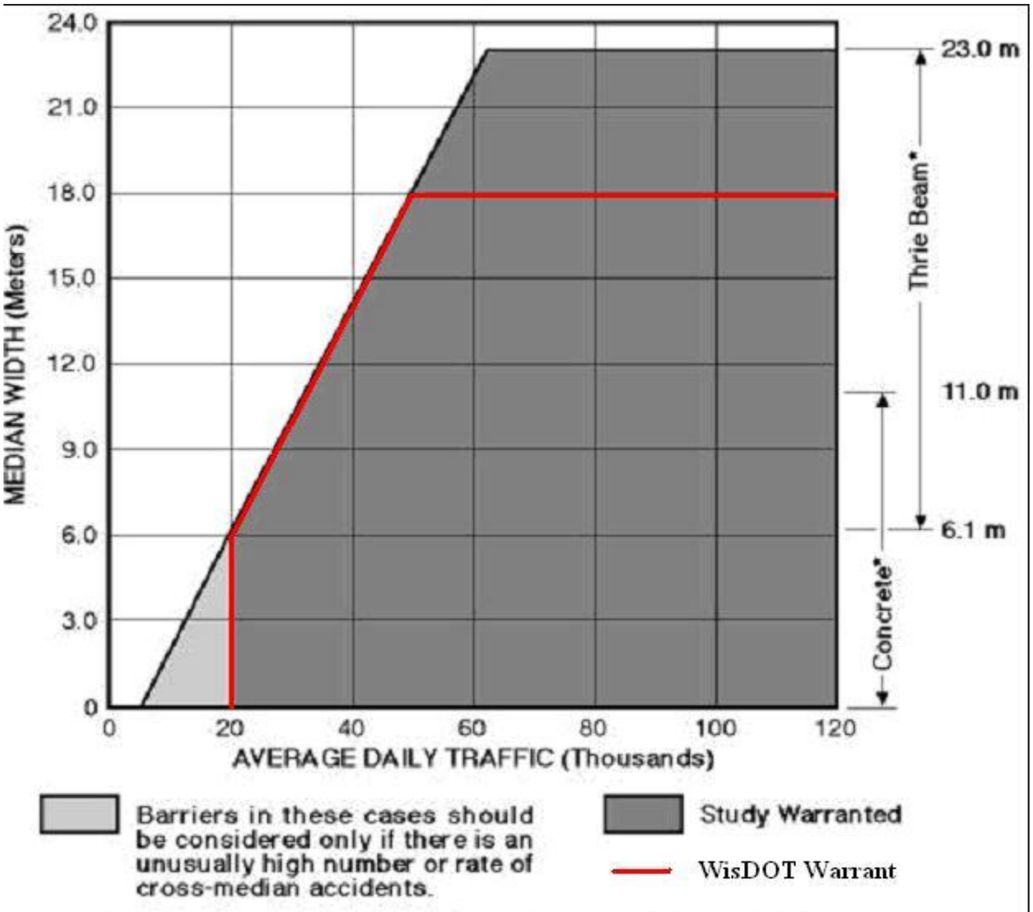


FIGURE 15Comparison of Caltrans and WisDOT Warrant Guidelines

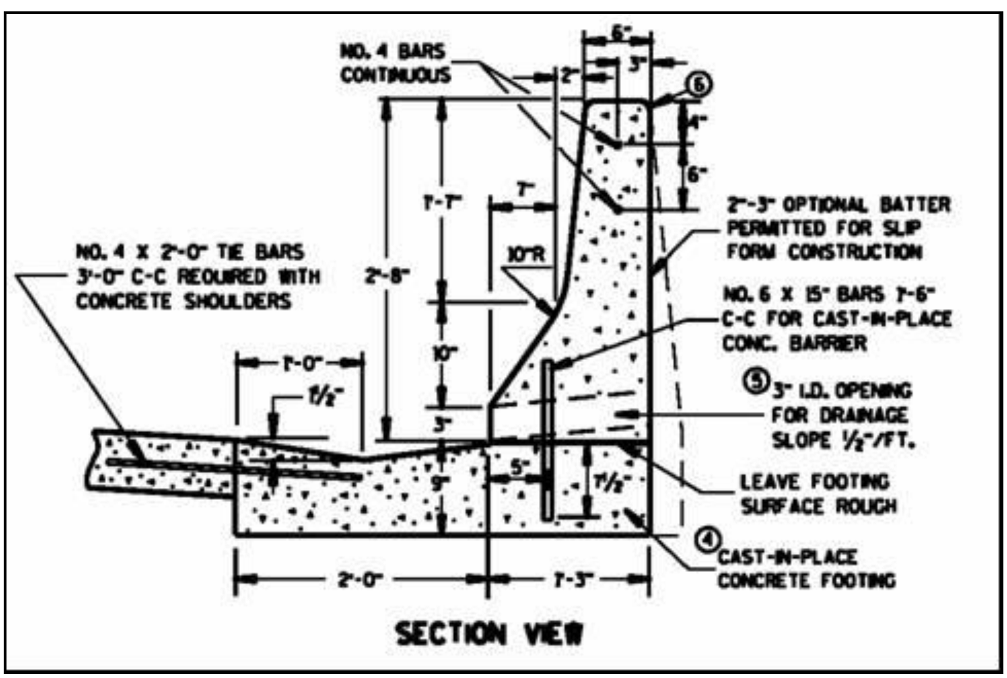


FIGURE 16Typical Concrete Barrier Profile (9)

Flexible Barriers

Flexible barriers, commonly known as cable-barriers, typically consist of three steel cables that are connected to a series of posts as shown inFIGURE 17. Cable barriers are the easiest and most inexpensive barrier system to erect, with installation cost estimates ranging from $44,000 to $55,000 per mile (*26*, *37*). However, due to their design, cable barriers also require the most maintenance. Every time a cable barrier is struck by a vehicle, the cables may need to be reattached to the posts. Flexible barriers are a popular system because they cause the least amount of damage to a vehicle. However, medians must be of sufficient width to allow for the stretching of the cable to prevent a vehicle from crossing over. The amount of deflection for an installation varies depending on site conditions (*41*). Several proprietary cable barriers have been developed for median applications. Three of the most common include the Brifen Wire Rope Safety Fence (WRSF), the Trinity Cable Safety System (CASS), and the Marion Steel barrier (*42*). Each of these systems contains cables that are pre-tensioned, unlike traditional cable-barrier systems that are not tensioned. TABLE 4 contains a review performed by the Ohio Department of Transportation (ODOT) on each of these systems, along with traditional cable barrier (*43*).

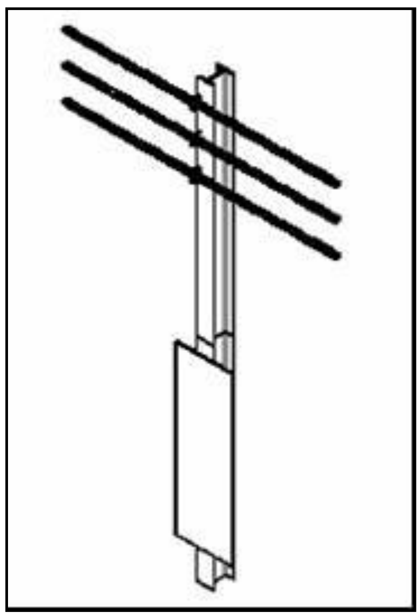


FIGURE 17Typical Three-Strand Cable Barrier Profile

TABLE 4ODOT Cable Barrier Comparison(43)

	Brifen	Marion	Trinity	Base (generic)
Description	4 cable woven, tensioned and pre-stretched	3 cable tensioned but not pre-stretched	3 cable tensioned and pre-stretched	3 cable un-tensioned and not pre-stretched
Product History	3000 km of use 20 foreign countries	New system, based on well used frangible sign posts	New System to the USA, but modified from an existing European system	Generic Cable has been in use in the US since 1960s but not an ODOT standard
Segment Length	14 miles	12 miles	3 miles	12 miles
Post Spacing & Crash Deflection	10 feet 6 inch spacing 7.9 foot spacing	6 feet 6 inch spacing 6.5 foot spacing	10 foot spacing 7.9 foot spacing	16 foot spacing 11.2 foot spacing
Application	On one side of a median slope	At edge of wide paved shoulder on one side	At edge of wide paved shoulder on one side	On one side of median slope
Approx. No. Hits	160 (6.5 hits/mile/year)	30 (5.0 hits/mile/year)	10 (6.7 hits/mile/year)	n/a
Issues	One penetration of unknown reason has been recorded. Cable sagging in severe hits. District decision to replace driven posts with concrete socketed foundation affects timeliness of repair.	Replacing of problem anchor foundations. Retrofitting of the remaining anchor foundation to the Project Engineer's satisfaction. Redesign of damaged line post foundations. Keeping watch on the cable tension.	Anchor system is the same as on the Marion Steel system and may be vulnerable to movement as well.	D-12 Maintenance wrote in 2000 of the problems in maintaining the cable and keeping parts. D-12 then recommended replacing the cable with Type 5 guardrail.
Performance Conclusions	Performing to NCHRP Report 350 standards	Performing to NCHRP Report 350 standards	Performing to NCHRP Report 350 standards	Conforms to previous crash test criteria, NCHRP Report 230 standards
Summary	Best accident data, longest evaluation time, proven system elsewhere, extra cable woven. System seems to be proving itself beneficial	Construction issues, first substantial installation for product, so manufacturer's installation and repair manual being written after the fact from our experiences.	Construction went smoothly and observed repair was very easy. Looks to be a good system, but the length, and thus exposure to accidents is limited.	District says cable needs immediate attention after an accident and parts are difficult to obtain.

Barrier Applications

Donnell and Hughes found seven common median barrier types used by state transportation agencies distributed amongst the three barrier categories. TABLE 5 presents a summary of each barrier type, design deflection, applicable site conditions, and other information (17).

TABLE 5Median Barrier Types and Placement Recommendations(17)

Barrier Type	Design Deflection	Recommended Site Conditions	Other Notes
Flexible Median Barrier Systems			
Weak-post, W-Beam	7 feet	Flat, traversable slopes	• Can remain effective after struck • Sensitive to mounting height • Requires proper end anchorage
Three-Strand Cable	12 feet	Flat, traversable slopes	• Inexpensive installation • Requires proper end anchorage • Ineffective after being struck • Expensive to maintain
Semi-Rigid Median Barrier Systems			
Box-Beam	5.5 feet	Flat, traversable slopes	• Posts designed to breakaway at impact • Posts must be repaired after being struck
Blocked-out W-Beam (strong post)	2 – 4 feet	Median width of 10 feet or greater	• Can remain effective after impact • May require rub-rail • Higher impact forces than flexible systems
Blocked-out Thrie Beam (strong post)	1 – 3 feet	Requires effective barrier height	• Can accommodate larger range of vehicles than W-Beam • No need for rub-rail • Higher impact forces than flexible systems
Modified Thrie-Beam	2 – 3 feet	Requires effective barrier height	• Can accommodate larger range of vehicles • Does not usually require immediate repair • Higher impact forces than flexible systems
Rigid Median Barrier Systems			
Concrete Median Barrier	0 feet	Use in narrow, symmetric medians	• Low life-cycle costs • Effective performance • Maintenance-free • High impact forces • High installation cost

CHAPTER III
STUDY DESIGN

In order to quantify the magnitude of crossover median crashes in Wisconsin, to identify the causes of crossover median crashes, and to determine highway locations that require additional median safety analysis, four hypotheses were developed along with five major research tasks. This chapter presents these hypotheses and provides a thorough description of the research study design.

Research Hypotheses

Based on the findings of the literature review and the research objectives, the following hypotheses were developed:

Hypothesis 1: Crossover median crashes remain a significant problem for the state of Wisconsin.

Hypothesis 2: There are relationships between the rate of crossover median crashes and both median width and ADT.

Hypothesis 3: There are differences in the number and length of sites identified as requiring additional median safety analysis depending on the definition of a crossover median crash.

Hypothesis 4: An improved median safety analysis warrant can be developed for application in Wisconsin.

To test these hypotheses, the following research tasks were developed.

Task 1: Literature Review

A comprehensive literature review was recently undertaken by similar research efforts (6, 7). Task 1 updates this literature review, adding material identified since 2007. Recent research has focused on the effect medians have on safety and their relationship to crossover crashes as well as the development of revised warrants for the identification of highway segments that require additional analysis or the installation of median barrier. All elements of the literature review were presented in Chapter 2.

Task 2: Crossover Median Crash Analysis

The Wisconsin Motor Vehicle Accident Report (WMVAR) is a computer readable sheet to automate the downloading of crash information and store in a computer database. However, the current version of the form provides no entry to highlight a crash involving a vehicle crossing the median. Therefore, all crashes on divided highways in Wisconsin were initially reviewed to identify potential crossover crashes. Crash reports pertaining to crossover crashes were then selected for this analysis. Copies of the actual crash reports, which include any diagrams or narrative provided by the reporting police officer are stored on microfilm (for crashes occurring prior to December 2004) and as digital files (for crashes occurring after December 2004) at the WisDOT headquarters in Madison, Wisconsin.

Site Selection
With the assistance of WisDOT traffic engineering staff, Interstate, expressway, and freeway segments with a divided median were selected as examination sites from the state's roadway database. The highways selected are presented in TABLE 6. Crash reports for the examination sites were gathered for the seven year period from 2001 to 2007. A seven year period was chosen to get comprehensive, normalized results from the most recent years of data available.

Data Collection
The WisDOT crash database was initially queried at each of the selected roadway segments to identify potential crossover median and median entry crashes. Potential crossover median crashes were identified through query of the following topics in the WisDOT crash database:

- Traffic-way = "Divided highway, median strip, without traffic barrier";
- Highway = All (TABLE 6);
- County = Selected based on roadway (TABLE 9);
- Traffic Control = All; and
- Driver Action = All.

The associated crash numbers produced a list of crash reports that were relevant to the research and required detailed review of the narrative and diagram. Each of the over 37,000 potential crossover median crash reports identified was reviewed on microfilm or digital file by a researcher to inspect whether or not the crash involved a vehicle that a) entered the median, and/or b) crossed the median. Again, this step was needed because of the lack of a specific crossover median crash identifier in the current WMVAR form. Determination of actual crossover median crashes was made by examining the narrative and pictorial representation written by the reporting police officer on the WMVAR. Data from the crash report were collected and digital images of the report obtained and archived during the review process. After gathering crossover median crash information, median widths and average daily traffic volumes (ADTs) for each of the crash sites were added to the database. Median widths were obtained from the *Wisconsin State Trunk Highway Log* and ADTs from the *2005 Wisconsin Highway Traffic Volume Data Book*. To obtain the correct median width and ADT, each selected crash was located either through its WisDOT Reference Point (RP) number or crossroads reference. Several roadways and crash locations were verified through field visits.

TABLE 6Wisconsin Highways Reviewed for Crossover Crashes

Interstates	39, 43, 90, 94
U.S. Highways	10, 12, 14, 18, 41, 51, 53, 141, 151
WI State Highways	23, 29, 30, 35, 54, 57, 172, 441

Task 3: Data Analysis
Data analysis examined the crossover median crashes found as part of the crash data mining. Basic statistical metrics were initially derived, including the number of crashes by type, location, and frequency. Demographic and other related variables in the data set, including weather and ADT, were also evaluated. The following information was determined:

Median Width/ADT and Crossover Crash Rate Relationship

Two crossover median crash rates were considered against median width. First, the number of crossover median crashes per mile per year for each highway segment was calculated. Secondly, the number of crossover median crashes was adjusted for the number of vehicle miles traveled. Highway segments were determined to be a length of a specific roadway within a county that exhibited a consistent median width. Portions of a highway that were undivided or those that contained a median barrier were excluded from the total length of a segment. The number of crossover median crashes observed per mile per year was then also compared to the average ADT of each segment.

Initial First Action

Each selected crash was reviewed to determine the initial first action which caused the crash. Crashes were grouped into six categories:

- *Lost Control on Dry Pavement*: Driver of the vehicle lost control for a variety of different reasons, including: avoiding another vehicle, driver fell asleep, driver was distracted.
- *Lost Control Due to Weather*: Driver of the vehicle lost control directly due to snow, ice, sleet, wind, or rain. These weather-related attributes were evaluated independently from the dry weather lost control category.
- *Vehicle Collision*: Vehicle that crossed over the median made contact with another vehicle traveling in the same direction which produced the crossover action.
- *Barrier*: Vehicle first struck a barrier which caused a loss of control and the crossover action.
- *Signpost***:**Vehicle first struck a signpost which caused a loss of control and the crossover action.
- *Other*: These crossover crashes could not be classified by the other five categories.

Crossover Extent

Each selected crash was reviewed to determine the extent of the crossover action. Crashes were initially grouped into four categories:

- *Partial*: Vehicle crossed over the median and came to rest with some portion of the vehicle having made it onto the paved surface, including the interior shoulder.
- *Into*: Vehicle crossed over the median and came to rest within the paved surface of the opposite roadway.
- *Beyond*: Vehicle crossed over the median, the opposite roadway, and came to rest at a location beyond the exterior shoulder of the opposite roadway.
- *Object*: No vehicle crossed over the median, but an object or a trailer that detached from a vehicle, crossed over to the opposite roadway.

Crashes involving vehicles that only entered the median without penetrating the opposing traffic lane were identified on selected routes but not evaluated. Note that both single vehicle and multiple vehicle crashes were initially selected.

Crash Vehicle

Each selected crash was reviewed to determine the type of vehicle(s) involved in the crossover action and, if applicable, collision in the opposite roadway. Crashes were grouped into eight categories:

- *Passenger Car*: Passenger vehicle crossed over the median without striking another vehicle in the opposite roadway.
- *Truck*: Commercial truck crossed over the median without striking another vehicle in the opposite direction.
- *Passenger Car – Passenger Car*: Passenger vehicle crossed over the median and initially struck another passenger car in the opposite roadway.
- *Passenger Car – Truck*: Either a passenger vehicle crossed over the median and initially struck a commercial truck in the opposite roadway or a commercial truck crossed over the median and initially struck a passenger vehicle.
- *Truck – Truck*: Commercial truck crossed over the median and initially struck another commercial truck in the opposite roadway.
- *Motorcycle*: Motorcycle crossed over the median without striking another vehicle in the opposite roadway.
- *Trailer*: Trailer in tow detached from a passenger vehicle and crossed over the median without striking another vehicle in the opposite direction.
- *Trailer – Passenger Car*: Trailer in tow detached from a passenger vehicle and crossed over the median and initially struck a passenger vehicle in the opposite roadway.

Crash Severity

Each selected crash was classified using data from the WMVAR based on the severity of the crash. Crashes were grouped into three categories.

- *Fatal*: At least one person was killed in the crash.
- *Personal Injury*: At least one person sustained bodily injuries during the crash.
- *Property Damage Only*: No person was hurt in the crash.

Crash Rate Analysis

A number of transportation agencies, including Caltrans, apply a crossover median crash rate in addition to an ADT/median width relationship to identify highway segments that require additional median safety analysis. An example of such an application is the Caltrans rates of 0.5 crossover median crashes of any severity per mile per year or 0.12 fatal crashes per mile per year. In both cases, a minimum of three crashes within a five year analysis period is required before a segment is flagged for further analysis. Also note that the Caltrans definition only includes multiple-vehicle, opposite direction crashes. Single vehicle crashes are not included in their analysis.

To be consistent with the literature and facilitate the use of the rates presented above, WisDOT adopted the Caltrans definition of median crossover crashes for this and all future research on this topic. As previously discussed, the Wisconsin definition uses a crash rate warrant of 0.5

crossover median crashes per mile per year (all crash severities) or 0.12 fatal crossover median crashes per mile per year, with at least three crossover median crashes over a five year period, to determine sites that warrant additional analysis on the basis of crash history. A crossover median crash is defined as a crash in which a vehicle crosses the median and strikes or is struck by a vehicle from the opposite direction. Therefore, only multiple-vehicle crashes are considered, and the evaluation variable 'extent' is only considered in relation to the final resting position of the crossing vehicle.

Task 4: Crash Rate Sensitivity Analysis and Warrant Development

After completing the analysis using the Caltrans, now Wisconsin, definition of a crossover median crash, a broader look at the crossover median crash history was conducted to help identify 'sites of interest' or other locations that do not meet the warrant criteria but may be worthy of additional monitoring. For example, a site where several single vehicle crossover median crashes have occurred would not meet the formal definition of a crossover median crash, but may be a site worthy of further evaluation, monitoring, or low-cost safety improvements. The combination of the results of Tasks 1 through 4 will provide the foundation for the development of a Wisconsin-based warrant for median barrier placement.

CHAPTER IV
RESEARCH RESULTS

A primary objective of this research was to determine the magnitude of crossover median crashes in the state of Wisconsin. As previously stated in Chapter 3, the total number of crossover median crashes was calculated through a review of crash reports on Wisconsin highways for the period between 2001 and 2007, using the Wisconsin definition of a crossover median crash. In addition, the data from each selected crossover median crash were used to establish a relationship between median width or ADT and crossover median crashes as well as the causes and characteristics of crossover median crashes. This chapter documents the research findings.

The first section of this chapter provides an analysis of all the selected crossover median crashes, including years, roads, and locations. The relationship between median width or ADT and crossover median crashes is then explored. Crash characteristics analyzed to determine the significant factors affecting crossover median crashes and the results of crossover median crash rate analyses are then presented.

Crossover Crash Totals

A total of 37,277 crash reports were obtained from the WisDOT crash data archives for the period between 2001 and 2007. Reports for those crashes occurring between 2001 and 2003 were reviewed and analyzed between May and September of 2004 and the results documented in a previous report (6). Crash reports for crashes occurring between 2004 and 2005 were reviewed between June and July of 2006 and combined with the 2001 to 2003 dataset and the results were documented by Witte et al. (7). This report adds the data from the years 2006 and 2007. The crashes reviewed were initially selected from a query of the WisDOT crash database or identified by WisDOT traffic engineering staff as possible crossover crashes. After completing the review, 1,899 crashes were identified as potential crossover median crashes. Each selected crash was re-examined to both determine the first action (potential cause) of the crash and to also confirm that each crash met the definition of a crossover median crash. A total of 243 crashes were disqualified from the selected crash total during this process.

Crossover crashes involving objects, such as a tire, animal, crash debris, or person, were removed as it was determined that standard median safety improvements, such as barriers, would not have prevented these objects from traveling airborne across the median. Tire crossovers compromised 108 of the 139 total object crossover crashes; the remaining 31 crashes were made up of a variety of objects, including debris, deer, and people. Only crashes that occurred at a location without a median barrier were selected. Roadway segments with a median barrier installed were not included due to the fact that the research objective was to look only at roadway segments classified as "non-barrier." This criterion disqualified 88 crashes that involved a vehicle crossing the median in spite of an existing barrier; most of these vehicles vaulted or flipped over the barrier. An additional 16 crashes were removed due to the driver's purposeful intent to cross the median as described in the police narrative. Using Wisconsin's definition of crossover median crashes, which only includes crashes in which a vehicle crosses the median and strikes or is struck by a vehicle from the opposite direction, single vehicle crossover crashes were removed. To this end, a total of 309 multi-vehicle crossover median crashes were identified. TABLE 7 outlines the reductions undertaken to achieve the final crossover median crash total.

As presented in TABLE 6, segments of four Interstate and 16 other Wisconsin highways were examined to quantify crossover median crashes. TABLE 8 displays the distribution of crossover median crashes for each of the five years evaluated and shows that the total number of annual crossover median crashes steadily increased till 2005 and have been on decline since then. This decline could possibly be due to the installation of median barriers at the CMC hotspots identified in the earlier reports.TABLE 9 displays a breakdown of crashes within each county along the roadways reviewed. In instances where two, or even three, highways run concurrently, the commonly referenced highway was selected. The length of the highway is the total mileage of the divided highway without median barrier that was reviewed. TABLE 9 shows that USH 41 in Winnebago County has the highest crossover median crash rate per mile per year for roadways where more than one crossover median crash was observed.

TABLE 7Summary of Crossover Crash Total Calculations

Initial Selected Crossover Crashes	**1,899**
Object Crossover Crashes	-139
Tire Crossover Crashes	*(-108)*
Other Object Crossover Crashes	*(-31)*
Median Barrier Crossover Crashes (vehicle jumped existing barrier)	-88
Intentional Crossover Crashes (median u-turns or police evasion)	-16
Single Vehicle Crashes and Trailer Crossover	-1347
Final Selected Multi-Vehicle Crossover Crashes	**309**

TABLE 8Multi-Vehicle Crossover Median Crashes by Year

Year	**Crossover Median Crashes**
2001	30
2002	38
2003	45
2004	45
2005	71
2006	47
2007	33
Total	**309**

TABLE 9Crossover Median Crashes by Highway

Highway	County	I	P	B	Total	Highway Length (miles)	Crashes/ Year/ Mile
I-39	Columbia	11			11	25.82	0.06
	Dane	18	2	6	26	39.18	0.09
	Marathon	2	1		3	16.37	0.03
	Marquette	1			1	23.78	0.01
	Rock	17	4	5	26	25.42	0.15
	Waushara			1	1	18.88	0.01
I-43	Brown	3			3	22.33	0.02
	Manitowoc	3		1	4	33.9	0.02
	Ozaukee	8		3	11	27.54	0.06
	Rock	1			1	11.62	0.01
	Sheboygan	2			2	24.76	0.01
	Waukesha			1	1	16.22	0.01
I-90	La Crosse	5	1		6	20.28	0.04
	Monroe[1]	3			3	31.9	0.01
I-94	Columbia[1,2]	1			1	21.18	0.01
	Dane[2]	2		1	3	28.81	0.01
	Dunn	5		3	8	25.1	0.05
	Eau Claire	4		1	5	30.12	0.02
	Jackson	4			4	34.16	0.02
	Jefferson	7		2	9	24.55	0.05
	Juneau[1]	6	1		7	33.85	0.03
	Sauk[1]	1	1	1	3	15.4	0.03
	St. Croix	13	1	2	16	31.48	0.07
	Waukesha	3		1	4	24.65	0.02
USH 10	Portage	2		1	3	36.45	0.01
	Waupaca	1		1	2	29.59	0.01
	Winnebago	1			1	10.25	0.01
USH 12	Dane*	4		1	5	48.25	0.01
	Sauk	2			2	29.06	0.01
	Walworth	2			2	38.89	0.01
USH 14	Dane[3]			1	1	43.15	0.00
USH 18	Dane[3]	7		1	8	47.01	0.02
	Iowa			2	2	31.35	0.01
USH 41	Brown	15		1	16	25.12	0.09
	Dodge	2		1	3	6.98	0.06
	Fond du Lac	5		3	8	21.05	0.05
	Marinette	1			1	14.6	0.01
	Oconto	1			1	26.52	0.01
	Outagamie	5		2	7	18.63	0.05
	Washington	7	1		8	28.42	0.04
	Winnebago	19		8	27	26.07	0.15

TABLE 9TABLE 1Crossover Median Crashes by Highway (cont.)

Highway	County	I	P	B	Total	Highway Length (miles)	Crashes/ Year/ Mile
USH 45	Milwaukee	1			1	21.95	0.01
USH 51	Columbia	2			2	28.63	0.01
	Dane	2		1	3	41.25	0.01
	Lincoln			1	1	31.69	0.00
	Marathon[2]	2			2	32.42	0.01
USH 53	Eau Claire	1			1	21.45	0.01
	La Crosse	1		1	2	20.29	0.01
USH 141	Brown	2		1	3	20.47	0.02
USH 151	Columbia	2			2	6.8	0.04
	Dane[5]	3	1	2	6	51.88	0.02
	Dodge	2		1	3	26.43	0.02
STH 23	Sheboygan			2	2	22.61	0.01
STH 29	Brown	1			1	28.25	0.01
	Chippewa			1	1	39.04	0.00
	Clark			4	4	30.22	0.02
	Marathon	4		1	5	59.88	0.01
	Shawano	3		1	4	55.49	0.01
STH 30	Dane	1			1	3.28	0.04
STH 35	St. Croix	2		1	3	34	0.01
STH 54	Portage	2			2	27.71	0.01
STH 57	Door			1	1	53.69	0.00
	Sheboygan	1			1	24.17	0.01
STH 172	Brown	2			2	11.63	0.02
Total		228	13	68	309	1161.48	0.04

[1]*Crashes on concurrent sections of I-90/I-94 were counted as part of I-94.*
[2]*Crashes on concurrent sections of I-39/I-90, I-39/I-90/I-94, and I-39/USH 151 were counted as part of I-39.*
[3]*Crashes on concurrent sections of USH 12/USH 14 and USH 12/USH 18 were counted as part of USH 12.*
[4]*Crashes on concurrent sections of USH 41/USH 45 were counted as part of USH 41.*
[5]*Crashes on concurrent sections of USH 18/USH 151 were counted as part of USH 18.*

Crossover Median Crashes, Median Width, and ADT

The Wisconsin FDM guidelines use median width and ADT to determine if a median barrier is warranted on a particular roadway. Recall from Chapter 1, FIGURE 8that if a combination of median width and ADT intersect at the appropriate location in the figure, then a median barrier is warranted. To evaluate this relationship, the median width at each crossover median crash was plotted against the corresponding roadway ADT at the crash location, and presented onFIGURE 18. The median barrier standard from FIGURE 8 was then inserted into FIGURE 18to highlight which crashes occurred at locations that warrant a median barrier, as presented in FIGURE 19. Considering all 309 multi-vehicle crossover median crashes, 99 (32 percent) occurred at locations at which the Wisconsin FDM currently indicates that a median barrier is warranted. TABLE 10 lists the total number of crossover median crashes by median width.

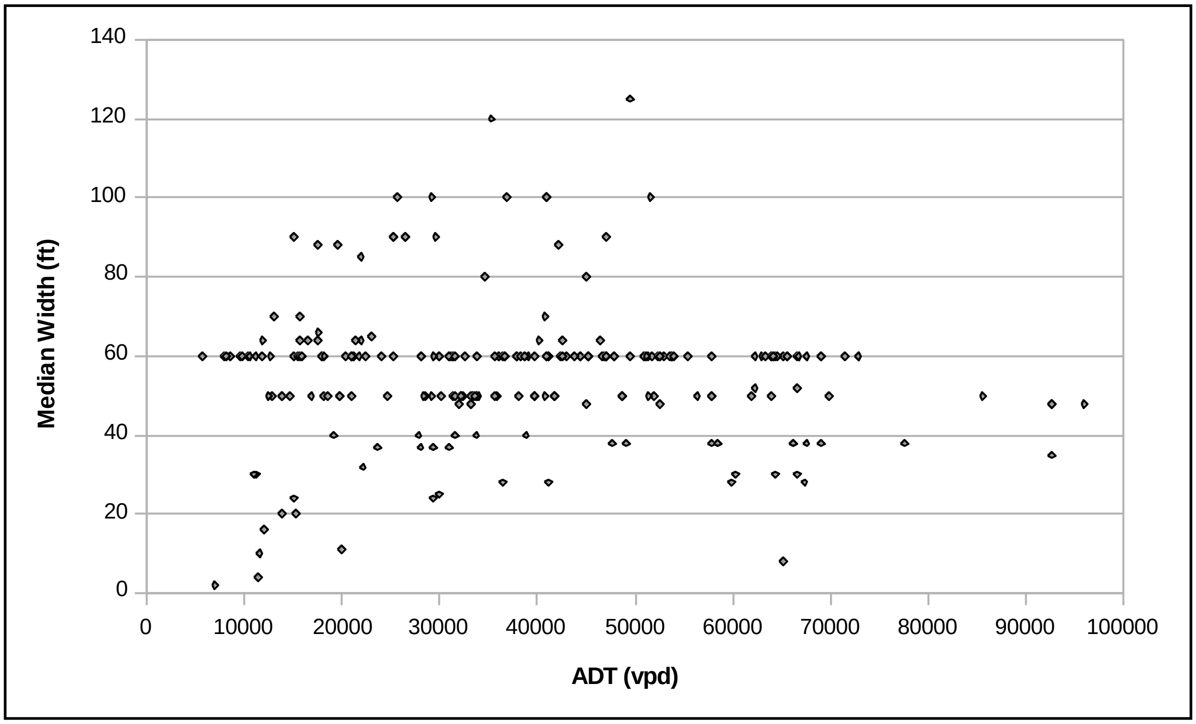


FIGURE 18Crossover Median Crashes

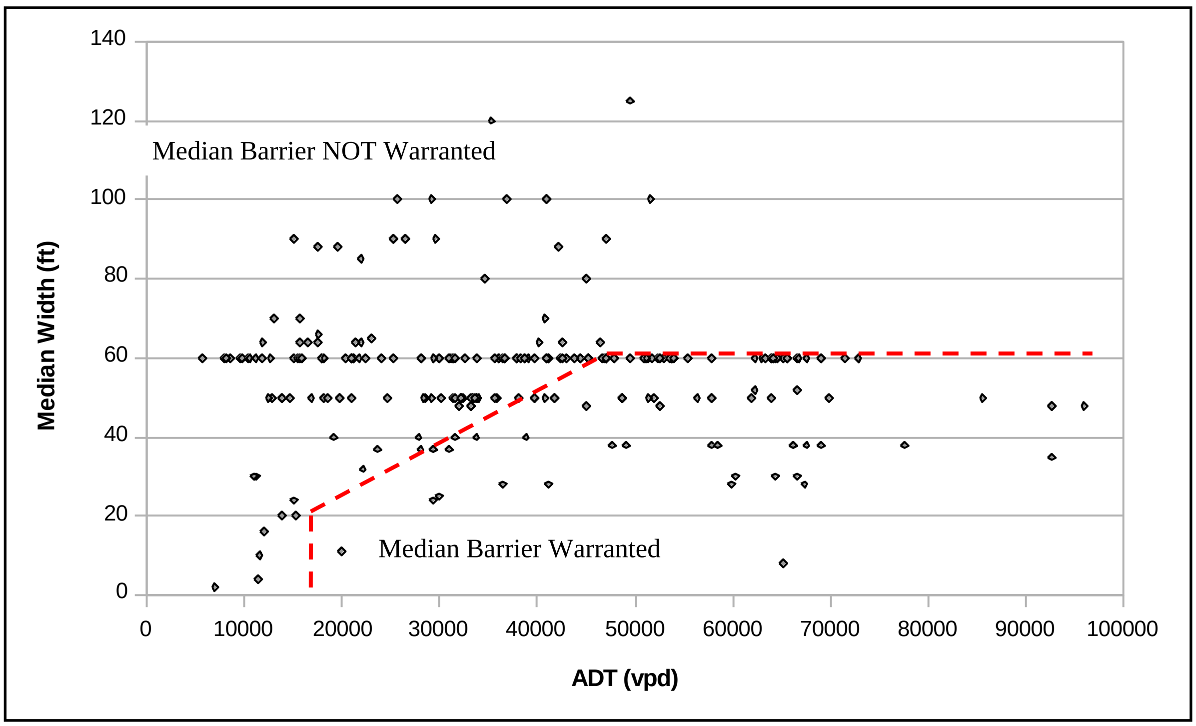


FIGURE 19Crossover Median Crashes with the FDM Median Barrier Standard

TABLE 10Crossover Median Crashes and Median Width

Median Width (ft)	Approximate Median Width Miles in Database (%)	Crossover Median Crashes
< 30	2.1	23(7.4%)
30 – 39	2.9	27(8.7%)
40 – 49	4.1	13(4.2%)
50 – 59	17.0	61(19.8%)
60 – 69	52.1	156(50.5%)
70 – 79	2.8	4(1.3%)
80 +	19.0	25(8.1%)
Total	100.0	309(100%)

In an attempt to derive a crossover median crash rate, crashes were grouped together based on their location. Crash segments were created by grouping crashes by county and then by selected sections of the selected highways that exhibited a consistent median width. These segments along with details regarding segment length, number of crossover median crashes, ADT, and crash rates are included at Appendix A. Two crash rates were calculated and compared against the median width of each segment.

The number of crossover median crashes per mile per year was calculated for each of the homogeneous median width segments. FIGURE 20displays the crash rate plotted against the median width for each segment. The least square line of best-fit included within FIGURE 20shows some decrease in crossover median crash frequency with increasing median width. The coefficient of determination (R^2) value of the least square line suggests that there is a relationship between median width and the number of crossover median crashes per mile per year. Nevertheless, the low R^2 value is a result of the wide distribution of values at the 50 and 60 foot median widths.

The number of crossover median crashes for each segment was normalized by vehicle miles traveled (VMT) to obtain a crossover median crash rate and plotted against the median width for each segment. FIGURE 21displays the 162 highway segments and their median width. The least square line of best-fit included with the figure suggests a decrease in the crossover median crash rate with increasing median width. The coefficient of determination (R^2) value of the least square line suggests that there is a relationship between these two variables. It is also noted that several highway segments exhibit noticeably high crossover median crash rates in spite of large median widths. These results are generally consistent with the findings of the research conducted by Noyce and McKendry (6*)*and Witte et al *(7).*

The number of crossover median crashes per mile per year was also plotted against the ADT of each segment as presented in FIGURE 22. As expected, the least square line of best-fit included with FIGURE 22 shows that the crossover median crash rate increases with increasing ADT. Unlike the median width relationships, the coefficient of determination (R^2) value of the least square line in this case suggests that there is a stronger relationship between the crash rate and ADT.

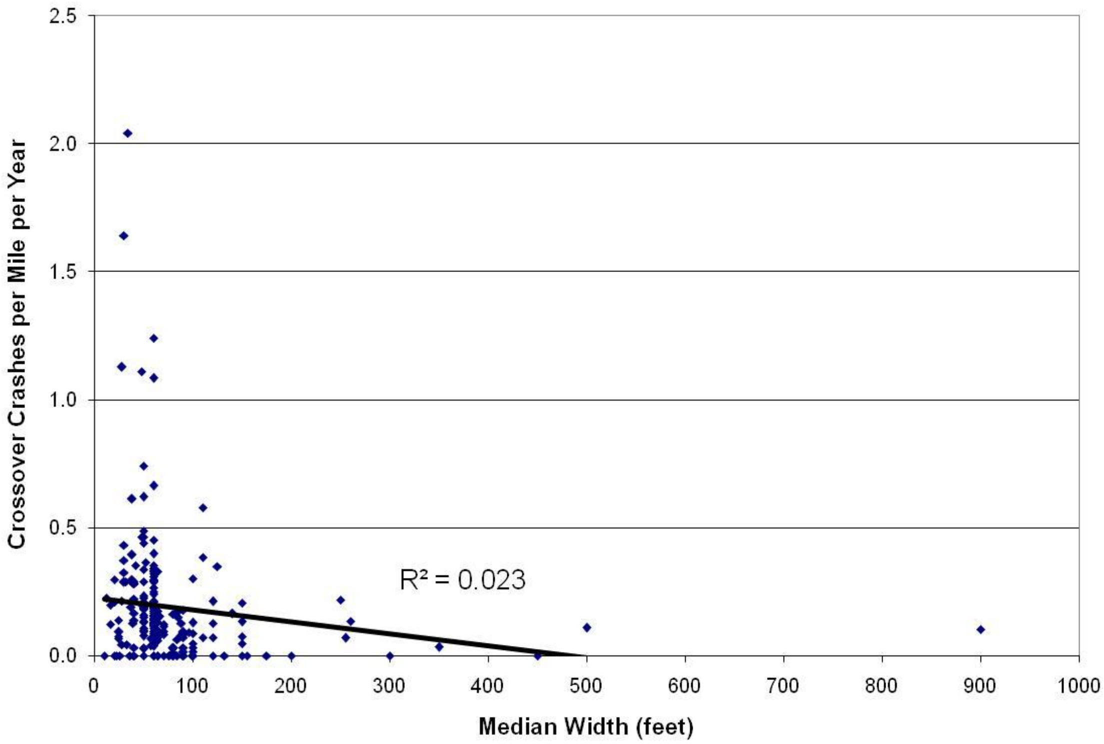


FIGURE 20Crossover Median Crash Rates (per Mile per Year) vs. Median Width

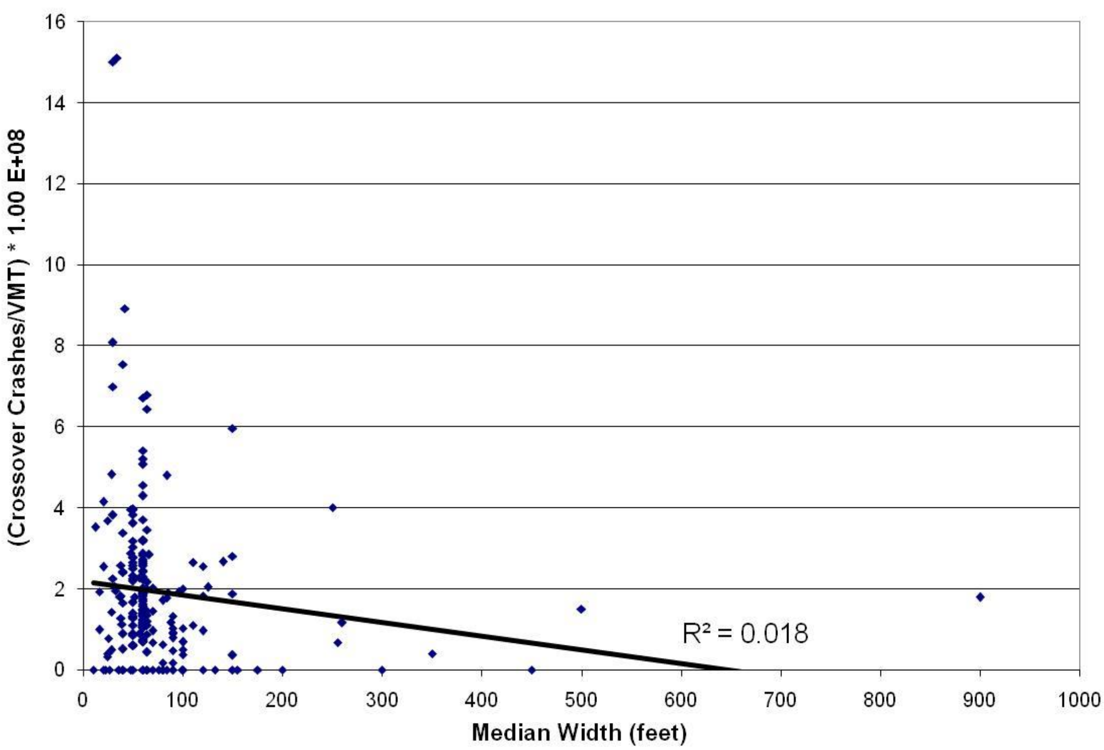


FIGURE 21Crossover Median Crash Rates (VMT) vs. Median Width

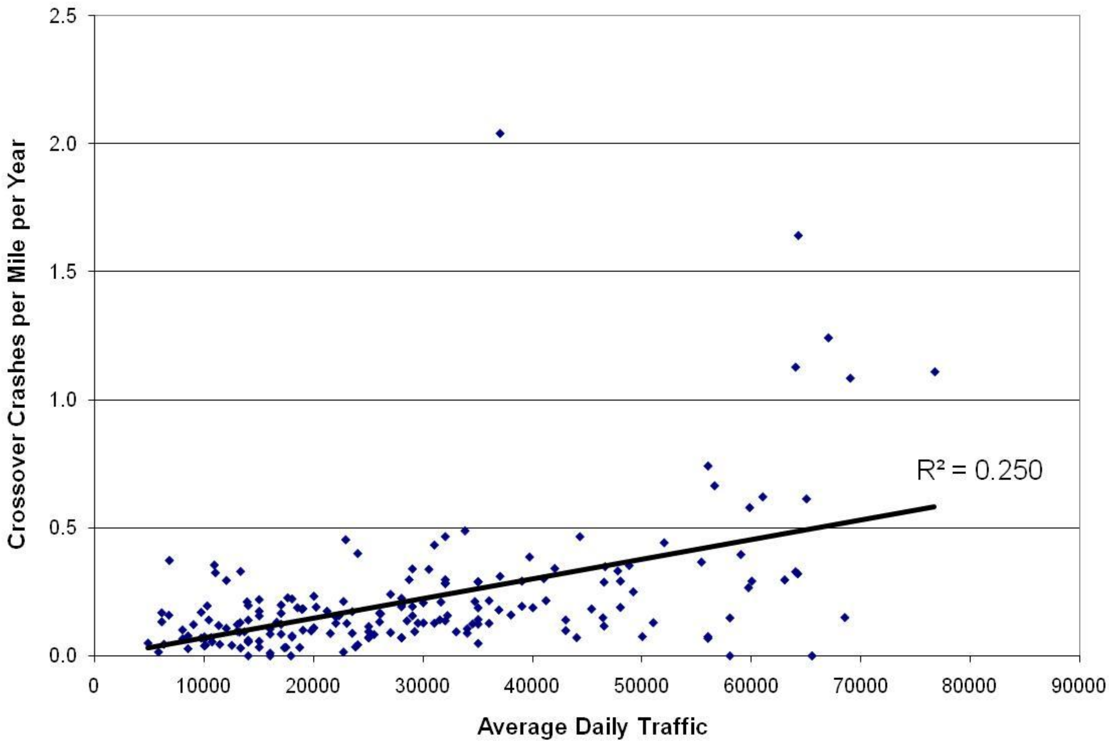


FIGURE 22Crossover Median Crash Rates (per Mile per Year) vs. Average Daily Traffic

Crossover Crash Vehicles and Crash Severity
The number of vehicles involved in each selected crash was obtained from each WMVAR form. TABLE 11 lists the number of crossover median crashes by the total number of vehicles involved. In addition, the type of crossover vehicle collision was obtained from a review of the same crash reports. Note that according to the Wisconsin definition, a vehicle has to cross the median and collide with an opposing vehicle to be considered a crossover median crash. TABLE 12 lists the number of crashes for each crossover crash vehicle type.

Crash severity was obtained from WisDOT data and the associated crash reports. Crashes were classified as one of three levels of severity: property damage only, personal injury, and fatal. TABLE 13 lists the number of crashes by crash severity. FIGURE 23displays the relationship between the total vehicles involved in a crossover median crash and the severity of a crash. As the number of vehicles involved in a crossover median crash increases, the severity of the injuries increases, particularly for fatalities. Fatal crashes make up 18 percent of two vehicle crossover crashes, increasing to 25 percent of all three vehicle crossover crashes, and 40 percent of all crossover crashes involving five or more vehicles. A complete data summary of crossover median crash severity related to total crash vehicles involved is presented in TABLE 14.

TABLE 11Crossover Median Crashes by Total Vehicles Involved

Total Vehicles Involved	Crashes
2	**217 (70.2%)**
Passenger Car – Passenger Car	121
Passenger Car – Truck	78
Truck – Truck	18
3	**76(24.6%)**
Passenger Car – Passenger Car	39
Passenger Car – Truck	33
Truck – Truck	4
4	**11 (3.6%)**
Passenger Car – Passenger Car	9
Passenger Car – Truck	2
5 or more	**5 (1.6%)**
Passenger Car – Passenger Car	5
Totals	**309 (100%)**

TABLE 12Crossover Median Crashes by Crash Vehicle Type

Crossover Crash Vehicle Type	Crashes
Multiple Vehicle Total	
Passenger Car – Passenger Car	174 (56.3%)
Passenger Car – Truck	113 (36.6%)
Truck – Truck	22 (7.1%)
Total Crossover Median Crashes	**309 (100%)**

TABLE 13Crossover Median Crashes by Crash Severity

Crash Severity	Crashes
Property Damage Only	61(19.7%)
Personal Injury	184(59.6%)
Fatal	64(20.7%)
Total	**309(100%)**

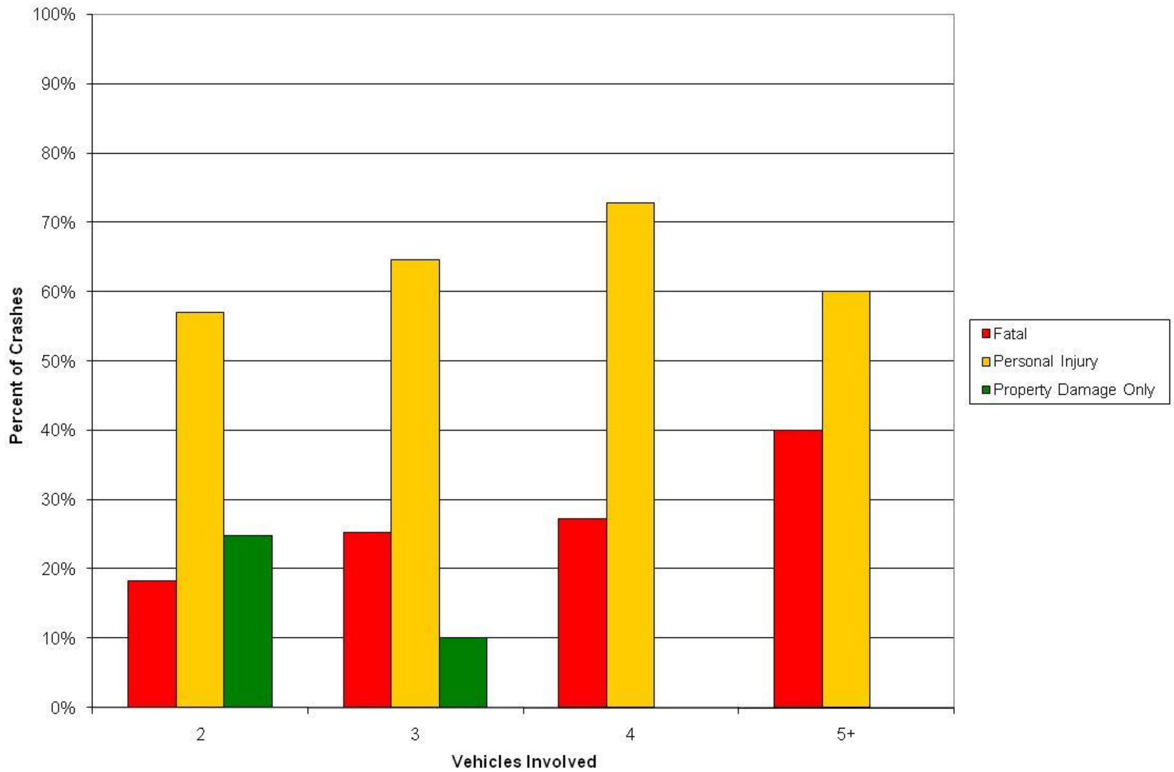


FIGURE 23Crossover Median Crash Severity by Total Vehicles Involved

TABLE 14Crossover Median Crash Severity by Total Vehicles Involved

Crash Severity / Total Vehicles	Property Damage Only	Personal Injury	Fatal	Totals
2	54 (24.9%)	123(56.7%)	40(18.4%)	**217**
3	7(9.2%)	50(65.8%)	19 (25.0%)	**76**
4	0 (0.0%)	8 (72.7%)	3 (27.3%)	**11**
5+	0 (0.0%)	3 (60%)	2 (40%)	**5**
Totals	61(19.7%)	184(59.5%)	64(20.7%)	**309**

The crossover crash vehicle type is also of interest in how it relates to crash severity. It was hypothesized that the collision of a passenger car with a truck would be more severe than two passenger cars impacting each other. FIGURE 24 displays the relationship between the crossover crash vehicle type and the severity of the crash.

Similar to the results found through examination of the total number of vehicles involved in a crossover median crash, fatal crashes significantly increase and property damage crashes noticeably decrease when a vehicle that has crossed the median makes impact with a vehicle traveling in the opposite direction. The percentage of injury and fatal crashes also increased when a passenger car impacted with a truck, as compared to a passenger car – passenger car collision. Motorcycle, trailer, and trailer – passenger car crashes were excluded from FIGURE

24 due to an insufficient number of crashes. A summary of the crossover median crash severity related to the crossover crash vehicle type is presented in TABLE 15.

Crossover Median Crash Extent

A review of the selected crash reports was performed to determine the extent of the crossover in each crossover median crash. Given the fact that all of the identified crashes involved a collision with an opposing vehicle, the extent was primarily a function of the final resting position of the crossing vehicle, but also considered the impact point of the colliding vehicles if this information was available. Crossover crashes were classified into one of three categories: partial, into, or beyond. 'Partial' crossover median crashes were those in which some portion of the vehicle had crossed the median and came to final rest having entered into at least the shoulder of the opposing roadway. 'Into' crossover median crashes were those in which the vehicle had crossed the median and came to final rest within the opposing roadway travel lanes. 'Beyond' crossover median crashes were those in which the vehicle had crossed the median and passed through the opposing lanes before coming to final rest beyond the outside shoulder of the opposing roadway. 'Partial' crossover crashes accounted for four percent of the 309 total vehicle crossover crashes, while 74 percent were 'into' crossover crashes and 22 percent were 'beyond' crossover crashes. TABLE 16 presents the data regarding the extent of crossover and the crossover crash vehicle type.

It was hypothesized that the average median width at which partial crossover median crashes occur would be larger than the average median width at which into or beyond crossover median crashes occurred. TABLE 17 presents the mean, median, and mode median width values for each of the crossover crash extents. The mean median width for crashes that crossed the median and entered only partially into the opposing direction travel lane is greater than that for crossover crashes in which the vehicle traveled into or beyond the opposing direction travel lane. There is no difference recorded between median and mode average median widths for each of the crossover median crash extents due to the number of observations that occurred at locations with a median width of 60 feet.

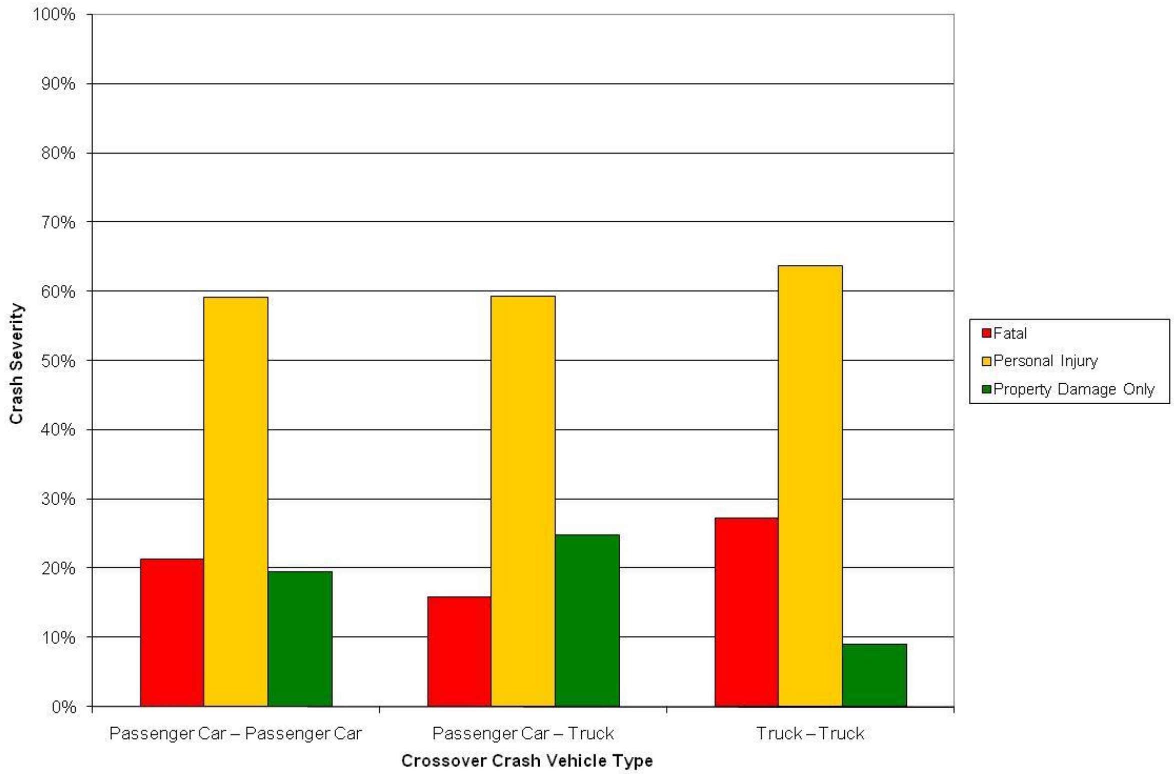


FIGURE 24Crossover Median Crash Severity by Crossover Crash Vehicle Type

TABLE 15Crossover Median Crash Severity by Crash Vehicle Type

Crash Severity / Crossover Crash Vehicle Type		Property Damage Only	Personal Injury	Fatal	Totals
Multiple Vehicles Type	Passenger Car – Passenger Car	37	103	34	**174**
	Passenger Car – Truck	18	67	28	**113**
	Truck – Truck	6	14	2	**22**
Totals		61	184	64	**309**

TABLE 16Crossover Median Crash Crossover Extent

Crossover Extent / Crossover Crash Vehicle Type	Partial	Into	Beyond
Multiple Vehicle Type Crashes			
Passenger Car – Passenger Car	7(53.8%)	127(55.7%)	40(58.8%)
Passenger Car – Truck	6 (46.2%)	83(36.4%)	24(35.3%)
Truck – Truck	0 (0.0%)	18(7.9%)	4(5.9%)
Totals	**13(100%)**	**228(100%)**	**68 (100%)**

TABLE 17Median Widths by Crossover Median Crash Extent

Median Width	Crossover Extent		
	Partial	**Into**	**Beyond**
Count	**13**	**228**	**68**
Mean	63	57	57
Median	60	60	60
Mode	60	60	60
Minimum	37	2	16
Maximum	100	730	100

The percentage of crashes recorded for each crossover median crash extent has been compared for a number of different median width categories in FIGURE 25.

FIGURE 26 displays the crash severity based on the extent of the crossover undertaken by the crash vehicle. Personal injury crashes that came to final rest in the opposing roadway begin to separate from those crashes that partially entered the opposing roadway and those that came to final rest beyond the outside shoulder of the opposite roadway. For fatal crashes, those that came to final rest in the opposing roadway make up over 75 percent of all fatal crashes.

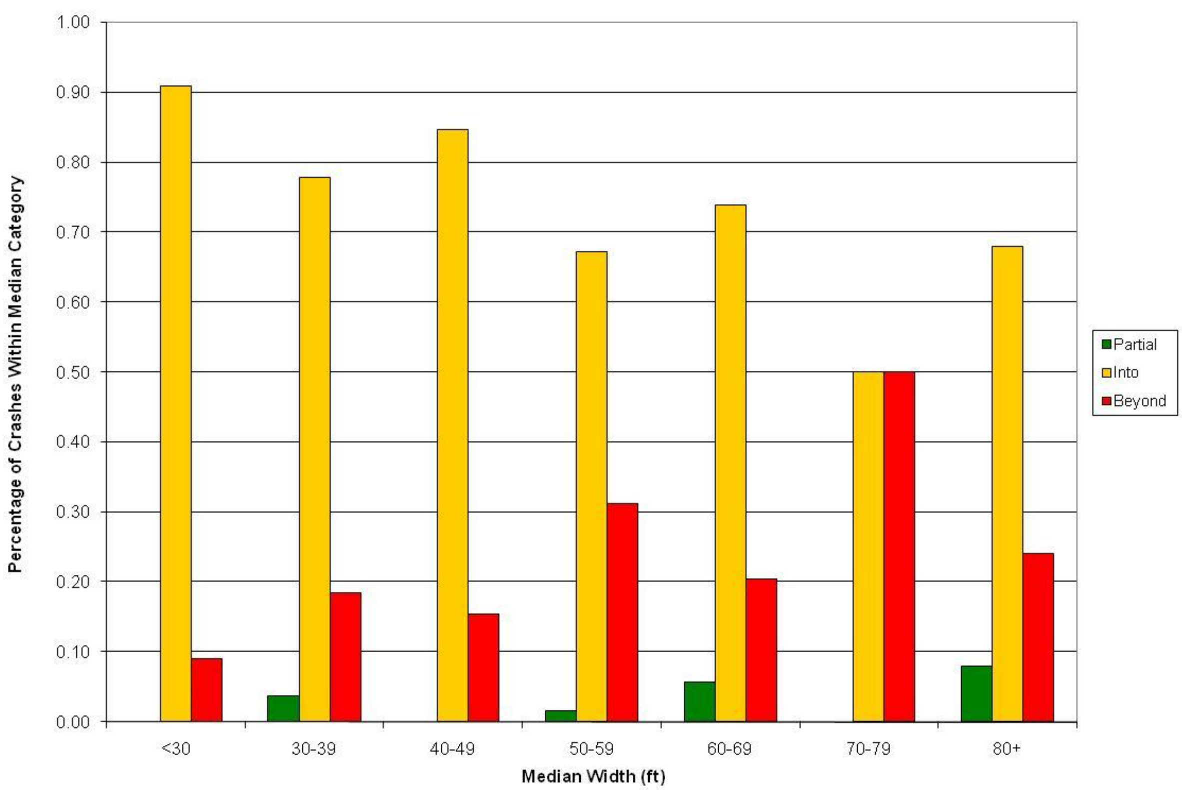


FIGURE 25Crossover Median Crash Extent by Median Width

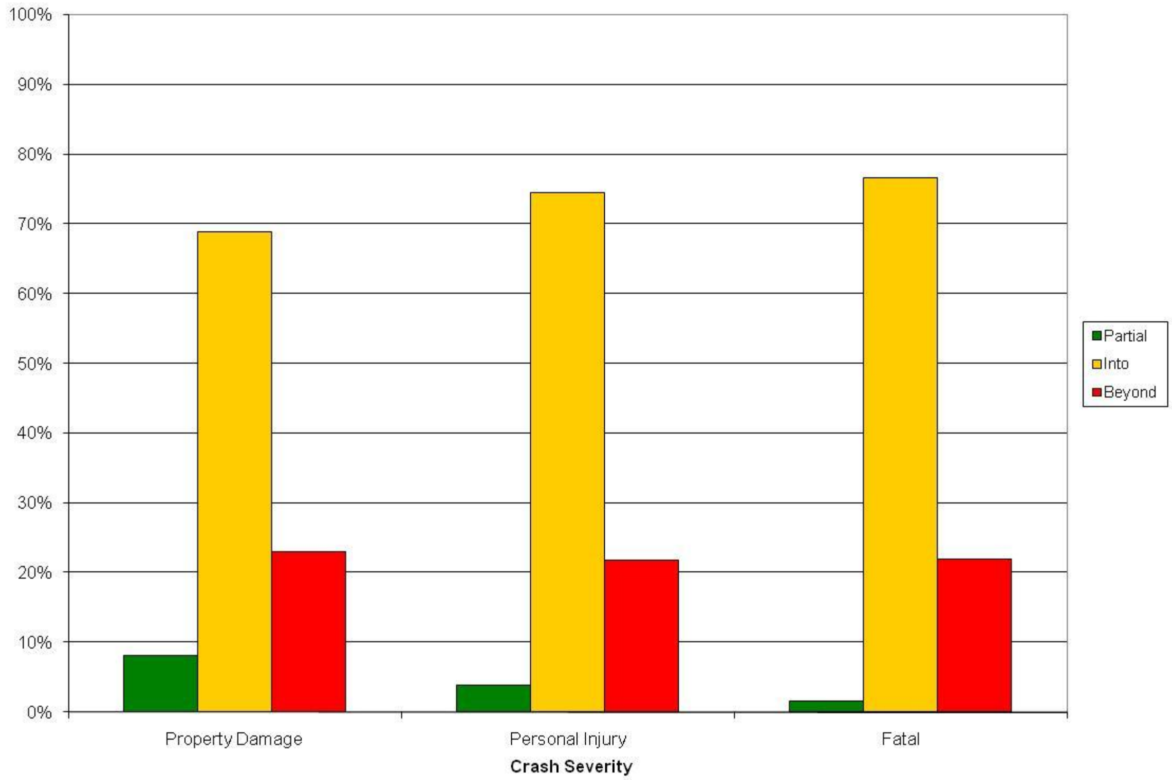


FIGURE 26Crossover Median Crash Crossover Extent by Crash Severity

When analyzing crashes that are outside the crossover median crash definition, such as single vehicle crashes, the extent provides additional information. Discussion of this variable is included later in the report.

Vehicle Action at Crash

To better understand what maneuvers each driver was performing before a crossover median crash occurred, it is important to know the vehicle's actions at the time of the crash. Information regarding each vehicle's actions at the time of the crash was obtained from WisDOT data and the associated crash reports. As shown in FIGURE 27, the majority of crashes involved a vehicle going straight on the road at the time of the crash, accounting for approximately 74 percent of all crossover median crashes. The next most common actions, changing lanes and slowing/stopping, represented only ten percent and four percent of the total number of crossover median crashes, respectively.

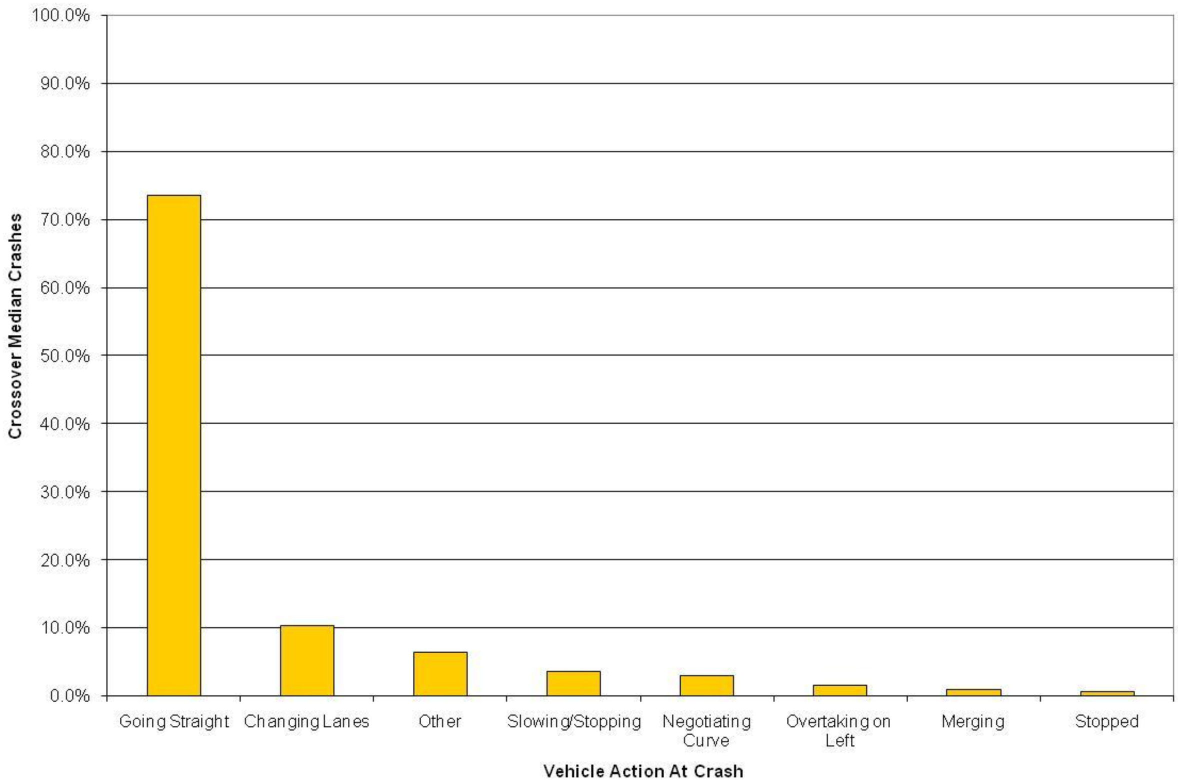


FIGURE 27Vehicle Action at Crash

These data suggests that the initiation of crossover median crashes are rarely related to the geometry of the roadway, but rather to some combination of driver inattention or unexpected change in the driving environment; i.e., stopped traffic ahead, or low surface friction (ice) that caused a loss of control of the vehicle. Driving maneuvers such as negotiating a curve, changing lanes, merging, or passing a vehicle do not seem to contribute significantly to the crossover median crash total. TABLE 18 presents a breakdown of the actions performed prior to the 227 crossover median crashes.

TABLE 18Vehicle Action at Crash

Vehicle Action	Crossover Median Crashes
Going Straight	227(73.5%)
Changing Lanes	32 (10.4%)
Other	20 (6.5%)
Slowing/Stopping	11(3.6%)
Negotiating Curve	9 (2.9%)
Overtaking on Left	5 (1.6%)
Merging	3 (1.0%)
TOTAL	227 (100%)

Crossover Median Crash Initial Event

A review of the selected crash reports was performed to determine the most likely initial event leading to each crossover median crash. Even though a variety of factors may have contributed to the outcome, what was sought was the primary or initial factor that generated all the events that followed. Crashes were classified into one of six categories: lost control on dry pavement, lost control due to weather, vehicle collision, barrier, signpost, or other.

Lost control on dry pavement crashes were crossover median crashes in which the initial loss of control event was on dry pavement, resulting in the vehicle traversing the median and entering the opposing roadway. This loss of control categorized a wide range of possibilities, including such things as avoidance maneuvers, distractions, blackouts, and inattentiveness. Lost control due to weather crashes were crossover crashes where, regardless of other actions contributing to the crash, weather and associated pavement conditions were cited in the crash report to be a contributing factor. Weather issues also relate to the condition of the roadway and include snow, ice, and wet roads from rain. Vehicle collision crossover crashes were crashes in which an impact with a vehicle traveling in the same direction precipitated a vehicle to traverse the median and enter the opposing roadway. Barrier crossover crashes were crashes in which a vehicle initially struck a roadway barrier, which caused the vehicle to traverse the median and enter the opposing roadway. Signpost crossover crashes were crashes in which a vehicle struck the post of a sign or delineator, causing the driver to lose control, and traverse the median. FIGURE 28 displays the breakdown of the initial causes for the crossover median crashes, excluding those crashes in which an object, not a vehicle, traversed the median.

The two largest initial causes for crossover median crashes, lost control on dry pavement and loss of control due to weather, make up a significant amount of the total number of crossover crashes. Of the 309 vehicle crossover crashes, 274, or 89 percent of those crashes were related to these two causes. Weather related crashes could be broken down into the road conditions ice, snow, and wet. TABLE 19 presents a breakdown of the causes for all 309 selected crossover median crashes.FIGURE 29 displays the breakdown of weather-caused crossover median crashes.

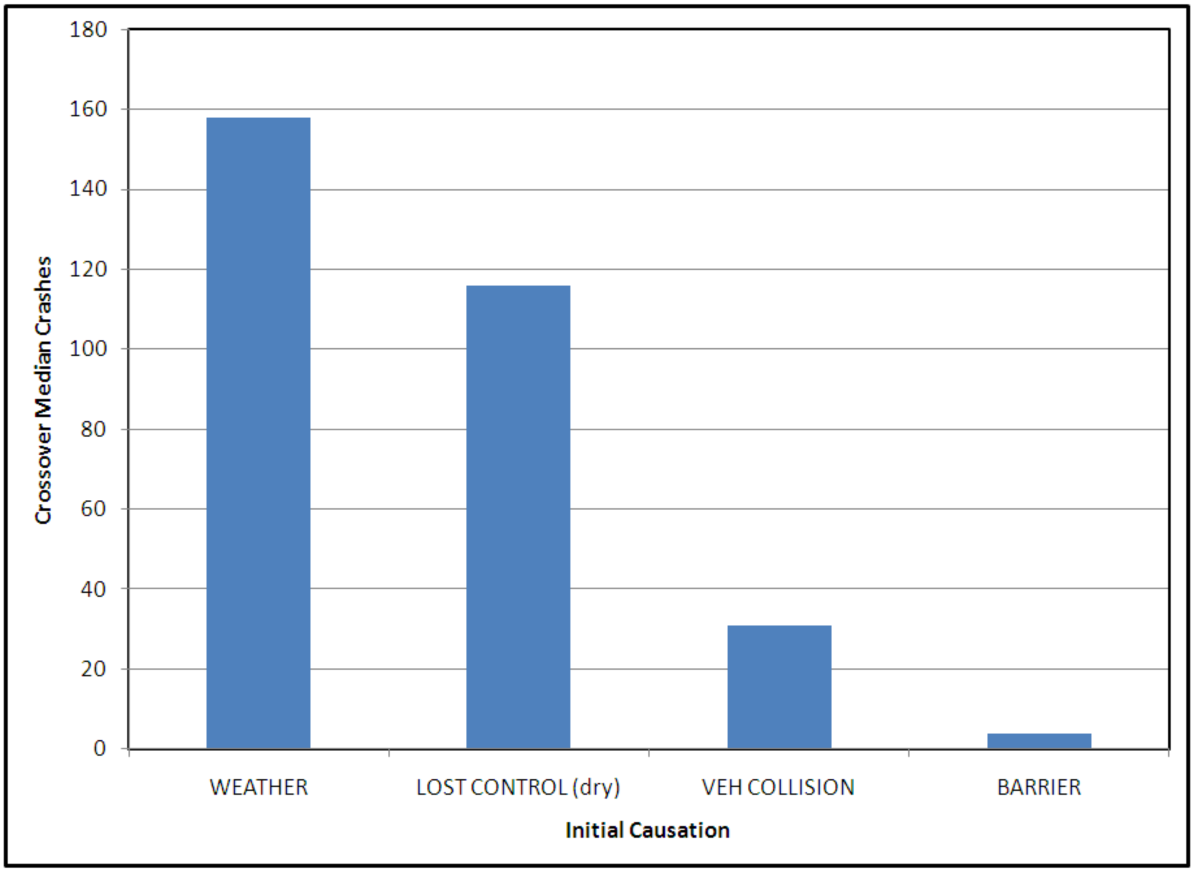


FIGURE 28Crossover Median Crashes by Initial Causes

TABLE 19Crossover Median Crashes by Initial Causes

Initial Cause of Crash	**Crashes**
Lost Control Due to Weather	158 (51.1%)
Snow	*72*
Ice	*49*
Wet	*37*
Vehicle Collision	31(10.1%)
Lost Control on Dry Pavement	116 (37.5%)
Barrier	4 (1.3%)
Total Crossover Crashes	**309 (100%)**

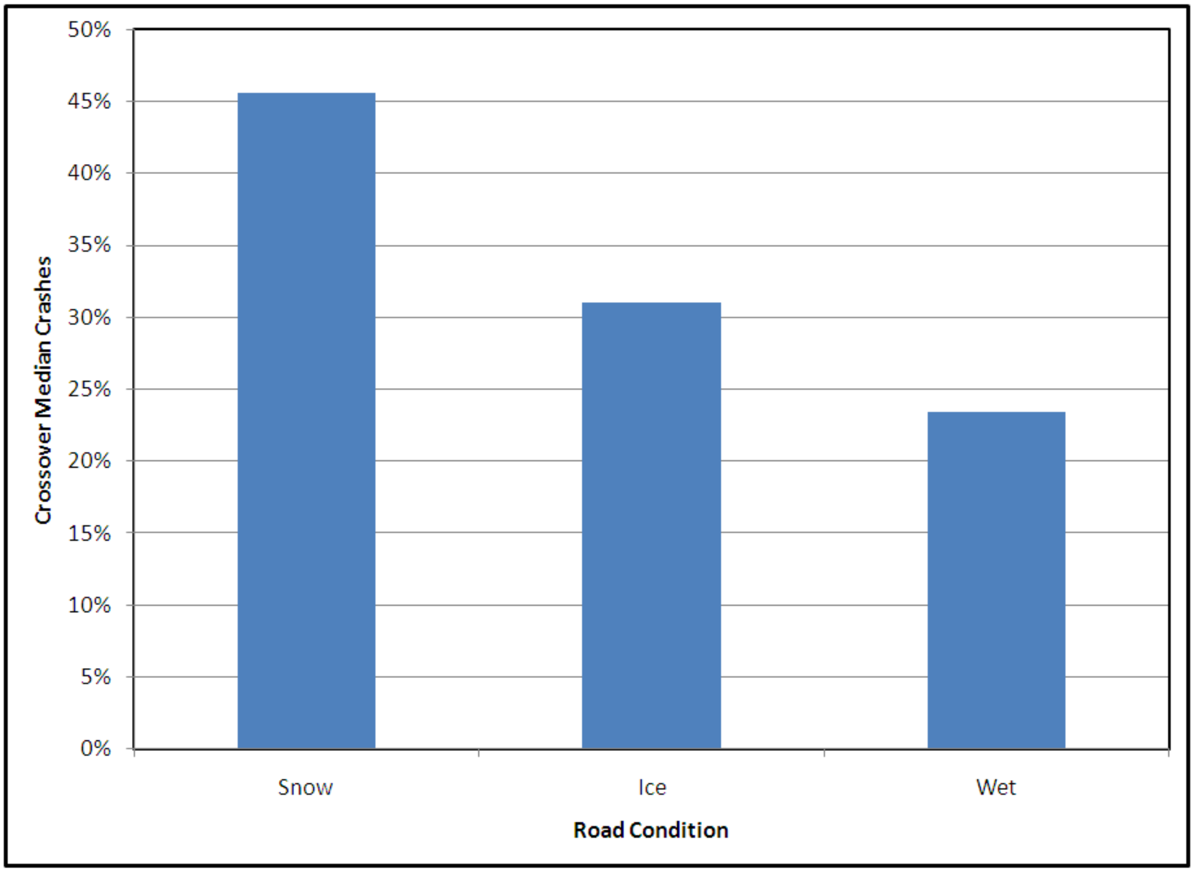


FIGURE 29Weather-Related Crossover Crash Breakdown

To understand the different types of crossover crashes and what leads to the most severe crashes, the four initial causations were examined to see how many crashes of each cause were property damage only, personal injury, and fatal. FIGURE 30displays the results. Weather is the dominant cause of property damage only crossover crashes, while lost control and weather represent approximately the same amount of personal injury crossover crashes. However, for fatal crashes, loss of control on dry pavement is the dominant initial action that causes a crossover median crash. TABLE 20 presents full results of the initial causation for each crossover median crash according to crash severity. Explanations for the less frequent weather-caused fatal crossover crashes are not clear as no measure of exposure or normalization by dry roads versus wet/snow/ice road were completed. It can be hypothesized that the infrequent number of days in which roads are not dry, the change in driver behavior with ice, snow, or wet road conditions, and simply fewer vehicles on the roadway during inclement weather are contributing factors.

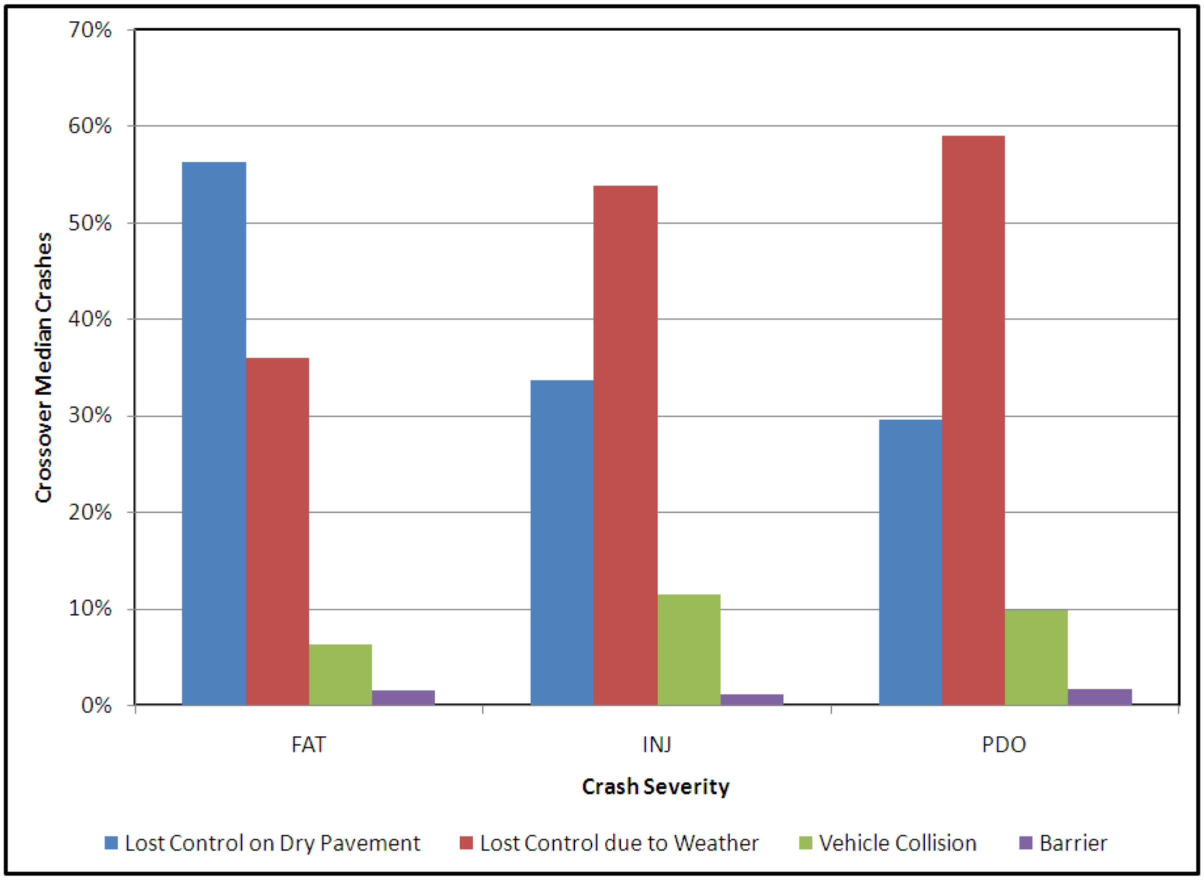


FIGURE 30Crossover Crash Initial Causation by Crash Severity

TABLE 20Crossover Crash Initial Causation by Crash Severity

Initial Cause of Crash	Property Damage Only	Personal Injury	Fatal
Lost Control on Dry Pavement	18 (29.5%)	62 (33.7%)	36 (56.3%)
Lost Control Due to Weather	36 (59%)	99 (53.8%)	23 (35.9%)
Ice	*12*	*30*	*7*
Snow	*16*	*47*	*9*
Wet	*8*	*22*	*7*
Vehicle Collision	6 (9.8%)	21 (11.4%)	4 (6.3%)
Barrier	1 (1.6%)	2 (1.1%)	1 (1.6%)
Total Vehicle Crossovers	**61 (100%)**	**184 (100%)**	**64 (100%)**

Crossover Crash Demographics

All demographic information related to the selected crossover median crashes were obtained from WMVAR data. First, the dates of the crossover crashes were grouped together by month. FIGURE 31 displays a month-by-month breakdown of the selected crossover median crashes. Though some months showed fluctuation from year to year, the five year averages show a definite pattern of an increase in crossover crashes during winter weather months, December to April. This finding appears to be consistent with previous results as 77percent of the crossover crashes caused by weather were due to either ice or snow covered roadways, conditions that are most prevalent during that five month period.

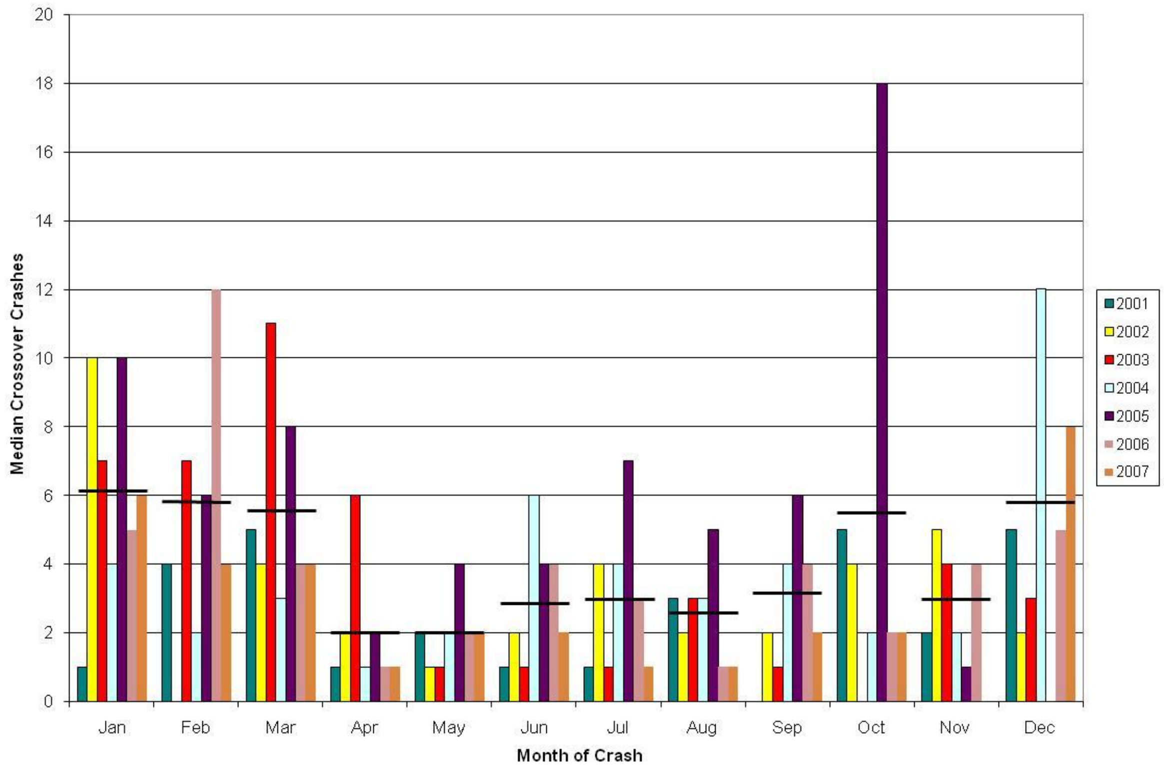


FIGURE 31Crossover Crashes by Month

TABLE 21 presents the crossover crashes by month according to the initial cause of the crash.Approximately 72percent of the weather-caused crossover crashes occurred during the five month period from December to April. The fact that more crossover median crashes occurred during the winter contrasts with average annual daily traffic (AADT) data which indicates that more driving occurs in Wisconsin during the summer months. Presented in TABLE 22, 2003 AADT for five randomly selected Wisconsin highway sections was averaged to generate a percentage of AADT for each month (*44*). As illustrated in FIGURE 32, AADT for Wisconsin peaks during August, with the lowest volumes occurring during from January through March. This contrasts with the fact that three of the four highest months on average for crossover median crashes are January, March, and October.

TABLE 21Monthly Crossover Crashes by Initial Causation

Month	Lost Control on Dry Pavement	Lost Control Due to Weather	Vehicle Collision	Barrier
January	8[1]	32	3	0
February	9	20	6	0
March	7	31	1	0
April	5	8	1	0
May	11	3	0	0
June	13	1	5	1
July	11	6	4	0
August	13	2	3	0
September	11	4	4	0
October	14	17	1	1
November	5	11	2	0
December	9	23	1	2
Totals	**116**	**158**	**31**	**4**

[1] Total number of crashes

TABLE 222003 ADT for Selected Wisconsin Highways

	Dane I-39/I-90		Columbia I-39/ I-90/I-94		Dodge USH 151		Fond Du Lac USH 41		Brown USH 41		WI Avg.
	ADT	%	ADT	%	ADT	%	ADT	%	ADT	%	%
Jan	64,894	6.64	42,382	6.31	13,759	6.85	26,195	6.76	33,912	7.36	**6.79**
Feb	69,409	7.11	44,703	6.65	14,214	7.08	27,407	7.08	35,161	7.63	**7.11**
Mar	72,120	7.38	48,049	7.15	15,215	7.58	28,248	7.29	36,042	7.82	**7.45**
Apr	96,664	9.90	51,196	7.62	16,258	8.09	30,141	7.78	36,025	7.82	**8.24**
May	82,319	8.43	56,891	8.47	16,806	8.37	33,240	8.58	37,663	8.17	**8.40**
Jun	86,139	8.82	64,851	9.65	17,922	8.92	34,923	9.02	40,101	8.70	**9.02**
Jul	91,647	9.38	72,488	10.79	18,011	8.97	37,280	9.63	40,405	8.77	**9.51**
Aug	93,980	9.62	72,918	10.85	19,014	9.47	38,911	10.05	43,470	9.44	**9.88**
Sep	83,144	8.51	58,452	8.70	17,638	8.78	34,247	8.84	40,280	8.74	**8.72**
Oct	83,160	8.51	57,068	8.49	18,249	9.09	33,682	8.70	41,254	8.95	**8.75**
Nov	78,363	7.02	54,379	8.09	17,203	8.57	32,695	8.44	38,784	8.42	**8.31**
Dec	74,848	7.66	48,686	7.24	16,563	8.25	30,315	7.83	37,615	8.16	**7.83**

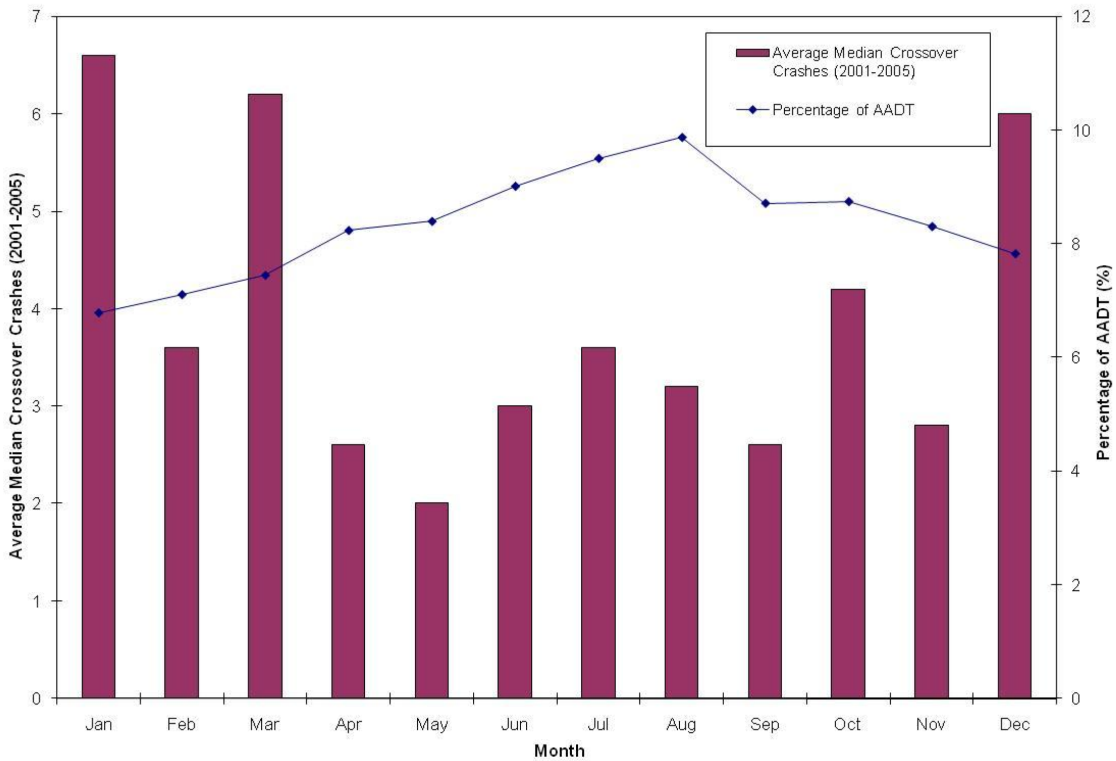


FIGURE 32Monthly Crossover Median Crashes and ADT

The age of drivers involved in crossover crashes were grouped into ten-year segments, beginning with the youngest drivers involved – fifteen year-olds – up to a final segment of drivers 80 years of age or older. FIGURE 33 displays the results of the 309crossover crashes.

The single largest cohort was drivers aged 15 to 24 representing approximately 33 percent of crossover median crashes. Numbers did not drop off sharply at the age of 25, but they began a steady decline. TABLE 23 presents the breakdown of crossover crashes by the age of the driver. When examined as a rate, the significance of the age of the driver in a crossover crash becomes more pronounced. Using 2007licensed driver data from WisDOT's 2007Department of Motor Vehicles Facts and Figures, the number of crossover median crashes by age were calculated as a rate of the total drivers for each age bracket (*45*). FIGURE 34 displays the results, and shows that younger drivers are more likely to be involved in a crossover median crash. The crossover crash rate of drivers under the age of 25 is almost twice as high as drivers aged 25 to 34, and three to four times higher than drivers aged 45 and over. There is a small spike in the crossover rate for drivers aged 75 to 84. The small amount of driving done by licensed drivers aged 85 and over explains the reason the spike in crossover crash rate does not continue. TABLE 24 presents the crash rates by age.

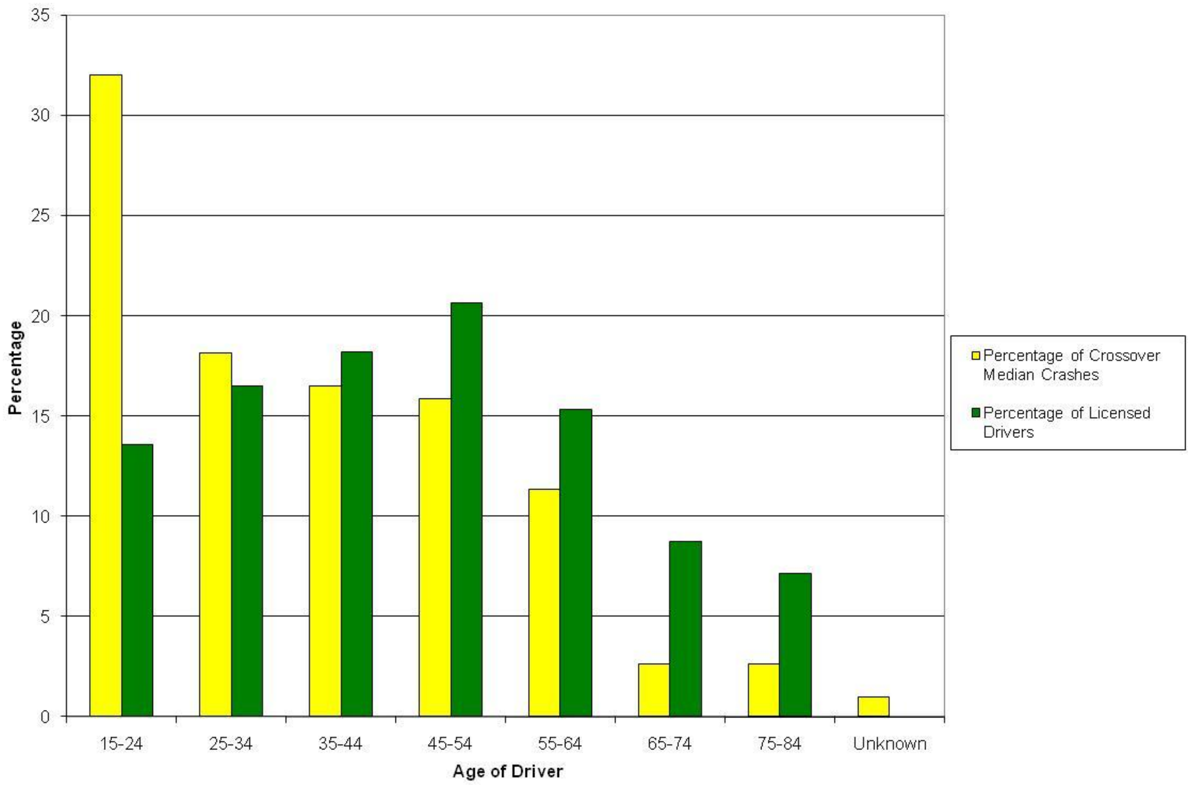


FIGURE 33Crossover Crashes by Age of Driver

TABLE 23Crossover Crashes by Age of Driver

Age of Driver	**Crossover Median Crashes**		**Licensed Drivers (2007)**	
	Frequency	Percent	Frequency	Percent
15-24	99	32.0	536,440	13.5
25-34	56	18.1	651,781	16.4
35-44	51	16.5	720,944	18.2
45-54	49	15.9	816,251	20.6
55-64	35	11.3	605,373	15.2
65-74	8	2.6	345,736	8.7
75-84	8	2.6	281,557	7.1
Unknown	3	1.0	-	-
Total	**309**	**100.0**	**3,958,082**	**100**

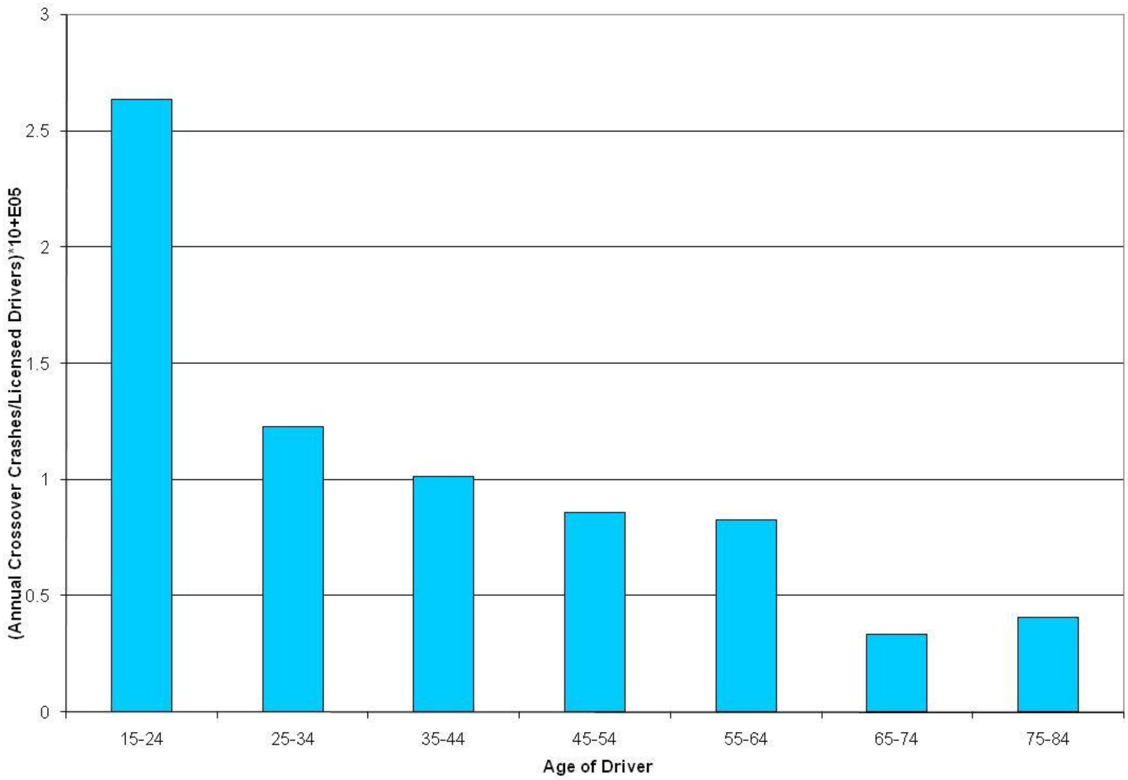


FIGURE 34Crossover Crash Rate by Age of Driver

TABLE 24Annual Crossover Crash Rate by Age of Driver

Age of Driver	**Crashes**	**WI Licensed Drivers**	**Annual Crossover Crash Rate (* 1.00 E+05)**
15-19	30	**207859**	2.06
20-24	69	328581	3.00
25-34	56	651,781	1.23
35-44	51	720,944	1.01
45-54	49	816,251	0.86
55-64	35	605,373	0.83
65-74	8	345,736	0.33
75+	8	281,557	0.41
Unknown	3	N/A	N/A
Total	**309**	**3,958,082**	1.12

Alcohol was marked as a factor on the WMVAR for 17crossover median crashes, or 5.5 percent of all the selected crossover median crashes. The extent of the alcohol involvement in each crash is unclear. Among the alcohol-related crossover median crashes, the following facts were found:

- Initial Cause of Crash
  - 52.9 percent were lost control crossover crashes
  - 29.4 percent weather-related crossover crashes
  - 11.7 percent were vehicle collision crossover crashes
  - 5.9 percent were barrier crashes
- Crash Vehicle Type
  - 64.7percent passenger car – passenger car crashes
  - 29.4 percent passenger car – truck crashes
  - 5.9 percent truck – truck crash
- Crash Severity
  - 11.8 percent were property damage only crashes
  - 52.9 percent were personal injury crashes
  - 35.3 percent were fatal crashes
- Age of Driver
  - 23.5 percent were crashes with drivers under the age of 25
  - 76.5 percent were crashes with drivers under the age of 35

Mapping Crossover Median Crashes

It is important to locate the crossover median crashes to more easily identify “hotspots,” i.e., locations where a significantly high amount of crossover median crashes are occurring in close proximity to one another. All 309crossover median crashes were plotted on the Wisconsin state highway network, illustrated in FIGURE 35. FIGURE 36 through FIGURE 42present the crossover median crashes for each studied year.

Crossover Median Crash Warrants

Examination of the map reveals several counties where crash clusters have formed. Using the selected crash rate criteria warranting additional analysis of 0.5 injury-causing crossover median crashes per mile per year and at least three injury-causing crossover median crashes during a five year period, FIGURE 43presents the crossover median crashes that meet this benchmark. In all, 14 roadway segments met the above criteria as summarized in TABLE 25.

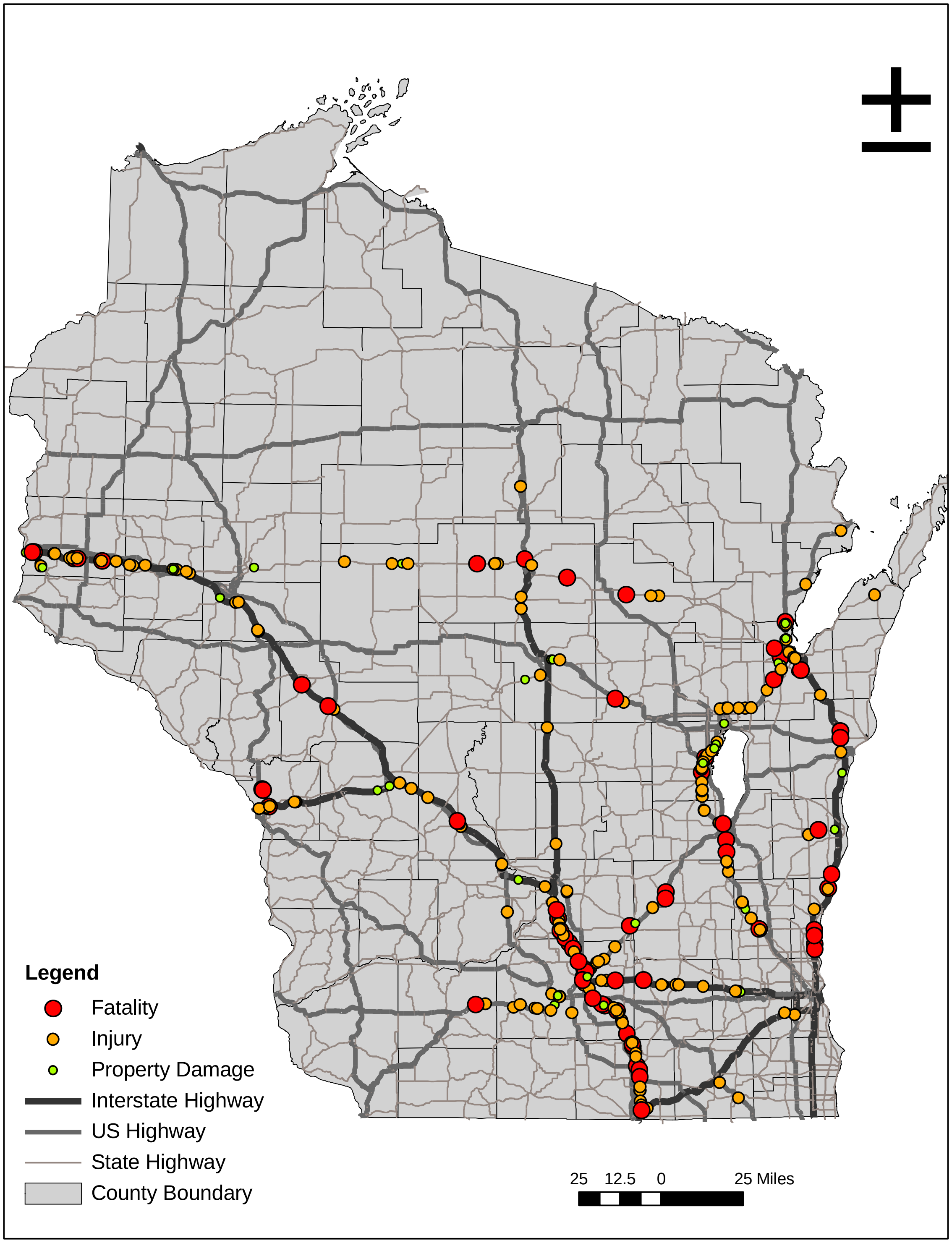


FIGURE 35Crossover Median Crashes (2001 – 2007)

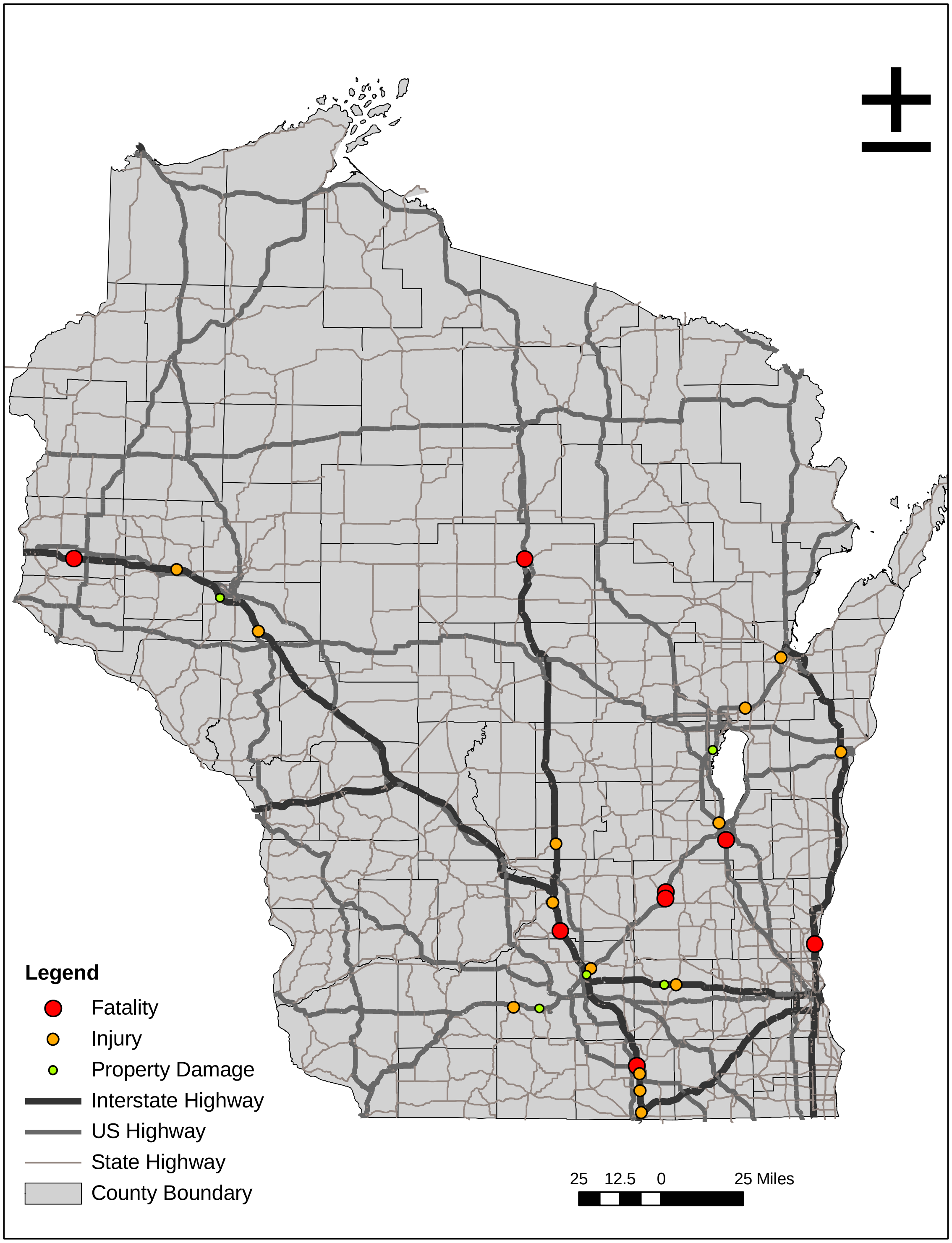


FIGURE 362001 Crossover Median Crashes

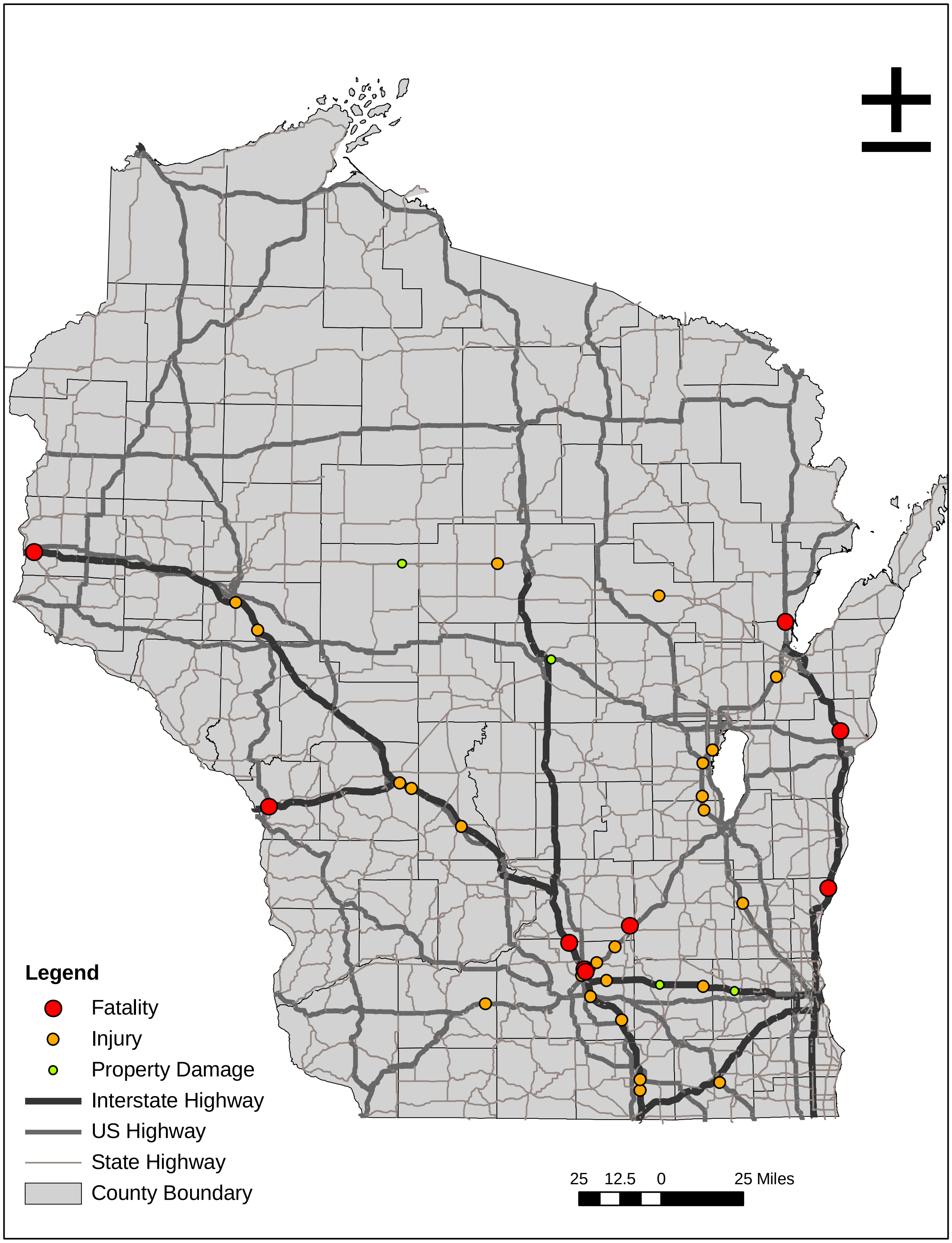


FIGURE 372002 Crossover Median Crashes

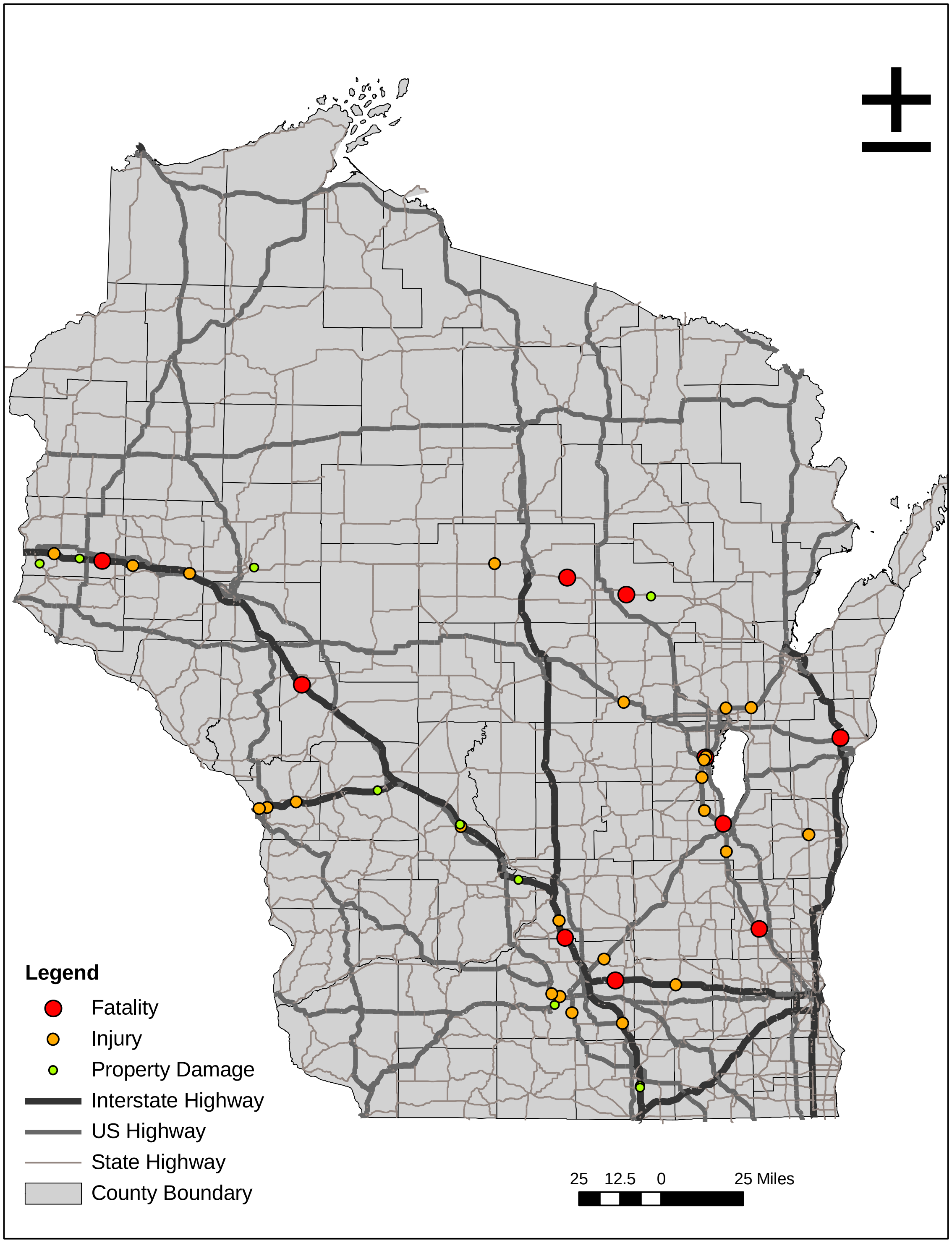


FIGURE 382003 Crossover Median Crashes

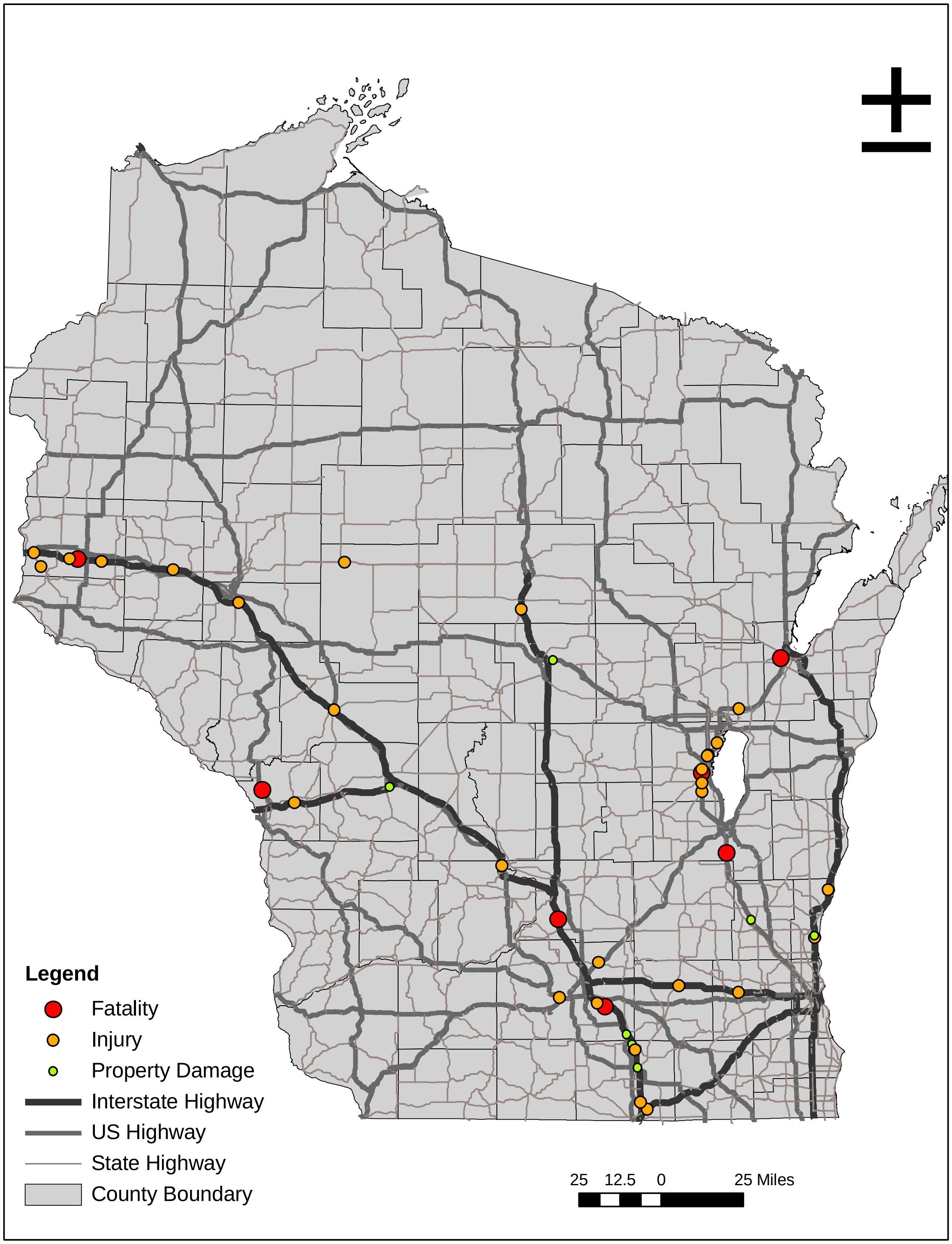


FIGURE 392004 Crossover Median Crashes

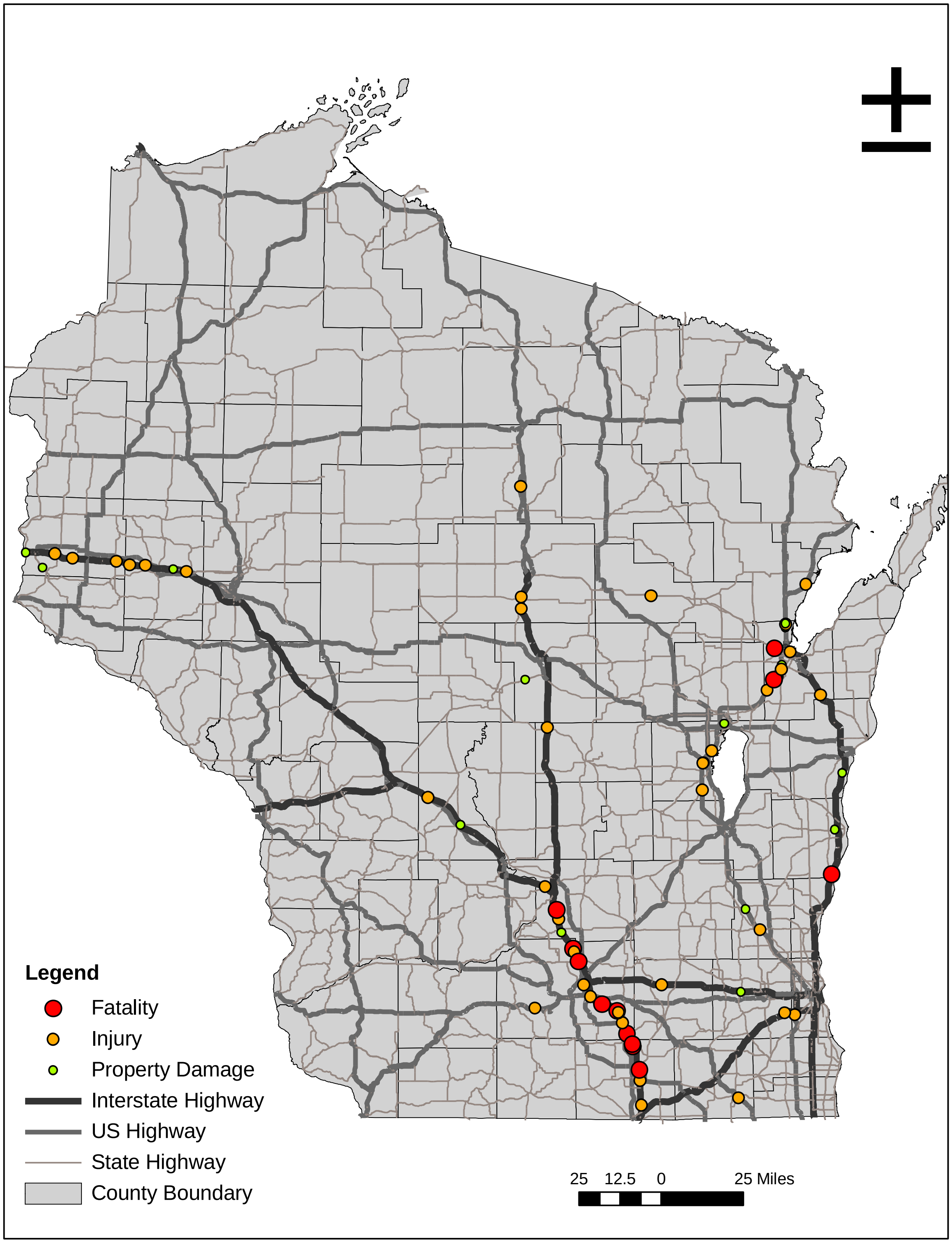


FIGURE 402005 Crossover Median Crashes

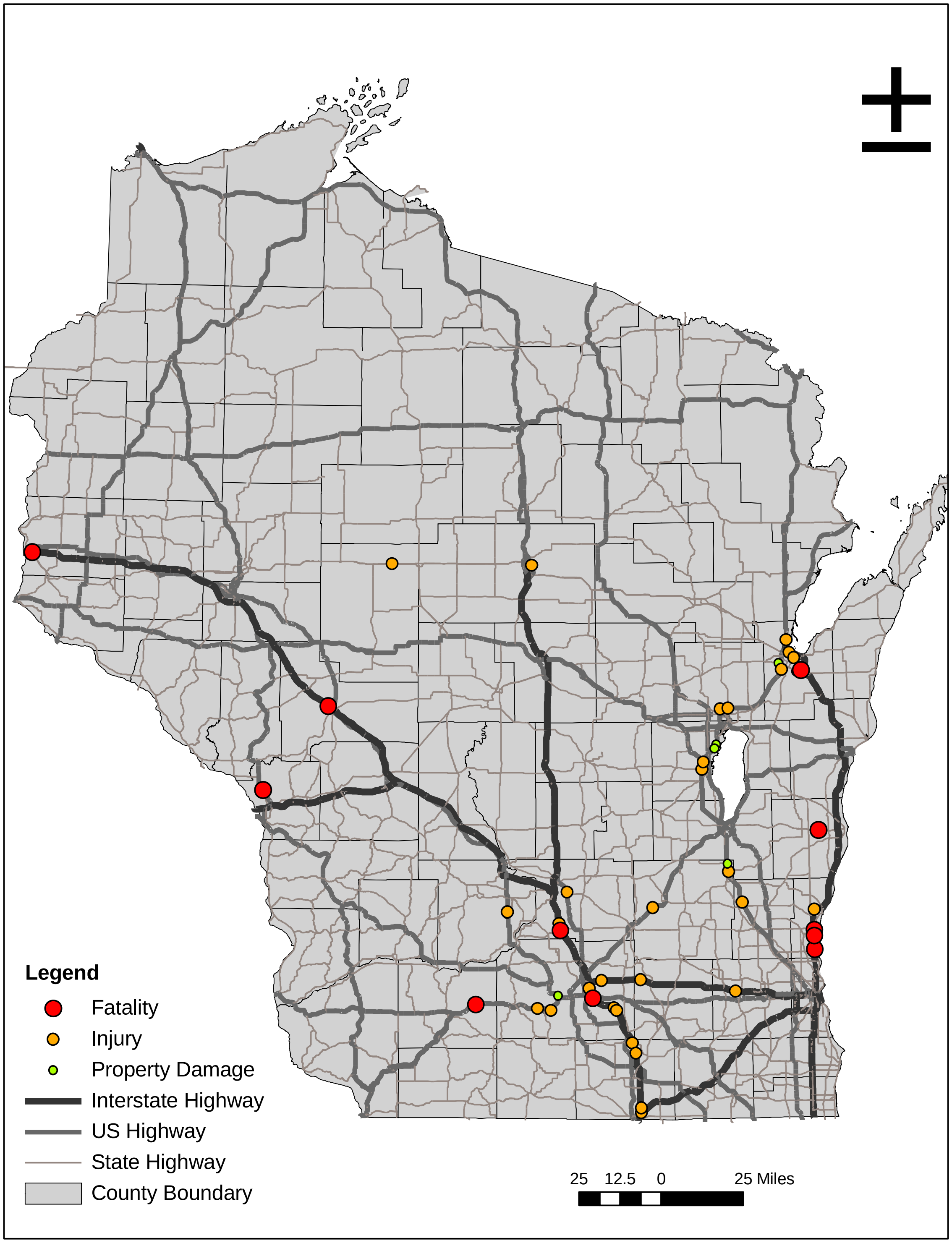


FIGURE 412006 Crossover Median Crashes

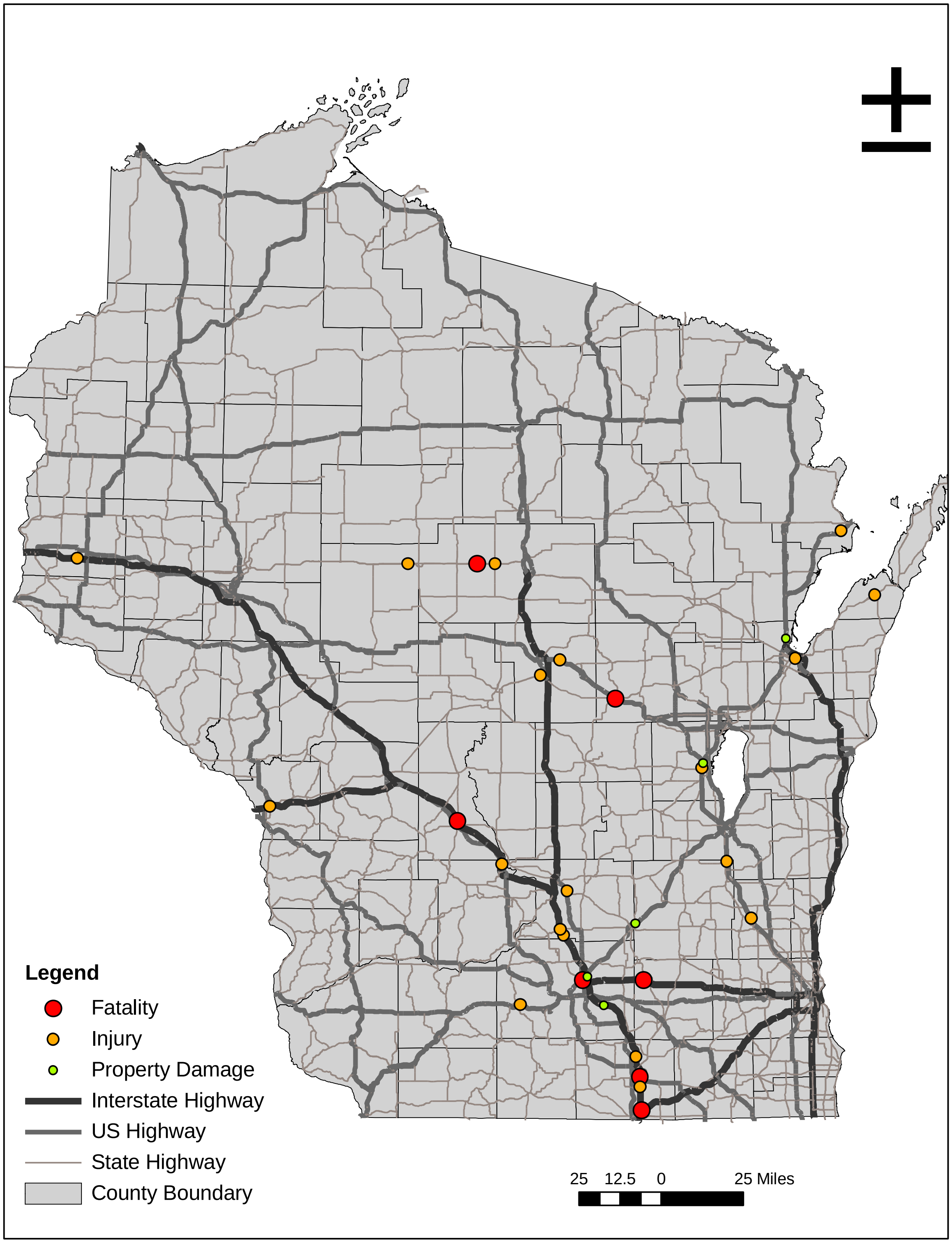


FIGURE 422007 Crossover Median Crashes

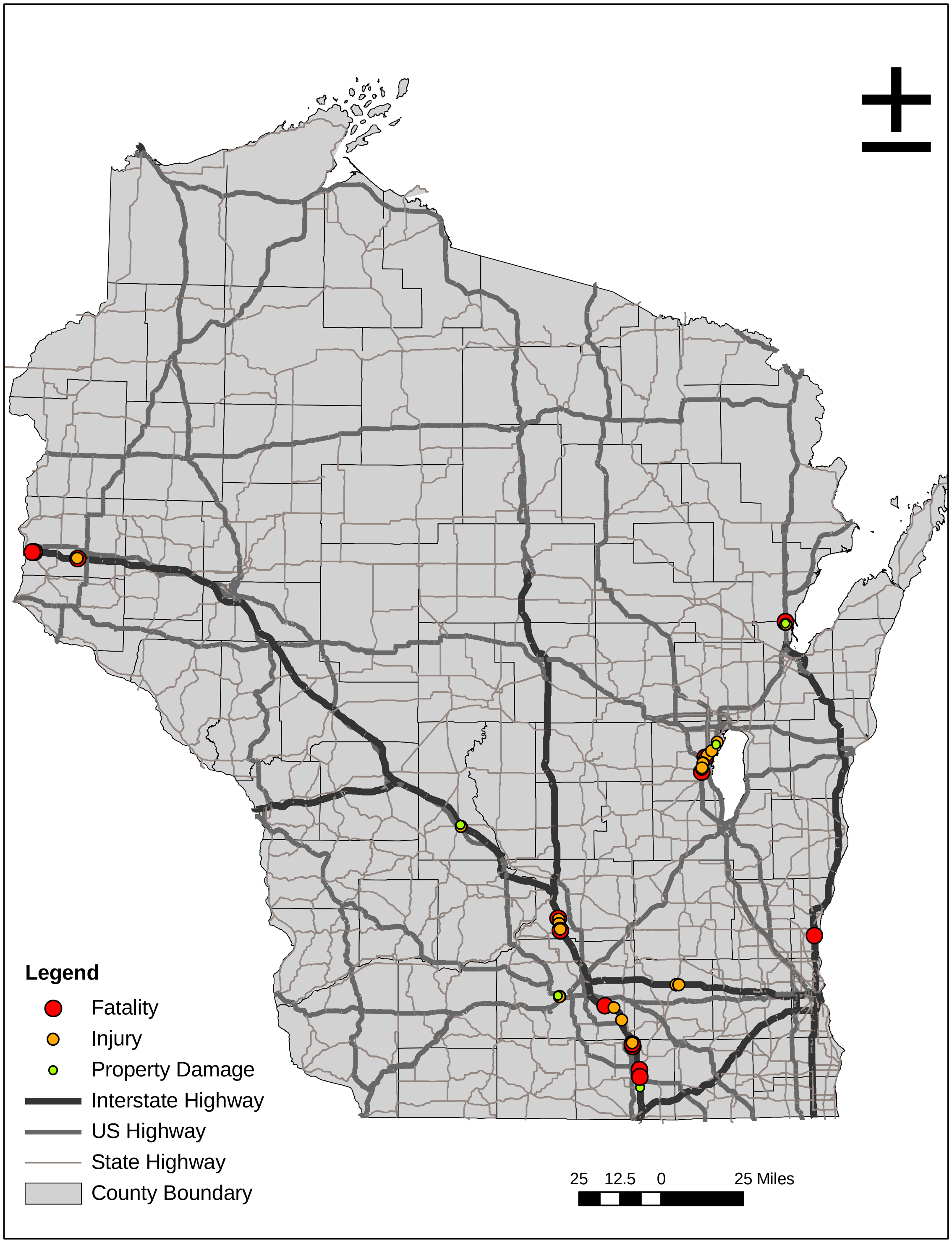


FIGURE 43Crossover Median Crashes Requiring Additional Analysis

TABLE 25Crossover Median Crash Segments Warranting Additional Analysis

HW	Mile Point Location	County	Number of Crashes	Crash Distribution (2001 -2007)	Crash Rate (per mile per year)
I-39	13.32 – 14.23	Rock	4	1/0/1/0/1/0/1	0.6
	23.48 – 24.28	Rock	4	0/0/0/1/2/1/0	0.7
	36.67 – 37.29	Dane	3	0/1/0/1/0/1/0	0.7
	67.48 – 69.74	Columbia	8	1/0/1/1/2/2/1	0.5
I-43	89.72 – 90.33	Ozaukee	3	0/0/0/2/0/1/0	0.7
I-94	2.72 – 3.16	St. Croix	3	0/1/0/1/0/1/0	1.0
	16.62 – 17.45	St. Croix	3	0/0/1/1/0/0/1	0.5
	170.71 – 171.38	Juneau	3	0/1/2/0/1/0/0	0.9
	266.19 – 266.98	Jefferson	3	1/0/1/1/0/0/0	0.5
USH 12	258.45 – 259.00	Dane	4	0/0/1/2/0/1/0	1.0
USH 41	120.56 – 121.86	Winnebago	5	0/0/0/2/0/1/2	0.6
	125.17 – 126.52	Winnebago	8	0/0/3/2/3/0/0	0.9
	130.40 – 130.57	Winnebago	3	0/0/0/1/1/1/0	2.5
	180.63 – 181.46	Brown	3	0/1/0/0/2/0/0	0.5

Fatal Crossover Median Crashes

Fatal crossover median crashes are of significance due to their high cost, both financially and in terms of loss of life. Over the sevenyear period studied, 64fatal crossover median crashes occurred on the selected roadways resulting in 85fatalities. TABLE 26 presents a breakdown of fatal crossover crashes by vehicles involved and crash vehicle type. FIGURE 44displays a map of the locations of the 64fatal crossover crashes.

In an effort to improve safety and understand the attributes of these crash types, TABLE 27 presents a detailed breakdown of each of the 64fatal crashes, including the location of the crash, amount of fatalities, initial causation event, reason for fatality, crash vehicle type, road condition, median width, date of crash, and age of driver.

TABLE 26Fatal Crossover Median Crashes by Vehicle Type

Crossover Crash Vehicle Type	Total Vehicles				Totals
	2	**3**	**4**	**5**	
Passenger Car – Passenger Car	22	7	3	2	**34**
Passenger Car – Truck	16	12	0	0	**28**
Truck – Truck	1	1	0	0	**1**
Totals	**39**	**20**	**3**	**2**	**64**

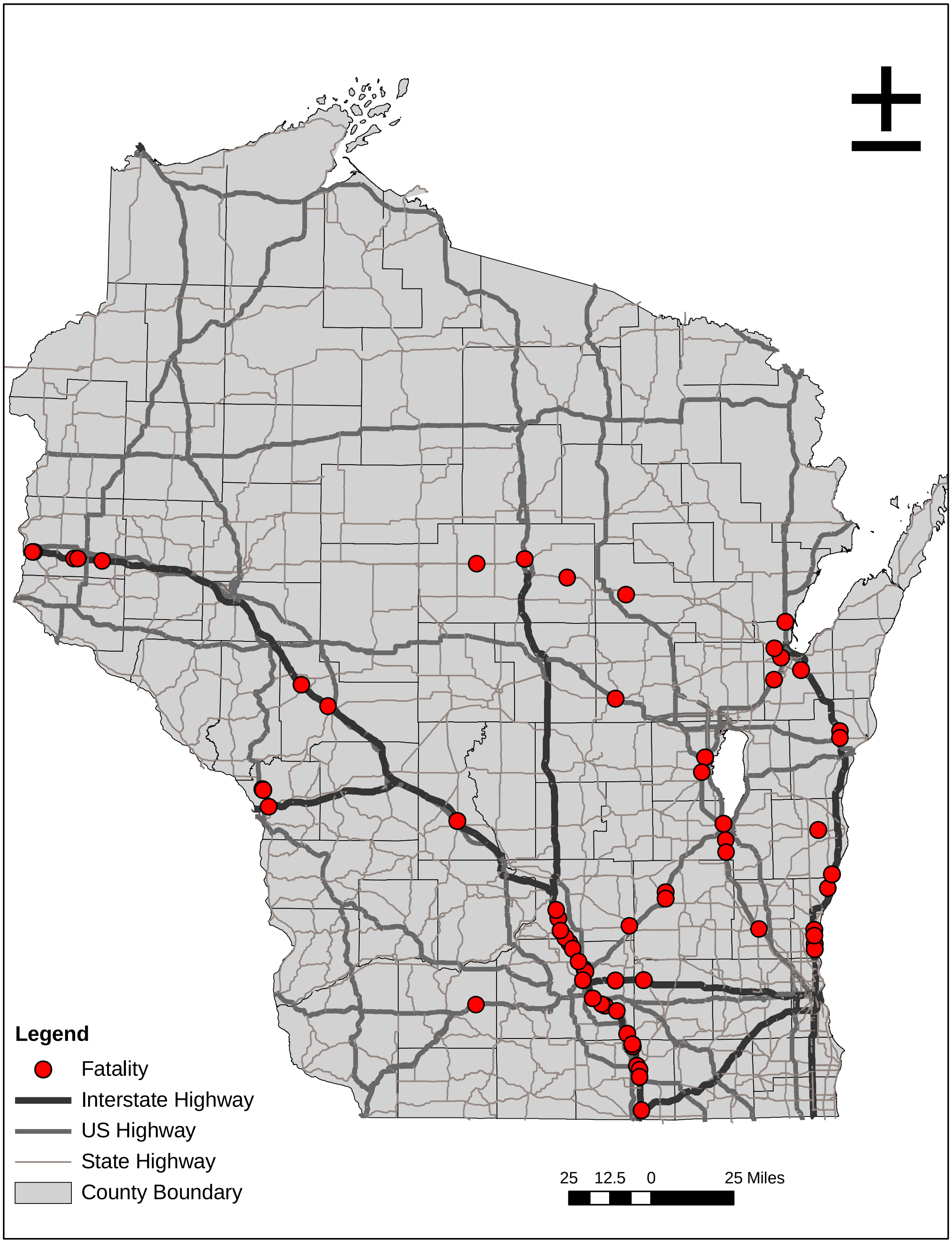


FIGURE 44Wisconsin Fatal Crossover Median Crashes (2001 – 2007)

TABLE 27Fatal Crossover Median Crashes

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
I-39	Columbia	1	Lost Control	Ejected Passenger	PC - PC	Dry	60	July 2001	63
		1	Ice	Impact with Opposing Direction Truck	PC – T	Ice	38	Dec. 2004	60
		2	Vehicle Collision	Vehicle Airborne,Impacted Opposing Direction Vehicle	PC – PC	Dry	50	Apr. 2005	54
		1	Vehicle Collision	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Apr. 2006	46
	Dane	1	Snow	Instantly Killed During Rollover	PC - PC	Snow	38	Jan. 2002	23
		1	Lost Control	Motorcyclist – Killed on Impact with Truck	PC – T	Dry	38	July 2002	57
		3	Wet Roadway	Driver – Impact; Passengers Ejected	PC – PC	Wet	38	Oct. 2002	16
		1	Lost Control	Driver Ejected	PC – PC	Dry	60	July 2003	38
		1	Vehicle Collision	Impact with Opposing Direction Truck	PC – T	Wet	60	June 2004	75
		1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	38	June 2005	29
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	100	Sept 2005	35
		2	Ice	Impact with Opposing Direction Truck	PC – T	Ice	60	Oct 2005	49
		1	Barrier Collision	Vehicle Overturned, Impact with Opposing Direction Truck	PC – T	Ice	125	Oct 2005	34

TABLE 27Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
I-39	Dane	3	Driver Condition	Impact with Opposing Direction Vehicle	PC – T	Dry	38	Oct 2005	79
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – T	Dry	60	Sept 2006	43
	Rock	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	Oct. 2001	56
		1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	June 2005	26
		1	Snow	Impact with Opposing Direction Truck	T – T	Snow	60	Oct 2005	31
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Oct 2005	82
		2	Lost Control	Impact with Opposing Direction Vehicle	PC - PC	Wet	60	Jan 2007	62
		1	Speeding, Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	May 2007	18
I-43	Brown	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	88	Sept 2006	20
	Manitowoc	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	64	June 2002	40
		2	Lost Control	Driver and Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	88	Aug. 2003	18
	Ozaukee	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	June 2001	49

TABLE 27Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
I-43	Ozaukee	2	Lost Control	Two Passengers Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Jan. 2002	78
		2	Driver Condition	Driver and Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Feb 2006	42
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – T	Wet	60	June 2006	42
		2	Lost Control	Two Passengers Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	60	July 2006	48
	Sheboygan	1	Vehicle Collision	Impact with Opposing Direction Truck	PC – T	Dry	90	Sept 2005	48
I-90	La Crosse	1	Snow	Impact with Opposing Direction Truck	PC – T	Snow	60	Apr. 2002	38
I-94	Dane	1	Wet Roadway	Impact with Opposing Direction Vehicle	PC – PC	Wet	60	Nov. 2003	28
	Jackson	2	Snow	Driver and Passenger Killed on Impact with Truck	PC – T	Snow	85	Mar. 2003	20
		1	Too Fast for Condition s	Driver and Passenger Killed on Impact with Opposing Vehicle and Following Truck	PC – T	Snow	65	Feb 2006	27
	Jefferson	1	Lost Control	Passenger Ejected, Impact with Opposing Direction Vehicle	PC – PC	Dry	80	Dec 2007	27

TABLE 27Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
I-94	Juneau	1	Too Fast for Conditions	Impact with Opposing Direction Truck	T – T	Ice	60	Dec 2007	71
	St. Croix	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	50	Dec. 2001	60
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	28	Sep. 2002	47
		3	Ice	Impact with Opposing Direction Vehicle (all 3 persons)	PC – PC	Ice	50	Mar. 2003	24
		1	Ice	Fatal Injuries Caused During Crash	PC – PC	Ice	50	Dec. 2004	27
		2	Lost Control	Driver and Passenger Killed on Impact with Opposing Vehicle	PC – PC	Dry	28	Oct 2006	86
USH 10	Waupaca	1	Lost Control	Impact with Opposing Direction Vehicle	PC - PC	Dry	60	May 2004	46
USH 18	Iowa	1	Snow	Impact with Opposing Direction Vehicle	PC - T	Snow	50	March 2006	17
USH 41	Brown	1	Ice	Driver Ejected	PC – PC	Ice	60	Nov. 2002	20
		1	Lost Control	Impact With Opposing Direction Vehicle	PC – T	Dry	60	Dec. 2004	17
		1	Vehicle Collision	Impact With Opposing Direction Truck	PC – T	Dry	60	Sept 2005	43
	Fond	2	Wet Roadway	Driver and Passenger Killed on Impact with Opposing Truck	PC – T	Wet	50	Mar. 2001	57

TABLE 27Fatal Crossover Median Crashes (cont.)

W	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
USH 41	Fond	4	Lost Control	Driver and Three Passengers Killed on Impact with Opposing Vehicle	PC – PC	Dry	50	Apr. 2003	18
		1	Lost Control	Impact With Opposing Direction Vehicle	PC – PC	Dry	50	June 2004	21
	Washington	1	Lost Control	Driver Ejected	PC – PC	Dry	37	Feb. 2003	46
	Winnebago	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	50	Feb. 2003	29
		1	Lost Control	Impact With Opposing Direction Vehicle	PC – PC	Fog	30	June 2004	63
USH 51	Dane	1	Driver Condition Vehicle Collision	Impact With Opposing Direction Vehicle	PC – PC	Wet	10	Mar 2007	65
	Marathon	1	Wet Roadway	Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Wet	40	Apr. 2001	66
USH 53	La Crosse	1	Wet Roadway	Impact With Opposing Direction Vehicle	PC – T	Wet	50	July 2004	17
		1	Too Fast for Condition	Impact With Opposing Direction Vehicle	PC – T	Snow	50	Feb 2006	22
USH 151	Columbia	2	Lost Control	2 Passengers Killed on Impact with Opposing Direction Vehicle	PC – T	Dry	90	Nov. 2002	22

TABLE 27Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
USH 151	Dodge	1	Lost Control	Driver Ejected	PC – T	Dry	60	Feb. 2001	15
		1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	Aug. 2001	49
STH 23	Sheboygan	1	Lost Control	Impact with Opposing Direction Vehicle	PC - PC	Dry	60	Dec 2006	
STH 29	Brown	2	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	July 2005	31
	Marathon	1	Ice	Impact with Opposing Direction Truck	PC – T	Ice	64	Jan. 2003	47
	Shawano	1	Snow	Impact with Opposing Direction Vehicle	PC – PC	Snow	60	Mar. 2003	21
	Marathon	1	Lost Control	Impact with Opposing Direction Vehicle	PC – T	Dry	60	June 2007	79

[1]*Impact was made with a vehicle that had attempted an illegal u-turn, causing the vehicle documented to traverse the median to the opposing roadway, without striking another vehicle. Fatality occurred in vehicle making illegal u-turn, not the crossover vehicle.*
[2]*PC = passenger car; T = truck*

The fatal crash warrant is a roadway segment with 0.12 fatal crossover median crashes per mile per year and at least three fatal crossover median crashes within a five year period. As shown in TABLE 28 and **Error! Reference source not found.**, there are twosites with a cluster of crashes hat satisfy these requirements. Sites are located in Columbia, Dane, and Rock counties.

TABLE 28Fatal Crossover Median Crashes Requiring Additional Analysis

HW	County (Crash Rate)	Mile Marker	Fatal	Initial Event	Fatality Reason	Crash Type[2]	Road Cond.	Month Year	Driv. Age
I-39	Rock/ Dane (0.15)	23.48	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	June 05	26
		24.11	1	Snow	Impact with Opposing Direction Truck	T – T	Dry	Dec 05	31
		26.33	2	Ice	Impact with Opposing Direction Truck	PC – T	Ice	Dec 05	49
	Dane/ Columbia (0.13)	60.89	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	June 05	29
		63.06	1	Snow	Instantly Killed During Rollover	PC - PC	Snow	Jan. 02	23
		63.64	1	Lost Control	Driver Ejected	PC – PC	Dry	July 03	38
		67.48	1	Lost Control	Ejected Passenger	PC-PC	Dry	July 01	63
		67.58	1	Vehicle Collision	Impact with Opposing Direction Vehicle	PC – PC	Dry	Apr. 2006	46
		68.71	1	Ice	Impact with Opposing Direction Truck	PC – T	Ice	Dec. 04	60

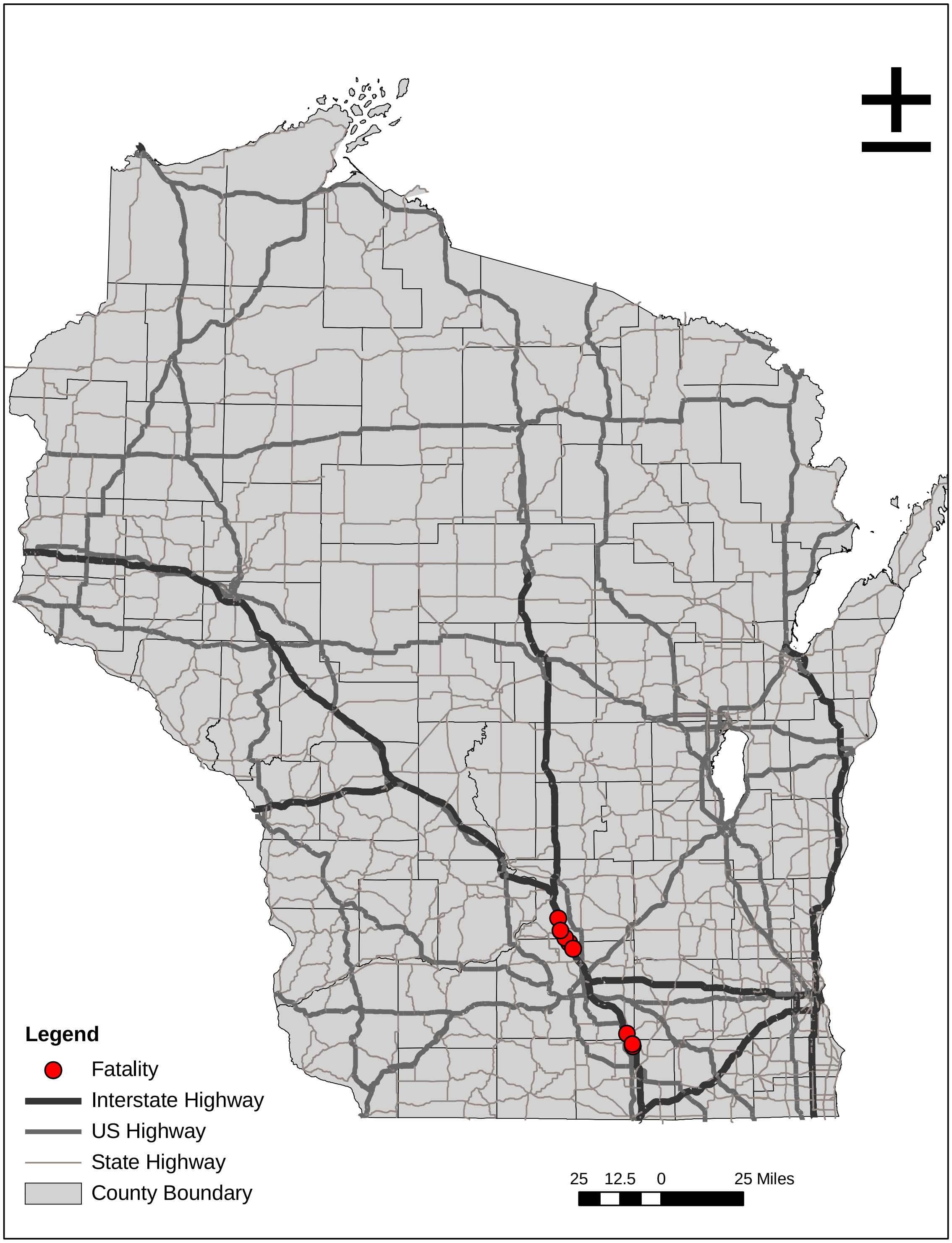


FIGURE 45Fatal Crossover Median Crashes Warranting Additional Analysis

CHAPTER V
IDENTIFYING SITES FOR MONITORING

Crossover median crashes evaluated included on those crashes involving multiple vehicles. There were an additional 1,348 crossover median crashes identified that included only a single vehicle. In these cases, the crossover vehicle was fortunate enough to find a gap in the opposing traffic that prevented a head-on collision. Although these crashes fall outside of the definition of crossover median crashes, they can provide clues to other sites that may warrant more focused monitoring in the years to come or low-cost safety improvements. Therefore, an analysis including these additional crashes follows.

Injury Crossover Median Crashes – Single and Multiple Vehicle

The first analysis combined single and multiple vehicle crashes under the assumption that both meet the Wisconsin definition of a crossover median crash. Examination of FIGURE 46through FIGURE 53reveals several counties where crash clusters have formed. If we were to use the same crash rate criteria warranting additional analysis of 0.5 crossover median crashes per mile per year and at least three crossover median crashes during a five year period, FIGURE 54presents the crossover median crashes that would meet this benchmark. In all, 45 roadway segments would meet the above criteria as summarized in TABLE 29.

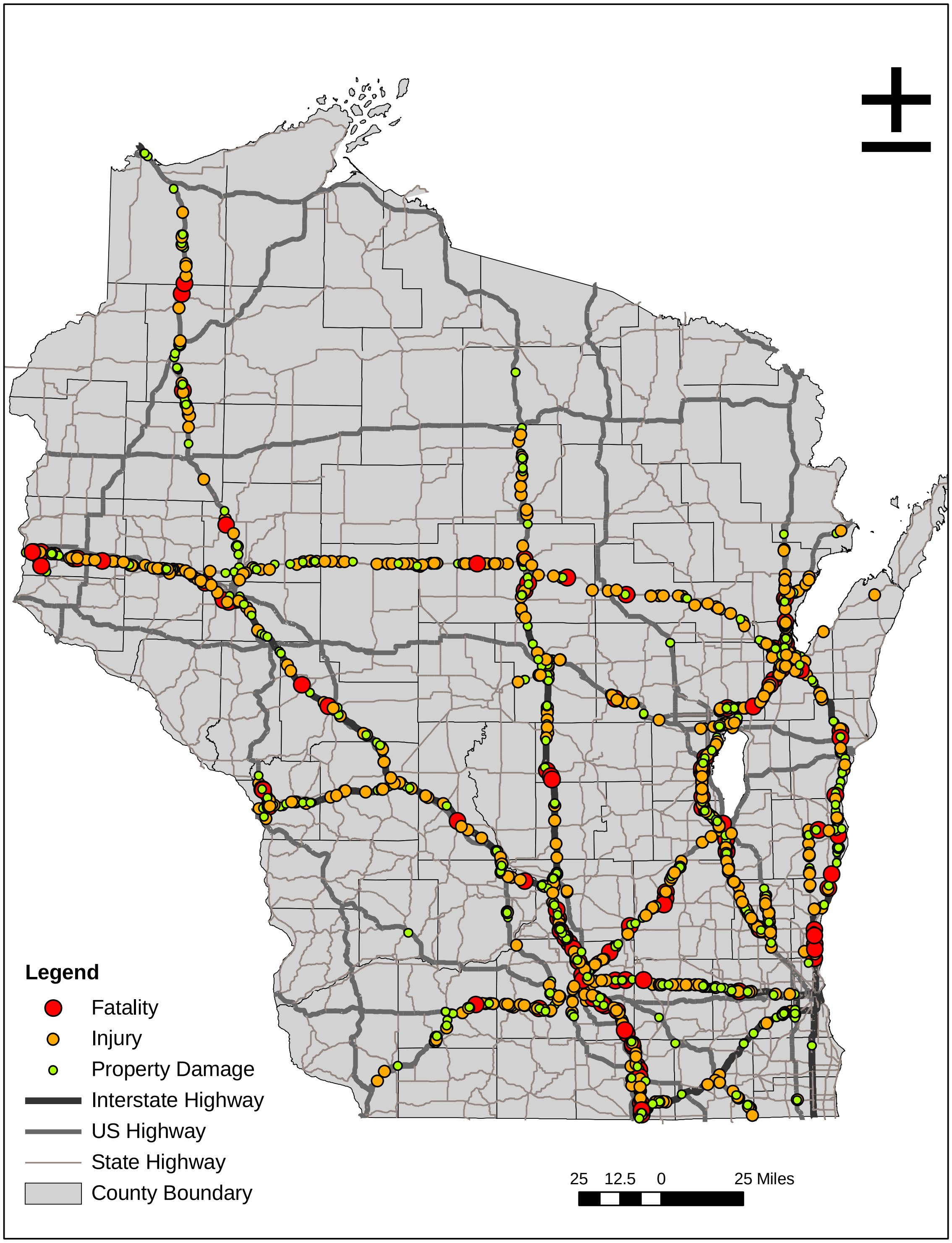


FIGURE 46Crossover Median Crashes, Single and Multiple Vehicles (2001 – 2007)

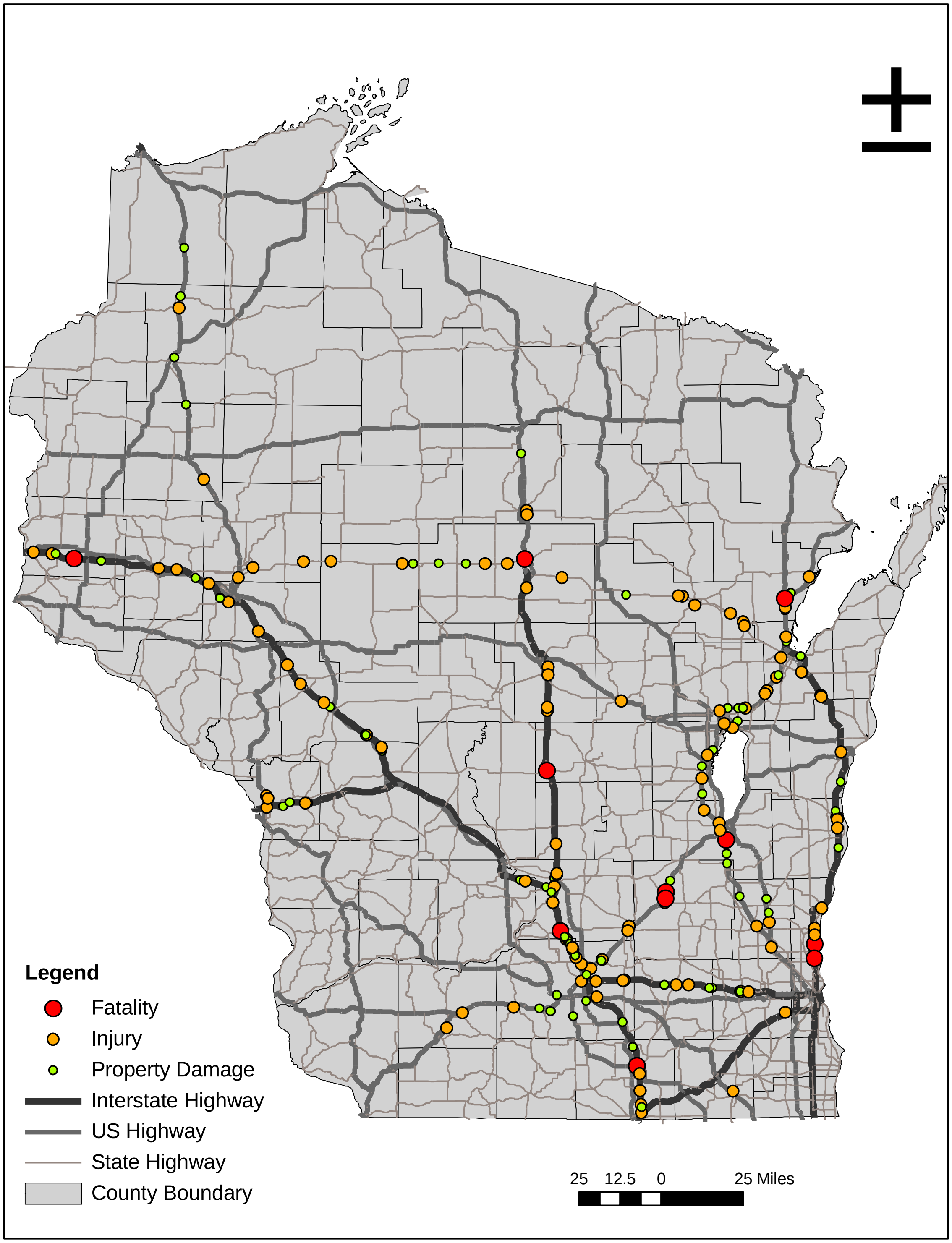


FIGURE 472001 Crossover Median Crashes, Single and Multiple Vehicle

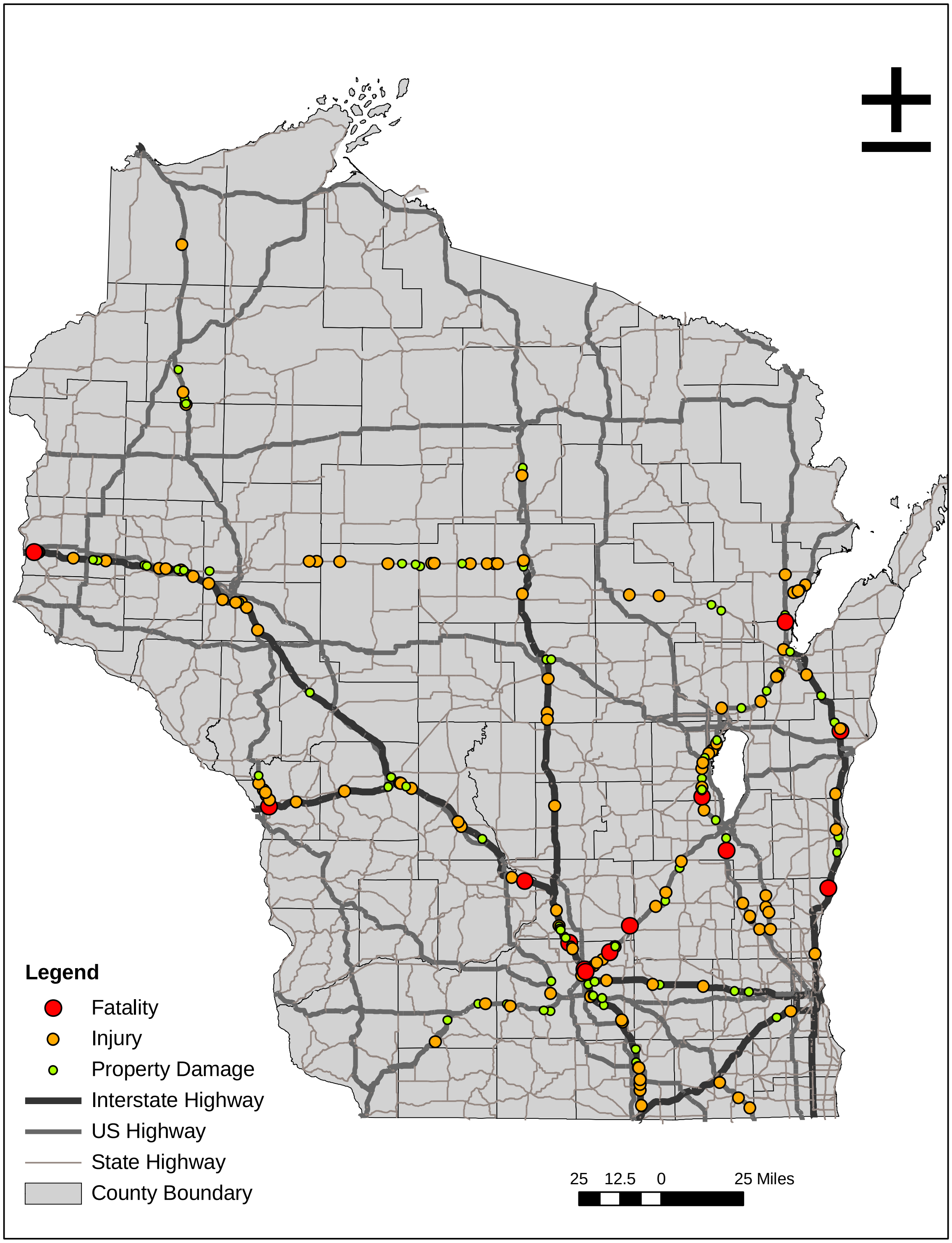


FIGURE 482002 Crossover Median Crashes, Single and Multiple Vehicle

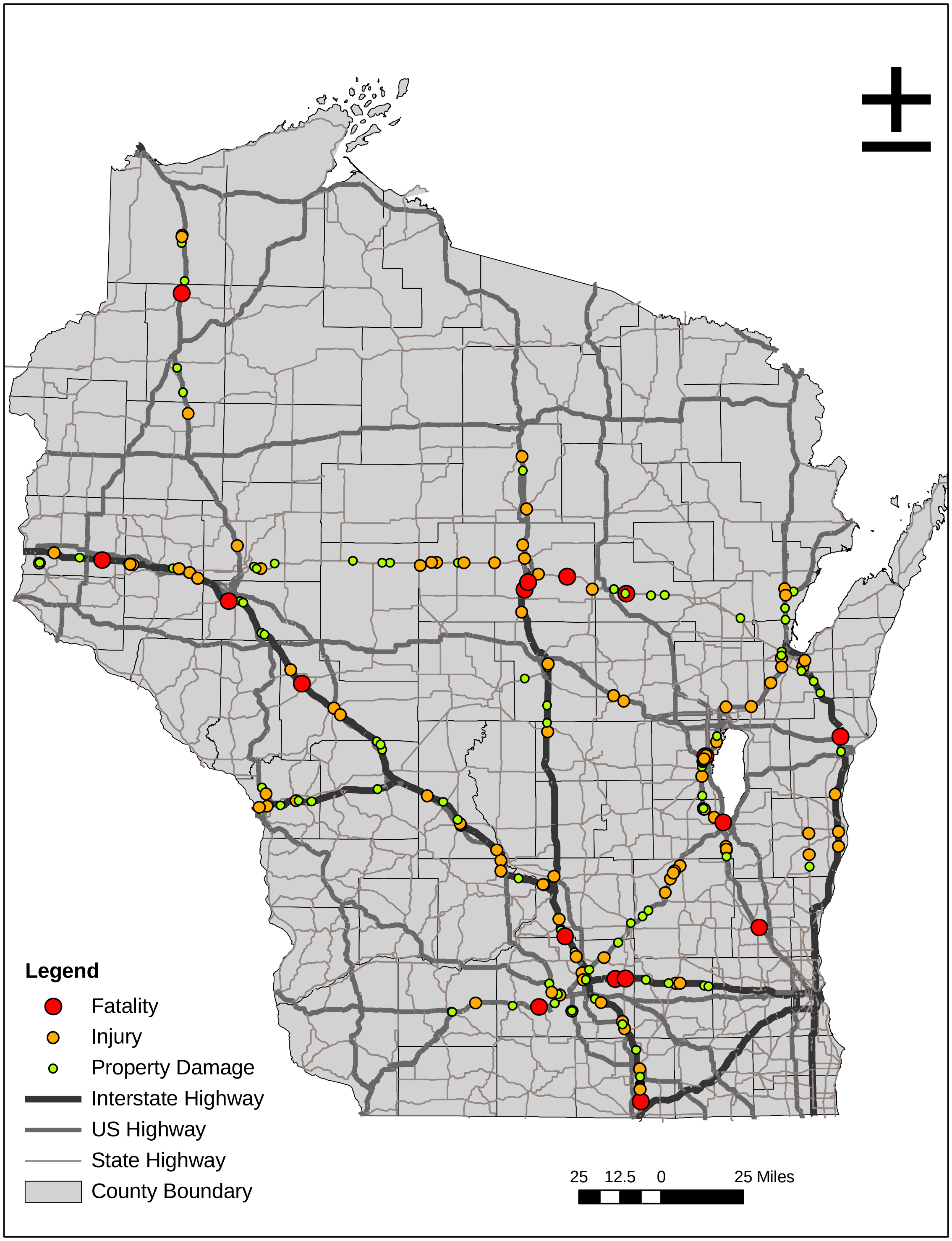


FIGURE 492003 Crossover Median Crashes, Single and Multiple Vehicle

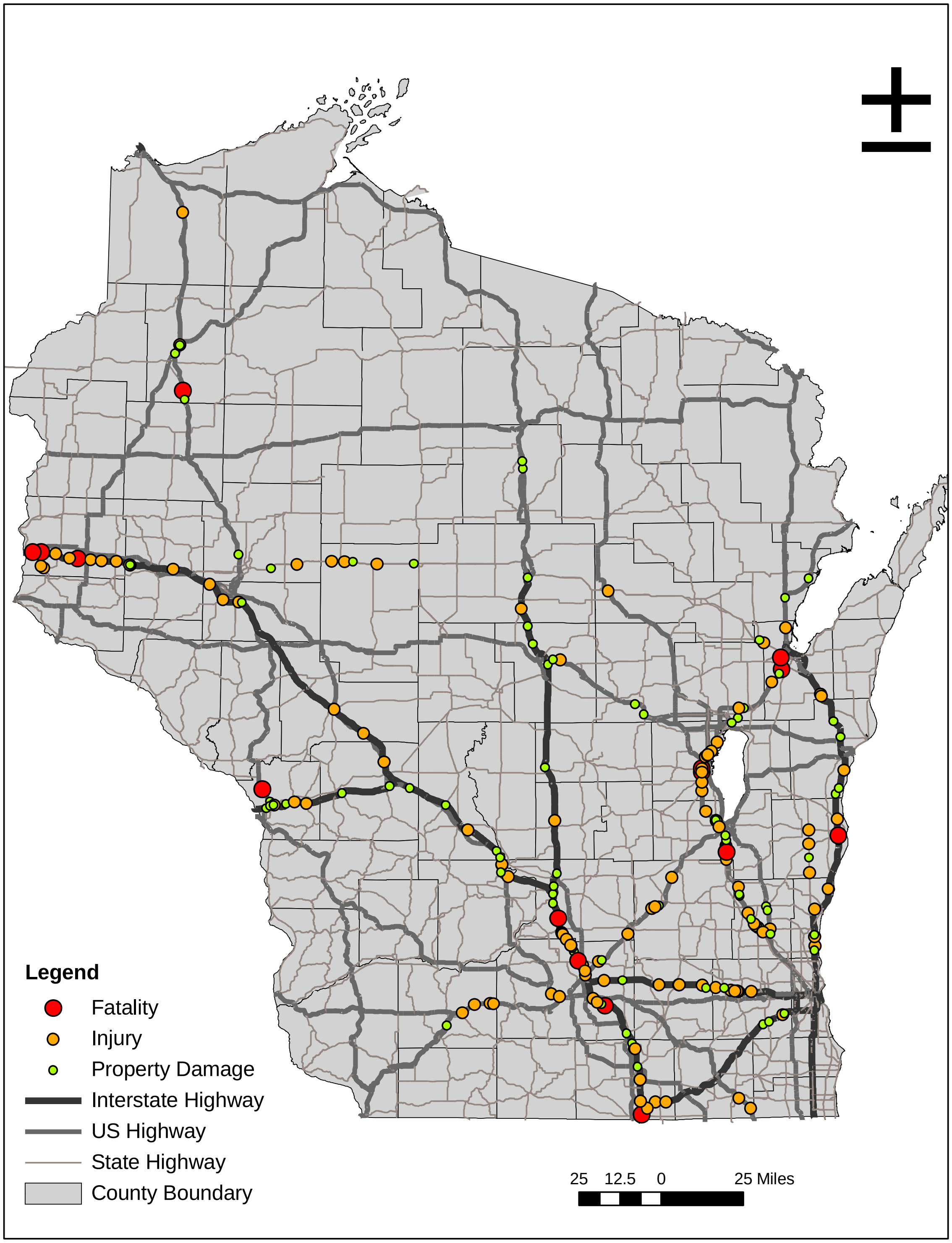


FIGURE 502004 Crossover Median Crashes, Single and Multiple Vehicle

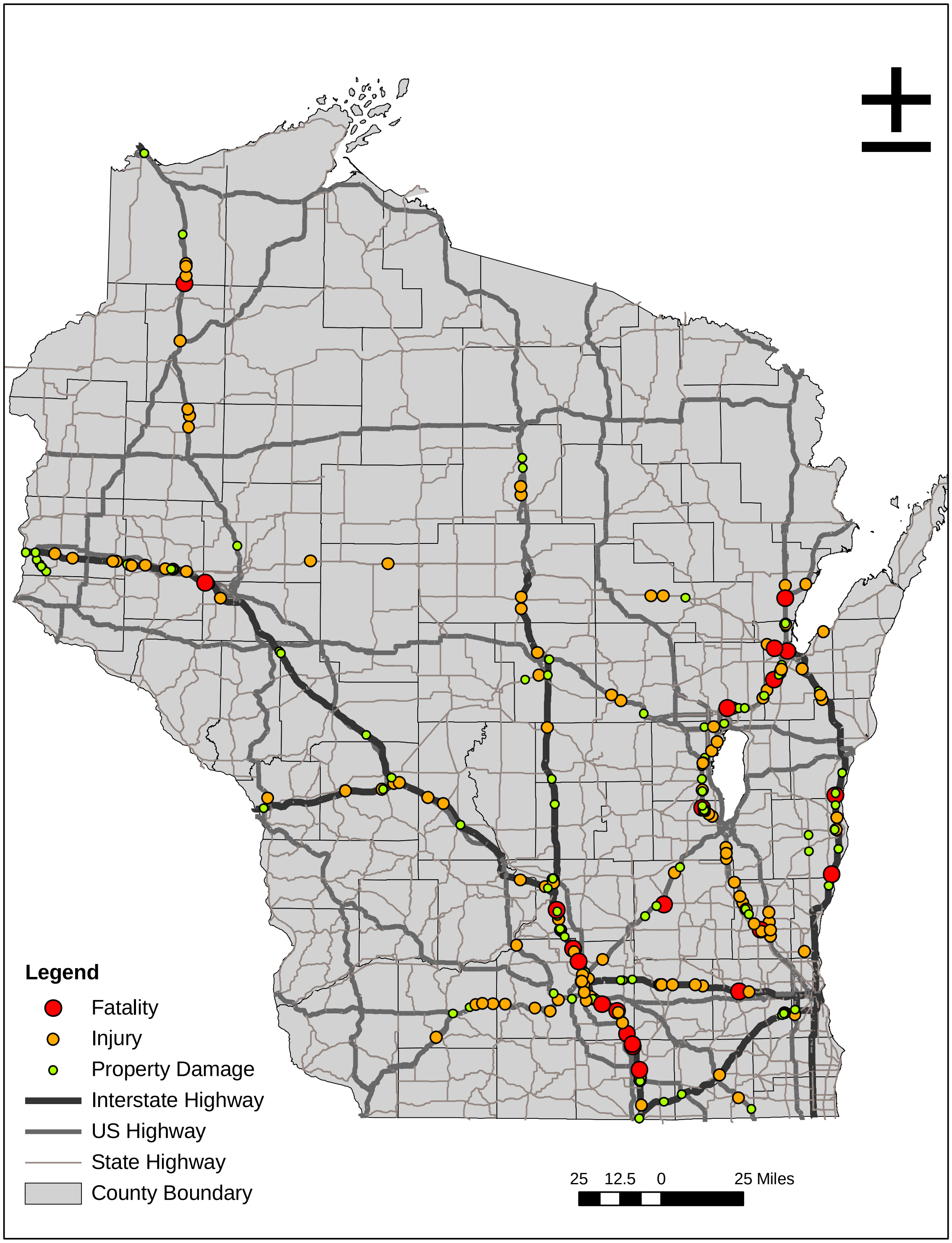


FIGURE 512005 Crossover Median Crashes, Single and Multiple Vehicle

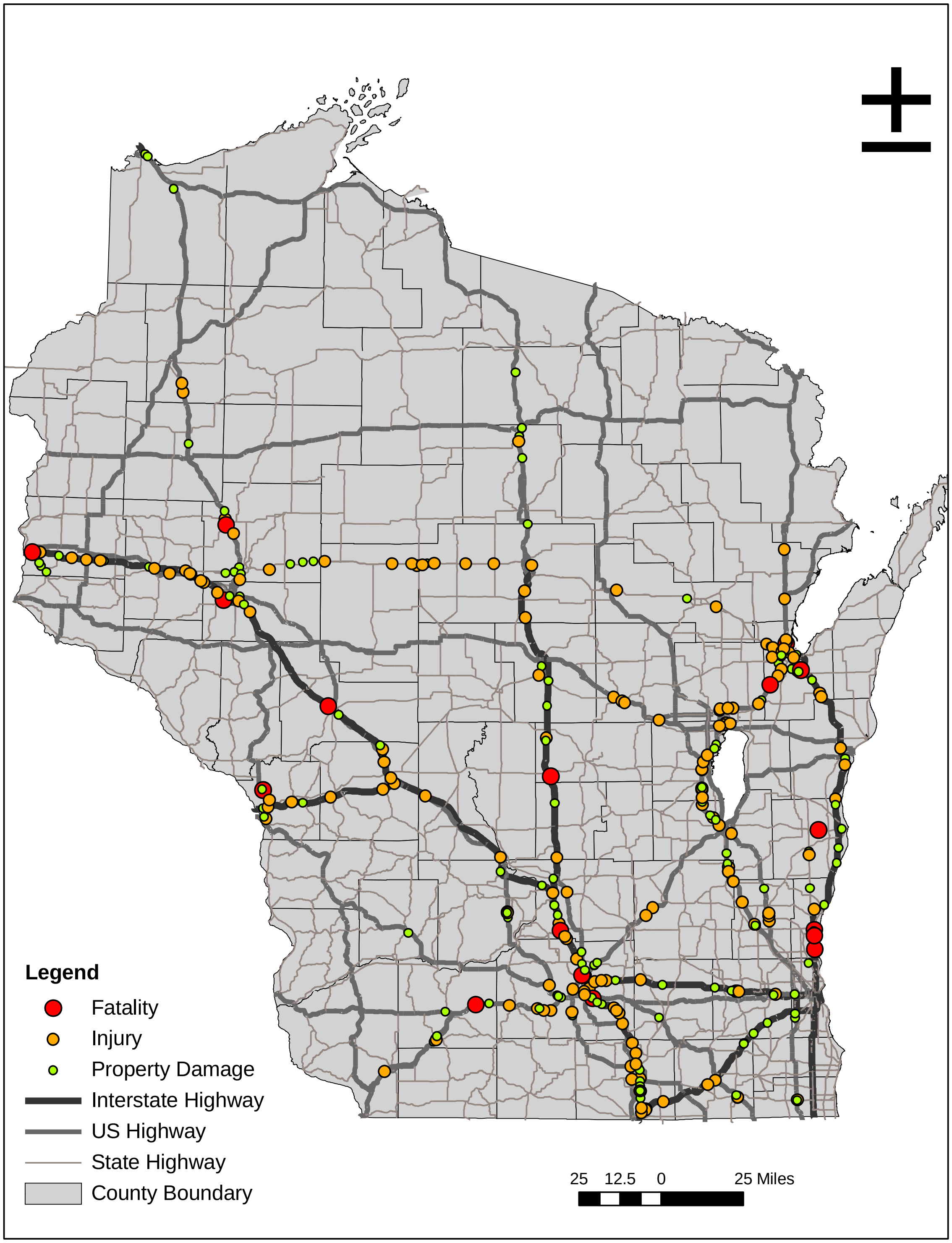


FIGURE 522006 Crossover Median Crashes, Single and Multiple Vehicle

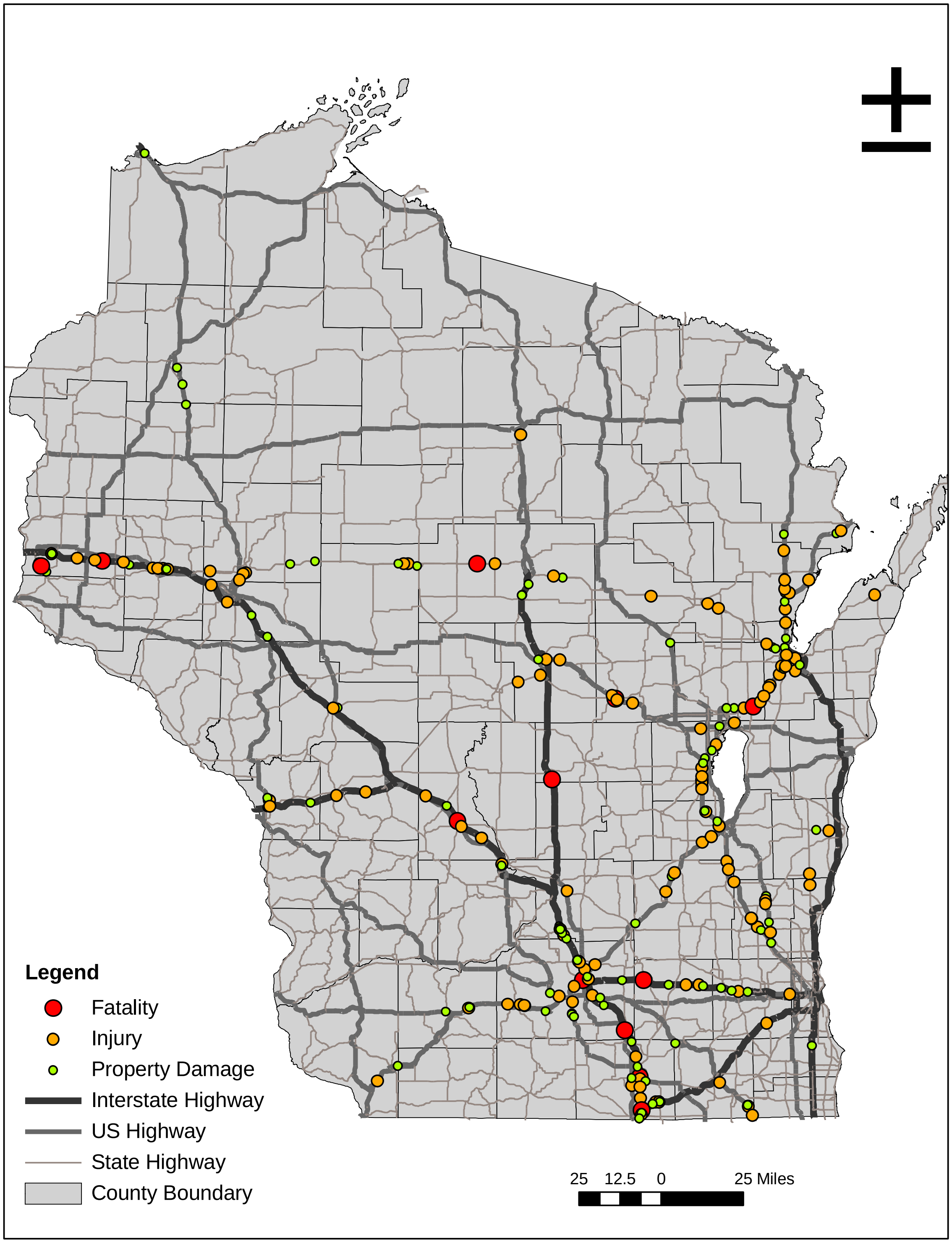


FIGURE 532007 Crossover Median Crashes, Single and Multiple Vehicle

TABLE 29Potential Crossover Median Crash Segments Warranting Additional Analysis

HW	Mile Point Location	County	Number of Crashes	Crash Distribution (2001 -2007)	Crash Rate (per mile per year)
I-39	1.75 –5.36	Rock	13	3/2/1/1/1/2/3	0.5
	6.72 – 7.94	Rock	5	1/1/1/1/0/0/1	0.6
	12.07 – 14.23	Rock	13	1/1/3/1/4/1/2	0.9
	15.65 – 17.67	Rock	8	1/2/0/1/1/2/1	0.6
	21.95 – 24.63	Rock	11	1/2/0/3/3/1/1	0.6
	30.47 – 31.18	Dane	4	0/0/2/0/1/1/0	0.8
	33.61 – 34.58	Dane	4	0/0/0/0/3/1/0	0.6
	35.37 – 37.29	Dane	8	1/2/0/1/1/3/0	0.6
	40.02 – 40.85	Dane	6	0/1/1/0/1/2/1	1.0
	42.13 – 45.41	Dane	12	0/1/1/3/4/3/0	0.5
	51.01 – 53.63	Dane	12	1/5/0/1/1/2/2	0.7
	55.01 – 58.10	Dane	15	3/0/2/3/3/1/3	0.7
	59.29 – 70.50	Dane/Columbia	69	13/12/5/11/15/6/7	0.9
	83.74 – 85.00	Columbia	6	1/0/1/1/2/1/0	0.7
	85.75 – 86.54	Columbia	3	2/0/0/1/0/0/0	0.5
	107.05 – 107.65	Marquette	3	0/1/0/0/1/1/0	0.7
	174.4 – 176.09	Marathon	6	0/1/1/0/1/0/3	0.5
I-43	6.67 – 7.01	Rock	3	0/0/0/0/0/0/3	1.3
	7.97 – 8.97	Rock	3	0/0/0/1/1/1/0	0.5
	56.72 – 57.02	Waukesha	4	0/0/0/1/3/0/0	2.1
	85.57 – 86.00	Ozaukee	3	0/0/0/1/0/2/0	1.0
	86.95 – 87.60	Ozaukee	3	1/0/0/1/1/0/0	0.7
	89.72 – 90.33	Ozaukee	5	1/0/0/2/0/2/0	1.2
	91.58 – 92.42	Ozaukee	4	2/0/0/0/0/2/0	0.8
	119.87 – 120.44	Sheboygan	4	1/0/1/0/1/1/0	1.0
	124.69 – 125.10	Sheboygan	3	0/0/2/1/0/0/0	1.1
	133.40 – 134.10	Sheboygan	3	0/0/0/2/1/0/0	0.6
	136.42 – 137.36	Manitowoc	4	0/1/1/0/2/0/0	0.6
	156.18 – 156.92	Manitowoc	3	0/2/0/1/0/0/0	0.6
	170.42 -171.57	Brown	7	1/1/1/1/1/2/0	0.9
	180.34 – 181.48	Brown	4	1/0/1/0/1/1/0	0.5
	189.73 – 190.17	Brown	3	0/1/0/0/1/1/0	1.0
I-90	3.09 – 4.02	La Crosse	6	1/1/1/0/0/1/2	0.9
	7.77 – 8.38	La Crosse	3	1/0/1/1/0/0/0	0.7
	12.11 – 12.78	La Crosse	3	0/1/1/1/0/0/0	0.6
I-94	2.72 – 4.99	St. Croix	12	1/3/0/4/1/3/0	0.8
	7.99 – 9.94	St. Croix	7	2/0/1/1/1/0/2	0.5
	14.47 – 17.45	St. Croix	9	0/1/1/2/2/1/2	0.4*
	20.89 – 23.03	St. Croix	8	0/4/1/2/0/0/1	0.5
	24.09 – 25.27	St. Croix	5	1/1/0/1/0/1/1	0.6
	27.93 – 28.77	St. Croix	3	0/0/0/1/2/0/0	0.5
	36.56 – 38.21	Dunn	8	0/0/2/3/3/0/0	0.7
	39.81 – 42.39	Dunn	10	1/0/1/0/2/3/3	0.6
	44.11 – 46.68	Dunn	9	0/3/0/0/4/0/2	0.5

TABLE 29Potential Crossover Median Crash Segments Warranting Additional Analysis (cont.)

HW	Mile Point Location	County	Number of Crashes	Crash Distribution (2001 -2007)	Crash Rate (per mile per year)
I-94	50.04 – 52.14	Dunn	9	0/4/1/0/2/2/0	0.6
	56.06 – 57.59	Dunn/Eau Claire	5	1/0/1/1/1/1/0	0.9
	63.79 – 64.28	Eau Claire	3	2/0/0/0/1/0/0	0.9
	65.18 – 65.77	Eau Claire	3	0/1/0/0/1/1/0	0.7
	66.79 – 67.16	Eau Claire	4	1/0/1/1/0/0/1	1.5
	69.73 – 72.01	Eau Claire	10	0/4/1/4/0/1/0	0.6
	94.38 – 95.33	Jackson	5	1/0/1/0/3/0/0	0.8
	115.04 – 115.76	Jackson	4	1/0/1/1/0/0/1	0.8
	117.67 – 118.52	Jackson	3	0/0/2/0/0/1/0	0.5
	133.67 – 135.02	Monroe	5	1/0/1/0/0/3/0	0.5
	155.97 – 156.73	Juneau	4	0/1/0/0/0/2/1	0.8
	162.44 – 163.05	Juneau	3	0/0/1/1/1/0/0	0.7
	169.09 – 171.40	Juneau	11	0/3/4/0/1/0/3	0.7
	178.38 – 178.87	Juneau	4	0/1/0/1/1/0/1	1.2
	188.59 – 189.54	Sauk	5	0/0/1/2/0/0/2	0.8
	191.39 – 191.71	Sauk	3	0/0/1/1/0/1/0	1.3
	198.05 – 198.35	Sauk	5	2/0/1/0/2/0/0	2.4
	199.88 – 200.26	Sauk	3	1/1/0/1/0/0/0	1.1
	205.27 – 206.27	Columbia	4	0/0/2/0/1/1/0	0.6
	244.74 – 245.62	Dane	4	0/1/0/1/0/2/0	0.7
	250.58 – 251.62	Dane	4	1/0/2/1/0/0/0	0.6
	261.47 – 262.11	Jefferson	4	0/1/0/0/3/0/0	0.9
	266.19 – 266.98	Jefferson	3	1/0/1/1/0/0/0	0.5
	273.36 – 275.16	Jefferson	7	0/1/2/1/1/0/2	0.6
	284.71 – 286.53	Waukesha	12	2/1/0/3/2/3/1	0.9
	288.08 – 289.03	Waukesha	6	1/1/0/2/1/0/1	0.9
USH 10	179.50 – 180.40	Portage	4	0/1/0/1/1/0/1	0.6
	202.23 – 202.98	Waupaca	3	0/0/1/0/0/1/1	0.6
	203.64 – 204.57	Waupaca	5	0/1/0/0/3/0/1	0.8
	205.57 – 206.56	Waupaca	6	1/0/1/0/0/3/1	0.9
USH 12	222.85 – 223.35	Sauk	4	0/0/0/0/0/4/0	1.1
	255.77 – 256.47	Dane	5	0/1/1/1/1/0/1	1.0
	258.00 – 259.00	Dane	10	1/0/2/2/0/4/1	1.4
	330.86 – 332.99	Walworth	6	0/1/0/1/1/3/1	0.5
USH 14	137.05 – 138.82	Dane	8	1/0/2/0/0/2/3	0.7
USH 18	59.59 – 60.22	Iowa	3	0/0/2/0/1/0/0	0.7
	65.79 – 66.29	Iowa	5	0/0/0/0/3/0/2	1.4
	68.52 – 69.32	Iowa	4	0/1/0/1/1/1/0	0.7
	77.51 – 78.85	Dane	4	0/1/0/0/1/1/1	0.4*
	87.42 – 88.78	Dane	6	1/0/2/0/1/2/0	0.6
	90.42 – 91.21	Dane	4	0/1/0/1/0/1/1	0.7
	92.67 – 92.97	Dane	5	2/1/0/0/1/1/0	2.4
	95.31 – 96.00	Dane	3	1/0/1/0/1/0/0	0.6
USH 41	65.05 – 69.29	Washington	16	1/1/1/4/5/2/2	0.5

TABLE 29Potential Crossover Median Crash Segments Warranting Additional Analysis (cont.)

HW	Mile Point Location	County	Number of Crashes	Crash Distribution (2001 -2007)	Crash Rate (per mile per year)
USH 41	70.67 – 71.60	Washington	6	0/2/0/1/1/0/2	0.9
	76.11 – 76.50	Washington	3	0/1/0/0/1/1/0	1.1
	78.34 – 78.74	Washington	4	1/0/0/2/1/0/0	1.4
	83.20 – 83.74	Washington/Dodge	5	0/0/0/0/2/2/1	1.3
	87.20 – 87.80	Dodge	3	0/0/0/0/0/2/1	0.7
	90.46 – 91.25	Dodge/Fond du Lac	3	0/0/0/1/1/0/1	0.5
	92.29 – 95.06	Fond du Lac	17	2/1/4/5/4/1/0	0.9
	96.50 – 97.51	Fond du Lac	5	2/1/0/1/1/0/0	0.7
	101.66 – 104.71	Fond du Lac	12	1/1/2/4/1/1/2	0.6
	107.59 – 111.37	Fond du Lac	20	2/1/4/1/8/2/2	0.8
	112.89 – 116.31	Winnebago	17	1/6/1/0/2/5/2	0.7
	117.41 – 119.16	Winnebago	11	1/1/1/3/1/0/4	0.9
	120.56 – 131.86	Winnebago	58	3/11/9/11/8/9/7	0.7
	141.23 – 142.07	Outagamie	4	0/1/1/0/0/2/0	0.7
	143.49 – 143.99	Outagamie	5	1/0/0/0/1/1/2	1.4
	146.87 – 147.35	Outagamie	4	1/0/0/2/1/0/0	1.2
	148.22 – 149.20	Outagamie	7	2/1/0/2/1/0/1	1.0
	156.04 – 157.27	Outagamie/Brown	5	1/0/0/0/3/0/1	0.6
	160.23 – 161.38	Brown	7	0/1/1/1/2/1/1	0.9
	162.93 – 173.09	Brown	38	4/5/5/6/6/8/4	0.5
	174.60 – 176.68	Brown	6	2/0/0/0/0/3/1	0.4*
	180.63 – 181.79	Brown/Oconto	6	0/2/1/0/2/0/1	0.7
	184.92 – 185.73	Oconto	4	2/0/1/0/0/0/1	0.7
	188.36 – 189.12	Oconto	5	1/0/1/1/1/1/0	0.9
	190.84 – 192.02	Oconto	5	1/1/1/1/0/0/1	0.6
USH 45	61.40 – 62.19	Washington	4	0/1/0/1/1/0/1	0.7
	65.14 – 65.49	Washington	4	1/0/0/0/1/1/1	1.6
	67.23 -68.31	Washington	4	1/1/0/0/1/1/0	0.7
	69.91 – 70.17	Washington	3	0/1/0/2/0/0/0	1.7
USH 51	13.22 – 13.70	Rock	3	0/0/0/0/0/1/2	0.9
	57.17 – 57.62	Dane	4	0/1/1/0/1/1/0	1.3
USH 53	7.59 – 10.42	La Crosse	11	2/3/2/0/1/0/3	0.5
	11.33 – 12.30	La Crosse	5	0/1/1/2/0/1/0	0.7
	150.08 – 150.89	Barron	3	0/0/1/0/1/0/1	0.5
	153.90 – 154.20	Barron	3	1/2/0/0/0/0/0	1.4
	157.59 – 158.33	Washburn	4	0/1/1/1/0/1/0	0.8
	164.90 – 166.01	Washburn	4	0/2/1/0/0/0/1	0.5
	237.06 - 237.50	Douglas	3	0/0/0/0/1/1/1	1.0
USH 151	103.50- 103.77	Dane	4	0/1/0/0/0/2/1	2.1
	104.70 – 105.20	Dane	3	0/1/0/1/0/1/0	0.9
	106.22 – 107.88	Dane	7	2/2/1/1/1/0/0	0.8
	120.42 – 121.01	Columbia	3	1/1/1/0/0/0/0	0.7
	129.75 – 130.87	Dodge	4	0/1/0/1/1/1/0	0.5
	143.13 – 144.06	Dodge	4	0/0/2/0/1/0/1	0.6

TABLE 29Potential Crossover Median Crash Segments Warranting Additional Analysis (cont.)

HW	Mile Point Location	County	Number of Crashes	Crash Distribution (2001 -2007)	Crash Rate (per mile per year)
USH 151	145.97 – 146.09	Dodge	3	0/1/1/0/1/0/0	3.6
STH 23	208.29 – 208.67	Sheboygan	3	0/1/0/0/2/0/0	1.1
STH 29	80.91 – 81.46	Chippewa	4	2/0/1/0/0/0/1	1.0
	123.96 – 124.56	Clark	3	0/1/1/0/1/0/0	0.7
	132.80 – 134.08	Clark	5	0/2/1/0/0/1/1	0.6
	138.07 – 139.56	Marathon	5	0/2/2/0/0/1/0	0.5
	147.38 – 148.38	Marathon	4	1/1/1/0/0/1/0	0.6
	157.03 – 158.11	Marathon	5	0/2/1/0/0/1/1	0.7
	203.75 – 204.08	Shawano	3	1/0/2/0/0/0/0	1.3
	253.05 – 253.25	Brown	3	0/0/0/01/1/1	2.1
	254.42 – 256.05	Brown	6	0/0/0/1/1/2/2	0.5
STH 30	0.00 – 1.28	Dane	4	2/0/1/0/1/0/0	0.6
STH 35	255.71 – 256.47	St. Croix	4	0/0/0/1/1/1/1	0.8
	257.19 – 259.29	St. Croix	12	0/0/2/2/3/2/3	0.8
STH 54	124.89 – 125.37	Portage	3	0/0/0/0/1/1/1	0.9
STH 57	54.71 – 54.81	Sheboygan	3	0/0/2/0/1/0/0	4.3
STH 172	9.74 – 9.95	Brown	3	0/0/0/0/0/1/2	2.0

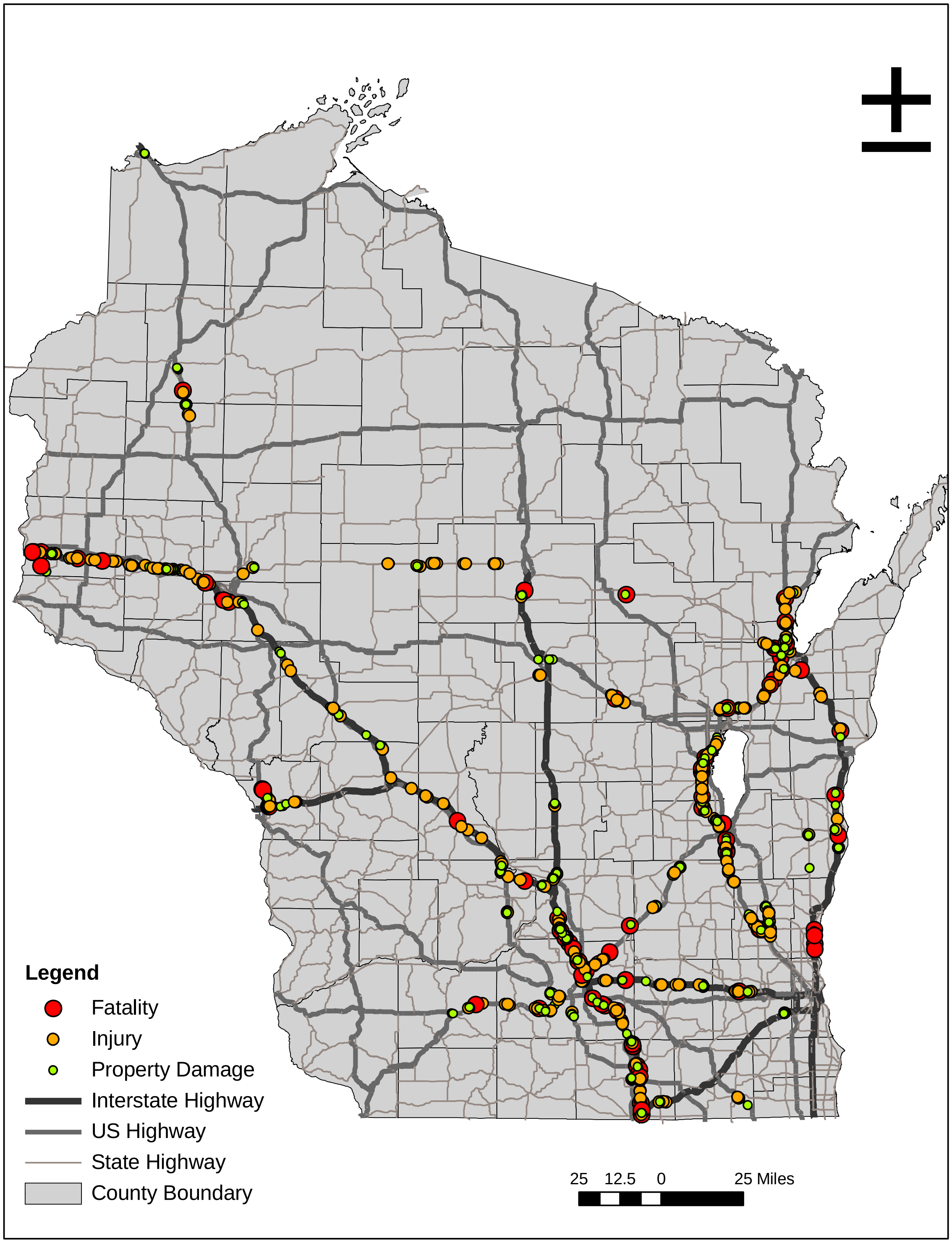


FIGURE 54Potential Crossover Median Crashes Requiring Additional Analysis

Fatal Crossover Median Crashes – Single and Multiple Vehicle

Fatal crossover median crashes are of significance due to their high cost, both financially and in terms of loss of life. Considering both single and multiple vehicle crashes over the five year period studied, 110fatal crossover median crashes occurred on the selected roadways resulting in 132fatalities. TABLE 30presents a breakdown of fatal crossover crashes by vehicles involved and crash vehicle type. FIGURE 55displays a map of the locations of the 81 fatal crossover crashes.

In an effort to improve safety and understand the attributes of these crash types, TABLE 31presents a detailed breakdown of each of the 110fatal crashes, including the location of the crash, amount of fatalities, initial causation event, reason for fatality, crash vehicle type, road condition, median width, date of crash, and age of driver.

The most common cause of a fatality was impact with a vehicle traveling in the opposite direction. Approximately 63percent of the fatalities, 69out of 110, were due to impact with an opposing direction vehicle. An additional 27fatalities were due to either a driver or passenger being ejected from a vehicle during a crash. The fact that 25percent of the fatalities were caused by ejections further stresses the well documented importance of seatbelt use.

TABLE 30Fatal Crossover Median Crashes by Vehicle Type

Total Vehicles Crossover Crash Vehicle Type		**1**	**2**	**3**	**4**	**5**	**Totals**
Single Vehicle Type	Passenger Car	33	4	1	0	0	**38**
	Truck	3	3	0	0	0	**6**
Multiple Vehicles Type	Passenger Car – Passenger Car	0	27	9	3	2	**41**
	Passenger Car – Truck	0	13	11	0	0	**24**
	Truck – Truck	0	1	0	0	0	**1**
	Totals	**36**	**48**	**21**	**3**	**2**	**110**

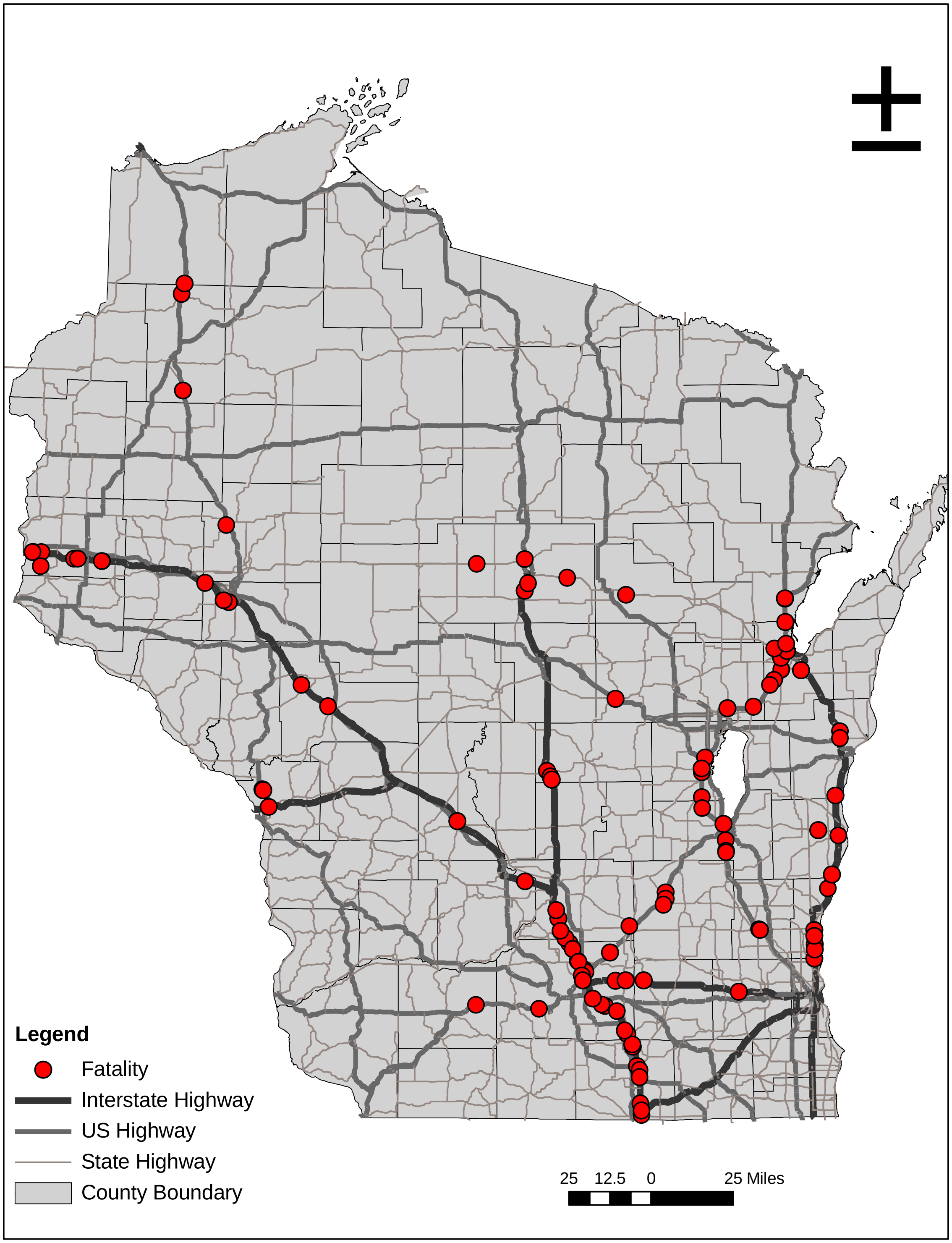


FIGURE 55Wisconsin Fatal Crossover Median Crashes (2001 – 2007)

TABLE 31Fatal Crossover Median Crashes

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
I-39	Columbia	1	Lost Control	Ejected Passenger	PC - PC	Dry	60	July 2001	63
		1	Ice	Impact with Opposing Direction Truck	PC – T	Ice	38	Dec. 2004	60
		2	Vehicle Collision	Vehicle Airborne,Impacted Opposing Direction Vehicle	PC – PC	Dry	50	Apr. 2005	54
		1	Vehicle Collision	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Apr. 2006	46
	Dane	1	Snow	Instantly Killed During Rollover	PC - PC	Snow	38	Jan. 2002	23
		1	Lost Control	Motorcyclist – Killed on Impact with Truck	PC – T	Dry	38	July 2002	57
		3	Wet Roadway	Driver – Impact; Passengers Ejected	PC – PC	Wet	38	Oct. 2002	16
		1	Lost Control	Driver Ejected	PC – PC	Dry	60	July 2003	38
		1	Vehicle Collision	Impact with Opposing Direction Truck	PC – T	Wet	60	June 2004	75
		1	Lost Control	Fatal Injuries Caused During Crash	PC	Dry	38	July 2004	18
		1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	38	June 2005	29
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	100	Sept 2005	35
		2	Ice	Impact with Opposing Direction Truck	PC – T	Ice	60	Oct 2005	49
		3	Driver Condition	Impact with Opposing Direction Vehicle	PC – T	Dry	38	Oct 05	79
		1	Barrier Collision	Vehicle Overturned, Impact with Opposing Direction Truck	PC – T	Ice	125	Oct 2005	34
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – T	Dry	60	Sept 2006	43
	Marathon	1	Vehicle Collision	Driver Ejected	PC	Dry	60	May 2003	58
		1	Wet Roadway	Passenger Killed During Rollover	PC	Wet	60	July 2003	27
	Rock	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	Oct. 2001	56
		1	Lost Control	Killed by Fire that Engulfed Truck Cab on Impact	T	Dry	60	Sep. 2003	33

TABLE 31Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
I-39	Rock	1	Barrier Collision	Fatal Injuries Caused During Crash	PC	Dry	60	Dec. 2004	54
		1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	June 2005	26
		1	Snow	Impact with Opposing Direction Truck	T – T	Snow	60	Oct 2005	31
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Oct 2005	82
		2	Lost Control	Impact with Opposing Direction Vehicle	PC - PC	Wet	60	Jan 2007	62
		1	Speeding, Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	May 2007	18
	Waushara	1	Lost Control	Passenger Ejected	PC	Dry	64	May 01	18
		1	Lost Control	Vehicle Overturned	PC	Dry	64	June 2006	67
		1	Lost Control	Vehicle Overturned	PC	Snow	64	Feb 2007	49
I-43	Brown	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	88	Sept 2006	20
	Manitowoc	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	64	June 2002	40
		2	Lost Control	Driver and Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	88	Aug. 2003	18
		1	Lost Control	Vehicle Overturned	PC	Dry	64	Aug.20 05	19
	Milwaukee	1	Lost Control	Driver Ejected	PC	Dry	50	Nov. 2001	17
	Ozaukee	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	June 2001	49
		2	Lost Control	Two Passengers Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Jan. 2002	78
		2	Driver Condition	Driver and Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Feb 2006	42
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – T	Wet	60	June 2006	42

TABLE 31Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
I-43	Ozaukee	2	Lost Control	Two Passengers Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	60	July 2006	48
	Sheboygan	1	Vehicle Collision	Fatal Injuries Caused During Crash	T	Dry	60	Oct. 2004	35
		1	Vehicle Collision	Impact with Opposing Direction Truck	PC – T	Dry	90	Sep 2005	48
I-90	La Crosse	1	Snow	Impact with Opposing Direction Truck	PC – T	Snow	60	Apr. 2002	38
I-94	Dane	1	Wet Roadway	Impact with Opposing Direction Vehicle	PC – PC	Wet	60	Nov. 2003	28
		1	Lost Control	Struck End of Bridge Guardrail on Opposing Direction's Inner Shoulder	PC	Dry	60	Dec. 2003	49
	Dunn	1	Snow	Driver Ejected	PC	Snow	50	Nov 2005	49
	Eau Claire	1	Lost Control	Fatal Injuries Caused by Rollover	PC	Dry	65	Nov. 2003	24
		1	Lost Control	Driver Ejected	PC	Dry	60	July 2005	37
		1	Lost Control	Collision with Embankment	PC	Dry	60	Apr. 2006	56
	Jackson	2	Snow	Driver and Passenger Killed on Impact with Truck	PC – T	Snow	85	Mar. 2003	20
		1	Too Fast for Conditions	Driver and Passenger Killed on Impact with Opposing Vehicle and Following Truck	PC – T	Snow	65	Feb 2006	27
	Jefferson	1	Lost Control	Passenger Ejected, Impact with Opposing Direction Vehicle	PC – PC	Dry	80	Dec 2007	27
	Juneau	1	Too Fast for Conditions	Impact with Opposing Direction Truck	T – T	Ice	60	Dec 2007	71
	Sauk	1	Snow	Driver Ejected	PC	Snow	60	Nov. 02	40
	St. Croix	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	50	Dec. 2001	60
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	28	Sep. 2002	47

TABLE 31Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
I-94	St. Croix	3	Ice	Impact with Opposing Direction Vehicle (all 3 persons)	PC – PC	Ice	50	Mar. 2003	24
		1	Lost Control	Passenger Partially Ejected	PC	Dry	50	Aug. 2004	38
		1	Vehicle Collision	Fatal Injuries Caused During Crash	T	Dry	28	Oct. 2004	52
		1	Ice	Fatal Injuries Caused During Crash	PC – PC	Ice	50	Dec. 2004	27
		2	Lost Control	Driver and Passenger Killed on Impact with Opposing Vehicle	PC – PC	Dry	28	Oct 2006	86
I-94	Waukesha	1	Wet Roadway	Passenger Ejected	PC	Wet	60	Aug.2005	46
USH 10	Waupaca	1	Lost Control	Impact with Opposing Direction Vehicle	PC - PC	Dry	60	May 2004	46
USH 18	Dane	1	Lost Control	Passenger Ejected	PC	Dry	50	Nov. 2003	19
	Iowa	1	Snow	Vehicle Rolled	T	Snow	50	Dec.2005	25
		1	Snow	Impact with Opposing Direction Vehicle	PC - T	Snow	50	Mar. 2006	17
USH 41	Brown	1	Ice	Driver Ejected	PC – PC	Ice	60	Nov. 2002	20
		1	Vehicle Collision	Driver Ejected	T	Dry	60	Aug. 2004	31
		1	Lost Control	Impact With Opposing Direction Vehicle	PC – T	Dry	60	Dec. 2004	17
		1	Vehicle Collision	Impact With Opposing Direction Truck	PC – T	Dry	60	Sep.2005	43
		1	Lost Control	Vehicle Overturned	PC	Dry	60	Nov. 2006	30
	Fond Du Lac	2	Wet Roadway	Driver and Passenger Killed on Impact with Opposing Truck	PC – T	Wet	50	Mar. 2001	57
		1	Lost Control	Driver Ejected	PC	Dry	50	Apr. 2002	20
		4	Lost Control	Driver and Three Passengers Killed on Impact with Opposing Vehicle	PC – PC	Dry	50	Apr. 2003	18
		1	Lost Control	Impact With Opposing Direction Vehicle	PC – PC	Dry	50	June 2004	21
		1	Lost Control	Driver Ejected	PC	Dry	50	May 2005	16

TABLE 31Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
	Oconto	1	Lost Control	Driver Ejected	PC	Dry	60	May 2001	20
		1	Lost Control	Vehicle Overturned – Passenger Killed	PC	Dry	60	Jan.2005	80
	Outagamie	1	Lost Control	Driver Ejected	PC	Dry	60	May 2005	24
		1	Lost Control	Driver Ejected	PC	Dry	60	Aug.2005	31
		1	Lost Control	Vehicle Overturned	PC	Dry	60	Jul. 2007	35
	Washington	1	Lost Control	Driver Ejected	PC – PC	Dry	37	Feb. 2003	46
		1	Vehicle Collision	Driver Ejected	PC	Dry	40	May 2005	34
	Winnebago	1	Vehicle Collision	Impact with Opposing Direction Vehicle[1]	PC	Dry	48	Apr. 2002	23
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	50	Feb. 2003	29
USH 41	Winnebago	1	Lost Control	Impact With Opposing Direction Vehicle	PC – PC	Fog	30	June 2004	63
		1	Lost Control	Driver Partially Ejected	T	Dry	30	Aug. 2004	67
USH 51	Dane	1	Lost Control	Pedestrian hit by vehicle	PC	Dry	50	Sep. 2006	23
		1	Driver Condition Vehicle Collision	Impact With Opposing Direction Vehicle	PC – PC	Wet	10	Mar 2007	65
	Marathon	1	Wet Roadway	Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Wet	40	Apr. 2001	66
USH 53	Chippewa	1	Lost Control	Collision with Trees	PC		80	June 2006	43
	Douglas	1	Ice	Passenger Ejected from Vehicle	PC	Ice	24	Jan.2005	28
	La Crosse	1	Wet Roadway	Impact With Opposing Direction Vehicle	PC – T	Wet	50	July 2004	17
		1	Too Fast for Condition	Impact With Opposing Direction Vehicle	PC – T	Snow	50	Feb 2006	22
	Washburn	1	Lost Control	Driver Ejected	PC	Dry	150	July 2003	36
		1	Lost Control	Fatal Injuries Caused During Crash	PC	Dry	84	Mar. 2004	68
USH 141	Brown	1	Lost Control	Driver Killed in Secondary Collision	PC	Dry	4	May 2005	86

TABLE 31Fatal Crossover Median Crashes (cont.)

HW	County	Fatal	Initial Event	Likely Fatality Cause	Crash Type[2]	Road Cond	Median Width	Month Year	Driver Age
USH 151	Columbia	2	Lost Control	2 Passengers Killed on Impact with Opposing Direction Vehicle	PC – T	Dry	90	Nov. 2002	22
	Dane	1	Vehicle Collision	Fatal Injuries Caused During Crash	PC	Dry	110	June 02	21
	Dodge	1	Lost Control	Driver Ejected	PC – T	Dry	60	Feb. 2001	15
		1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	Aug. 2001	49
		1	Lost Control	Vehicle Overturned	PC	Dry	60	Aug.20 05	86
STH 29	Brown	2	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	July 2005	31
	Marathon	1	Ice	Impact with Opposing Direction Truck	PC – T	Ice	64	Jan. 2003	47
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – T	Dry	60	June 2007	79
	Shawano	1	Snow	Impact with Opposing Direction Vehicle	PC – PC	Snow	60	Mar. 2003	21
STH 35	St. Croix	1	Lost Control	Vehicle Overturned	PC	Dry	30	May 2007	20

[1]*Impact was made with a vehicle that had attempted an illegal u-turn, causing the vehicle documented to traverse the median to the opposing roadway, without striking another vehicle. Fatality occurred in vehicle making illegal u-turn, not the crossover vehicle.*
[2]*PC = passenger car; T = truck*

Applying the warrant for fatal crossover median crashes of 0.12 fatal crossover median crashes per mile per year and at least three fatal crossover median crashes within a five year period, several potential sites are identified. As shown in TABLE 32and FIGURE 56, there are eightpotential sites with a cluster of crashes that satisfy these requirements. Sites are located in Columbia, Dane, Dodge, Fond du Lac, Rock, St. Croix, Milwaukee,Ozaukee, Eau Claire, and Winnebago counties.

TABLE 32Potential Fatal Crossover Median Crashes Requiring Additional Analysis

HW	County	Mile Point	Fatal	Initial Event	Fatality Reason	Crash Type[2]	Road Cond.	Month Year	Driver Age
I-39	Rock	23.48	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	June 05	26
		24.11	1	Snow	Impact with Opposing Direction Truck	T – T	Dry	Dec 05	31
	Dane	26.33	2	Ice	Impact with Opposing Direction Truck	PC – T	Ice	Dec 05	49
		52.64	3	Wet Roadway	Driver – Impact; 2 passengers ejected from other vehicle	PC – PC	Wet	Oct. 02	16
		53.51	1	Lost Control	Motorcyclist Killed on Impact with Truck	PC – T	Dry	July 02	57
		56.60	3	Lost Control	Both Drivers and Passenger Killed in Impact with Opposing Direction Truck	PC – T	Dry	Oct 05	79
		56.71	1	Lost Control	Fatal Injuries Caused During Crash	PC	Dry	July 04	18
		60.89	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	June 05	29
		63.06	1	Snow	Instantly Killed During Rollover	PC - PC	Snow	Jan. 02	23
		63.64	1	Lost Control	Driver Ejected	PC – PC	Dry	July 03	38
	Columbia	67.48	1	Lost Control	Ejected Passenger	PC-PC	Dry	July 01	63
		67.58	1	Vehicle Collision	Impact with opposing direction PC	PC – PC	Dry	Apr. 06	59
		68.71	1	Ice	Impact with Opposing Direction Truck	PC – T	Ice	Dec. 04	60
USH 41	Fond du Lac	93.19	1	Lost Control	Impact With Opposing Direction Vehicle	PC – PC	Dry	June 04	21
		93.59	1	Lost Control	Driver Ejected	PC	Dry	Apr. 02	20
		96.80	2	Wet Roadway	Driver and Passenger Killed on Impact with Opposing Truck	PC – T	Wet	Mar. 01	57
	Winnebago	120.56	1	Lost Control	Impact With Opposing Direction Vehicle	PC – PC	Fog	June 04	63
		121.51	1	Lost Control	Driver Partially Ejected	T	Dry	Aug. 04	67
		125.17	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	Feb. 03	29

TABLE 32Potential Fatal Crossover Median Crashes Requiring Additional Analysis (cont.)

HW	County	Mile Point	Fatal	Initial Event	Fatality Reason	Crash Type[2]	Road Cond.	Month Year	Driver Age
I-43	Milwaukee	83.12	1	Lost Control	Driver Ejected	PC	Dry	Nov. 01	17
	Ozaukee	84.63	2	Lost Control	Impact With Opposing Direction Vehicle	PC – PC	Dry	Jan. 02	78
		86.00	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Wet	Jun. 06	42
		87.60	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	Jun. 01	50
I-94	St. Croix	2.72	1	Vehicle Collision	Fatal Injuries Caused During Crash	T	Dry	Oct. 04	52
		2.72	2	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	Oct. 06	86
		3.16	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	Sep. 02	47
		4.88	1	Lost Control	Passenger Partially Ejected	PC	Dry	Aug. 04	38
	Eau Claire	65.44	1	Lost Control	Collision with Embankment	PC	Dry	Apr. 06	57
		65.77	1	Lost Control	Passenger Ejected	PC	Fog	Jul. 05	37
		67.14	1	Lost Control	Vehicle Rolled over	PC	Dry	Nov. 03	25
USH 151	Dodge	133.26	1	Lost Control	Vehicle Overturned	PC	Dry	Aug 05	86
		135.23	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	Aug. 01	49
		137.20	1	Lost Control	Driver Ejected	PC – T	Dry	Feb. 01	15

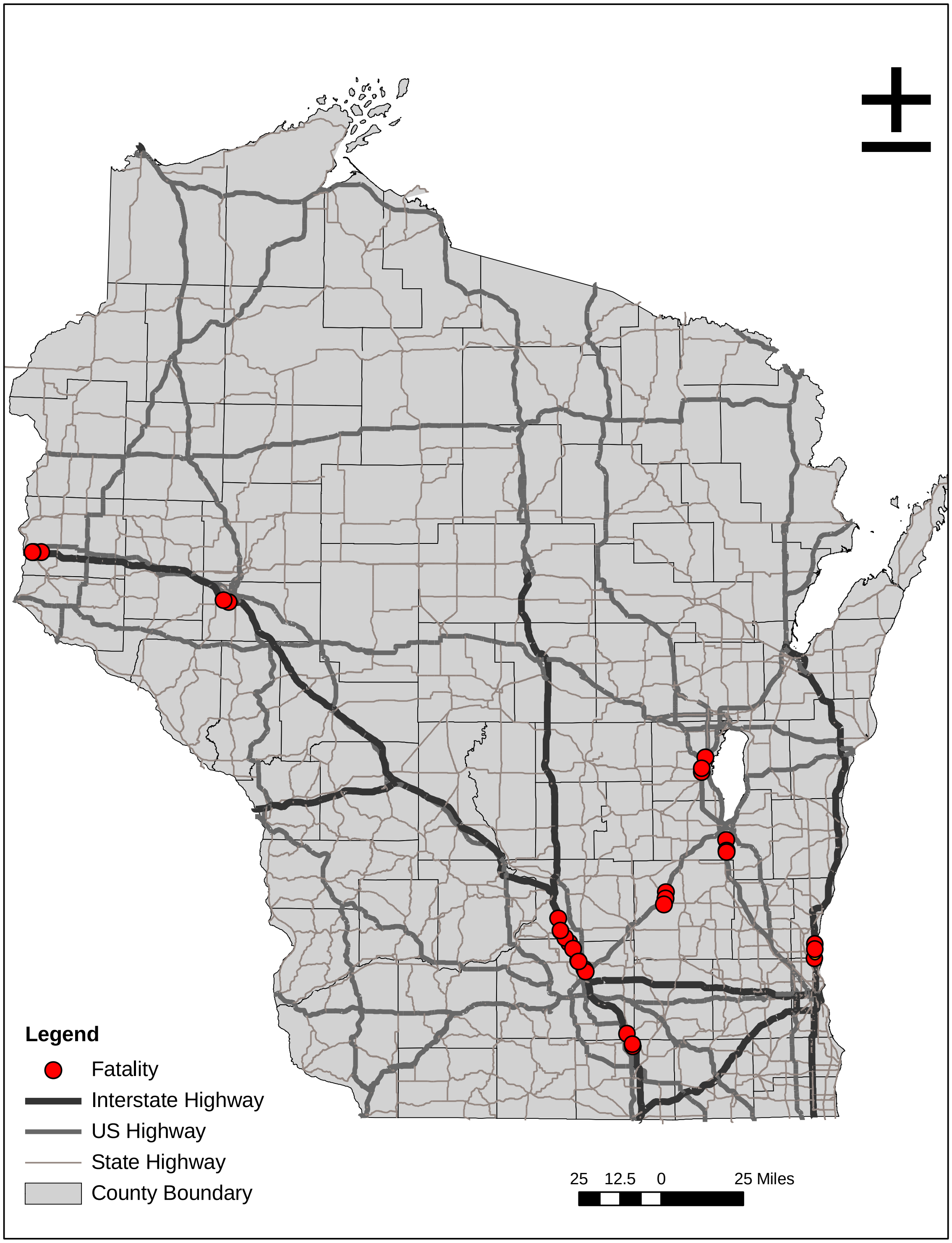


FIGURE 56Potential Fatal Crossover Median Crashes Warranting Additional Analysis

CHAPTER VI
CONCLUSIONS & RECOMMENDATIONS

Crossover median crashes are a concern for transportation officials across the country. The nature of a crossover crash; a vehicle that traverses a median and collides with another vehicle either head-on or side-swipe; creates a situation that is high cost, both financially and in terms of human injury. An initial report that quantified the amount of crossover crashes that occurred in Wisconsin for the three year period between 2001 and 2003 was published by Noyce and McKendry in June 2005 (6). A follow-up report was published by Witte et al. (7) in June 2007 to include five years of crash data between 2001 and 2005, complying with the Wisconsin definition of a crossover median crash. This report expands the Witte et al. (7) study with crash data from 2001 through 2007.

In Wisconsin, median barriers are installed on highways that meet a certain median width and ADT requirement. Under these requirements, highway segments with a speed limit greater than 55 mph are not required to install median barrier with a median width greater than 60 feet,or under specific ADT conditions for median widths of less than 60 feet. Nevertheless, many crossover crashes are observed on highway segments that do not meet the current warrants for median barrier protection.

There was a need in Wisconsin to quantify crossover crashes and determine at what locations, and if the standards for median barrier installation needed to be re-evaluated. The objectives of this research were to evaluate crossover crashes in Wisconsin, determine the relationship between crossover crashes, ADT, and median width, and quantify the differences between various crash rate warrant models. It was hypothesized that crossover median crashes remain a significant problem in Wisconsin; that crossover median crash rates would decrease as median widths increased and increase as ADT increased; that there were significant differences in the number of segments and overall length of highway identified for additional median safety analysisunder various definitions of a median crossover crash; and that an improved median safety warrant could be developed.

Crash reports for Wisconsin highways were reviewed to quantify crossover median crashes. Median width and ADT data for each selected crash site was analyzed to determine any potential correlation with crossover median crash rates. Data from each selected crash report were analyzed to determine which factors would most likely affect a crossover median crash and which factors would most likely increase the severity of a crossover median crash.

Hypothesis Analysis

Following the study and analysis of crossover median crashes, the following conclusions were made regarding each of the study hypotheses:

Hypothesis1
Crossover median crashes remain a significant problem for the state of Wisconsin.

Three-hundred and nine crossover median crashes where identified in this research over a seven year study period, having resulted in over 184 injury and 64 fatal crashes. The number of annual crossover median crashes increased from 30 in 2001to 70 in 2005 and decreased to 46 in 2006 and 33 in 2007. This decrease could be attributed to the installation of median barriers (concrete and cable) at the locations identified in the previous studies.The magnitude of crossover median crashes, an average of approximately 45 crashes per year over the seven year study period, indicates that this crash type continues to be a problem in Wisconsin.If one includes single vehicle crossover median crashes, this number grows to approximately 235 crashes per year. Tire track evidence associated with unreported crashes indicates even greater numbers.

Fourteen roadway segments in Wisconsin exceeded the benchmark of 0.5 crossover median crashes per mile per yearand at least three crossover median crashes within a five year period applying the Wisconsin definition of a median crossover crash. Two sites exceeded the 0.12 fatal crossover median crashes per mile per year benchmark and recorded at least three fatal crossover median crashes within a five year period applying this definition of a median crossover crash.Each of these sites require further investigation.

Hypothesis2
Crossover median crash rates showed some correlation to median width and decreased as median width increased. Crossover median crash rate also displayed some correlation to ADT and increased with increasing ADT.

Two crash rates, the number of crossover median crashes per mile per year and the number of crossover median crashes adjusted by vehicle miles traveled showed some correlation to median width for homogeneous median width highway segments. The line of best-fit through both data sets showed a slight decrease in crossover median crash rate as median width increasedbut the coefficient of determination was insignificant. The number of crossover median crashes per mile per year showed a stronger correlation to ADT although the statistical correlation is still weak. The wide range of ADT and significant mileage of 60 foot medians impacts the sensitivity of this analysis.

Hypothesis3
Locations warranting additional median safety analysisbased on the Wisconsincrash rate criteriaare sensitive to the definition of a crossover median crash.

Fourteen roadway segments in Wisconsin exceeded the benchmark of 0.5 crossover median crashes per mile per year, and at least three crossover median crashes within a five year period,consideringonly multiple vehicle crashes. Altering this definition to include single vehicle crashes resulted in an increase to 149 in the number ofpotential sites and overall length of highway identified foradditional analysis. Two sites exceeded the Wisconsin fatal warrant of 0.12 fatalcrossover median crashes per mile per year, and at least three fatal crossover median crashes within a five year period. Fatal crashes are less sensitive to the definition because most involve multiple vehicle crashes; however, ninepotential sites were identified when single vehicle crashes were included. It is clear that the definition of crossover median crashes can significantly effect the selection of sites requiring additional analysis.

Hypothesis4
The current Wisconsin median safety guidelines should be re-evaluated. Alternative guidelines for application in the short-term have been developed. Further research is required to develop longer-term median safety guidelines.

Median width and ADT combinations for each of the observed crossover median crashes were plotted. Approximately 68 percent of the selected crossover median crashes occurred on roadways with median widths that did not warrant a median barrier. Of these crashes, many occurred on roadways with typical median widths of 50 or 60 feet and common cross-slopes. These results suggest that the current median barrier standards in the state of Wisconsin should be re-evaluated.

Conclusions
Several important findings can be summarized from this research:

Crossover Median Crash Severity

- A significant amount of crossover median crashes involved either personal injury or a fatality. Personal injury crashes accounted for 60percent of crossover median crashes, while 21 percent of crossover median crashes involved a fatality.

Crossover Median Crash Actions, Causes, and Crossover Extent

- Most crossover median crashes involved vehicles that were going straight on the roadway prior to the crash. Vehicles that were going straight accounted for 74percent of the crossover crashes. The next most common action was changing lanes at10 percent.
- A majority of the crossover median crashes were the result of either a loss of control of a vehicle on dry pavement or loss of control of a vehicle due to weather. Loss of control on dry pavement was the initial causation for 38percent of crossover median crashes, while loss of control due to weather was the initial causation for 51 percent of the crossover median crashes. Vehicle collision was the initial causation for 10percent of crashes.
- Winter weather road conditions were most directly responsible for loss of control due to weather. Ice was responsible for 31percent of weather-related loss of control crashes, while snow accounted for 46percent of weather-related loss of control crashes. Wet roadways were the cause of only 23percent of weather-related loss of control crashes. The five month period between December and April accounts for 72percent of weather-related loss of control crashes. Loss of control on dry pavement crashes are more evenly distributed, with the largest five month period, Junethrough October, containing only 53percent of the total amount of loss of control on dry pavement crossover crashes.This is consistent with weather being identified as a significant variable leading to crossover median crashes in the multivariate statistical analysis conducted by Lu et. al (*19*).

- Lost control due to weather crashes resulted in more serious injury crashes but less fatal crashes than loss of control on dry pavement crashes. Weather-related loss of control crashes accounted for 59percent of all property damage only crashes, 54percent of personal injury crashes, and 36percent of fatal crashes. Conversely, lost control on dry pavement was the initial causation for 30 percent of property damage only crashes, 34percent of personal injury crashes, and 56percent of fatal crashes.

Crash Demographics

- Crossover median crashes are more of a problem for younger drivers. Drivers under the age of 25 account for approximately 1.8 times as many crossover median crashes as does any other age bracket. Drivers under the age of 25 were involved in 33percent of all crossover median crashes.
- Alcohol was a factor in 6 percent of the crossover median crashes. A majority of alcohol-related crossover crashes were caused by a loss of control on dry pavement, contributing to 53percent of the alcohol crossover crash total. Drivers under the age of 25 were involvedin 24percent of all alcohol-related crossover crashes. Personal injury crashes account for 53percent of all alcohol-related crossover crashes, while 35percent of alcohol-related crossover crashes were fatal.

Fatal Crashes

- All of the fatalities involved an impact with an opposing direction vehicle. At least sevenof the vehicle occupantswere ejected from the vehicle, which further emphasizes the need for vehicle occupants to wear seat belts.

Recommendations

Pennsylvania (*33*) and Texas (*34*) have recently developed median barrier guidelines that identify cost effective installation sites based on the combination of median width and ADT as well as crash rate. These procedures were developed using a cost/benefit evaluation and contain inherent procedures for prioritizing median barrier installation projects. It is recommended that a similar comprehensive study be undertaken in Wisconsin. This study will require development of crash frequency and severity probability prediction models for crossover median and median barrier crashes as well as determining cost and benefit information. Specific values of injury and fatality benchmark values can be considered to validate or calibrate the Caltrans values used to date. This research will require additional median geometric data (cross-slope; surface material; interchange proximity) on selected locations.

Site Summary

TABLE 33presents again the sites identified in Chapter 4 that met the Wisconsin definition for crossover median crashes of all severities.Recall that 14 sites were identified in this research.

TABLE 33Identified Median Crossover Crash Segments

HW	Mile Point Location	County	Number of Crashes	Crash Distribution (2001 -2007)	Crash Rate (per mile per year)
I-39	13.32 – 14.23	Rock	4	1/0/1/0/1/0/1	0.6
	23.48 – 24.28	Rock	4	0/0/0/1/2/1/0	0.7
	36.67 – 37.29	Dane	3	0/1/0/1/0/1/0	0.7
	67.48 – 69.74	Columbia	8	1/0/1/1/2/2/1	0.5
I-43	89.72 – 90.33	Ozaukee	3	0/0/0/2/0/1/0	0.7
I-94	2.72 – 3.16	St. Croix	3	0/1/0/1/0/1/0	1.0
	16.62 – 17.45	St. Croix	3	0/0/1/1/0/0/1	0.5
	170.71 – 171.38	Juneau	3	0/1/2/0/1/0/0	0.9
	266.19 – 266.98	Jefferson	3	1/0/1/1/0/0/0	0.5
USH 12	258.45 – 259.00	Dane	4	0/0/1/2/0/1/0	1.0
USH 41	120.56 – 121.86	Winnebago	5	0/0/0/2/0/1/2	0.6
	125.17 – 126.52	Winnebago	8	0/0/3/2/3/0/0	0.9
	130.40 – 130.57	Winnebago	3	0/0/0/1/1/1/0	2.5
	180.63 – 181.46	Brown	3	0/1/0/0/2/0/0	0.5

TABLE 34presents the sites that meet the fatal crash definition. TABLE 35repeats the 16 total sites considering both warrants with added location information. TABLE 36provides a summary of the sites identified in the previous studies. Note that TABLE 36sites were identified using the previous definition that included single vehicle crashes. The shaded lines indicate sites that were identified in both studies.

It is recommended that the sites in TABLE 35be considered for safety improvements, potentially median barrier. Sites presented in TABLE 29and TABLE 32of Chapter 5, should be monitored for future crash history, and be considered for low-cost safety improvements in an attempt to minimize future crashes at these locations. These countermeasures may include shoulder improvements, shoulder rumble strips and/or enhanced pavement marking. Other potential countermeasures should also be considered.TABLE 37 summarized the measures that have been taken at the crash segments identified in TABLE 33.

TABLE 34Identified Fatal Median Crossover Crash Segments

HW	County (Crash Rate)	Mile Marker	Fatal	Initial Event	Fatality Reason	Crash Type[2]	Road Cond.	Month Year	Driv. Age
I-39	Rock/ Dane (0.15)	23.48	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	June 05	26
		24.11	1	Snow	Impact with Opposing Direction Truck	T – T	Dry	Dec 05	31
		26.33	2	Ice	Impact with Opposing Direction Truck	PC – T	Ice	Dec 05	49
	Dane/ Columbia (0.13)	60.89	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	June 05	29
		63.06	1	Snow	Instantly Killed During Rollover	PC - PC	Snow	Jan. 02	23
		63.64	1	Lost Control	Driver Ejected	PC – PC	Dry	July 03	38
		67.48	1	Lost Control	Ejected Passenger	PC-PC	Dry	July 01	63
		67.58	1	Vehicle Collision	Impact with Opposing Direction Vehicle	PC – PC	Dry	Apr. 2006	46
		68.71	1	Ice	Impact with Opposing Direction Truck	PC – T	Ice	Dec. 04	60

TABLE 35Segments Identified with Reference Location Information

Highway	County	Segment					
		Beginning			Ending		
		RP	MP	MM	RP	MP	MM
USH 12	Dane	012E 340 000	258.45	--	012E 340 100	259.00	--
IH 39	Rock	039N 218 000	13.32	175	039N 220 000	14.23	174
IH 39	Rock	039N 227 095	23.48	165	039N 228 000	24.28	164
IH 39	Rock/Dane*	039N 227 095	23.48	165	039N 228 172	26.33	161
IH 39	Dane	039N 235 000	36.67	151	039N 235 000	37.29	151
IH 39	Dane/ Columbia	039N 256 241	60.89	127	039N 262 053	68.71	118
IH 39	Columbia	039N 260 000	67.48	121	039N 262 000	69.74	118
USH 41	Winnebago	041N 101D000	120.56	118	041N 01D000	121.86	119
USH 41	Winnebago	041N 106 000	125.17	122	041N 07M000	126.52	124
USH 41	Winnebago	041N 108 000	130.4	128	041N 110 000	130.57	128
USH 41	Brown	041N 175D 000	180.63	178	041N177M000	181.46	179
IH 43	Ozaukee	043N 092G 000	89.72	90	043N 092G 000	90.33	91
IH 94	St. Croix	094E 003M000	2.72	--	094E 003M000	3.16	--
IH 94	St. Croix	094E 016M000	16.62	17	094E 016M000	17.45	18
IH 94	Juneau	094E 068T000	170.71	69	094E 069K000	171.38	70
IH 94	Jefferson	094E 267M000	266.19	267	094E 267M080	266.98	268

* Segment identified through fatal crash segment warrant; overlaps with shorter segment indentified though total crash segment warrant.

TABLE 36Segments Identified in Previous Studies(6,*7*)

Highway	County	Segment					
		Beginning			Ending		
		RP	MP	MM	RP	MP	MM
USH 12	Dane	012E 340 000	258.45	---	012E 340 100	259.00	---
IH 39	Rock	039N 212 000	6.97	181	039N 213 000	7.94	180
IH 39	Rock/ Dane	039N 227 095	23.48	165	039N 228 172	26.33	161
IH 39	Dane/ Columbia	039N 248 000	49.72	138	039N 253 000	55.21	132
IH 39	Dane	039N 250 060	52.64	135	039N 254 000	56.60	131
IH 39	Dane/ Columbia	039N 254 000	56.69	131	039N 263 000	72.00	116
IH 39	Dane/ Columbia	039N 256 241	60.89	127	039N 262 053	68.71	118
IH 39	Columbia	039N 260 000	67.48	121	039N 262 053	69.00	118
USH 41	Fond du Lac	041N 065G000	89.51	87	041N 073M000	96.30	94
USH 41	Fond du Lac	041N 081 000	102.56	100	041N 082 000	103.91	102
USH 41	Fond du Lac	041N 086M000	108.59	106	041N 088M000	110.37	109
USH 41	Winnebago	041N 091 000	112.89	110	041N 112 000	132.62	130
USH 41	Winnebago	041N 106 000	125.17	122	041N 108 151	128.49	127
USH 41	Brown	041N 151 000	163.55	159	041N 155M000	167.31	163
USH 41	Brown	041N 158C000	169.04	---	041N 163A000	172.29	---
USH 41	Brown	041N 177M000	180.63	178	041N 177M085	181.46	180
USH 53	LaCrosse	053N 011G000	6.56	---	053N 018D000	13.87	---
IH 90	Juneau	090E 069K000	69.00	69	090E 069K056	69.58	70
IH 94	Dunn	094E 52G000	52.10	52	094E 57T000	57.61	58
IH 94	Jefferson	094E 267M000	266.19	267	094E 267M080	266.98	268
IH 94	Waukesha	094E283M159	284.41	285	094E 287G000	286.39	287
USH 151	Dane	151N 082 000	103.52	---	151N 090K000	110.61	---
USH 151	Dodge	151N 116 000	132.23	---	151N 122M000	137.80	---

* Shaded rows overlap sites in TABLE 33, TABLE 34, and TABLE 35.

TABLE 37Measures Taken at Segments Identified in Current Study

Highway	County	Mileposts Begin	Mileposts End	Measures Taken
USH 12	Dane	258.45	259.00	Programmed for 2009
IH 39	Rock	13.32	14.23	Unavailable
IH 39	Rock	23.48	24.28	Programmed for 2010
IH 39	Rock/Dane	23.48	26.33	Programmed for 2010
IH 39	Dane	36.67	37.29	Unavailable
IH 39	Dane/ Columbia	60.89	68.71	Programmed for 2010
IH 39	Columbia	67.48	69.74	Programmed for 2010
USH 41	Winnebago	120.56	121.86	Scheduled for concrete barrier in 2014
USH 41	Winnebago	125.17	126.52	Scheduled for concrete barrier in 2013
USH 41	Winnebago	130.4	130.57	Scheduled for concrete barrier in 2014
USH 41	Brown	180.63	181.46	Limits of a proposed cable barrier project in 2010 can be extended to include this segment
IH 43	Ozaukee	89.72	90.33	Unavailable
IH 94	St. Croix	2.72	3.16	Cable barrier programmed for Fall 2011
IH 94	St. Croix	16.62	17.45	Cable barrier programmed for Spring/Summer 2011
IH 94	Juneau	170.71	171.38	Unavailable
IH 94	Jefferson	266.19	266.98	Unavailable

Discussion

The fact that several states, including California and Wisconsin, do not include single vehicle crashes in their definition of crossover median crashes is concerning to the authors. Because a single vehicle traversed the median and entered or crossed the opposing lane of traffic without impacting an opposing vehicle does not reduce the significance of this event. This significance is especially true when using crash data to identify potentially high crash segments. These single vehicle crashes are simply those that were fortunate enough to find a gap in the opposing traffic at the time of the median crossover or to have opposing vehicles make an emergency maneuver to avoid the collisions. A fraction of a second could have changed these single-vehicle crashes into multiple-vehicle crashes.

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APPENDIX A

Analysis of Homogeneous Median Width Segments of Studied Highways

TABLE A-1 Homogeneous Median Width Segment Analysis

Hwy	County	MP1	MP2	Median Width	CMCs	Length (miles)	ADT (vpd)	VMT	Crash Rates per mi/yr	Crash Rates per VMT
I-39	Columbia	64.60	69.21	60	35	4.610	69000	813276608	1.08	4.30
		69.21	72.10	38	6	2.890	63000	465507473	0.30	1.29
		72.10	90.42	50	17	18.320	26000	1217831160	0.13	1.40
	Marathon	166.01	175.07	90	6	9.060	25000	579103875	0.09	1.04
		175.07	182.38	60	8	7.310	29000	542005433	0.16	1.48
I-39/ I-90	Dane	25.42	33.13	60	8	7.710	58000	1143327465	0.15	0.70
		33.13	35.50	100	5	2.370	41000	248439398	0.30	2.01
		35.50	40.94	60	13	5.440	42000	584166240	0.34	2.23
		40.94	42.58	125	4	1.640	46600	195397062	0.35	2.05
		42.58	46.87	60	8	4.290	59700	654816913	0.27	1.22
		46.87	49.73	50	3	2.860	68500	500892893	0.15	0.60
		49.73	51.96	60	5	2.230	64200	366039671	0.32	1.37
		51.96	55.21	38	9	3.250	59000	490256813	0.40	1.84
		55.21	56.69	110	6	1.480	59800	226282602	0.58	2.65
		56.69	63.68	38	30	6.990	65000	1161659363	0.61	2.58
		63.68	64.60	60	8	0.920	67000	157598070	1.24	5.08
I-39/ I-90	Rock	0.00	25.42	60	59	25.420	47750	3103395934	0.33	1.90
I-39/ USH 51	Marquette	90.42	94.69	50	1	4.270	15000	163759876	0.03	0.61
		94.69	96.86	64	2	2.170	16600	92099248	0.13	2.17
		98.10	99.41	64	0	1.310	--	--	--	--
		99.41	101.71	132	0	2.300	--	--	--	--
		101.71	106.41	80	1	4.700	13300	159822443	0.03	0.63
		106.41	107.71	64	3	1.300	13300	44206207	0.33	6.79
	Portage	133.08	157.29	64	17	24.210	19000	1176079433	0.10	1.45
		157.29	166.01	90	2	8.720	18700	416913882	0.03	0.48
	Waushara	119.08	133.08	64	6	14.000	14000	501123000	0.06	1.20
I-43	Brown	169.52	177.79	64	10	8.270	23500	496891579	0.17	2.01
		177.79	186.74	88	8	8.950	29500	675045919	0.13	1.19
		186.74	187.48	64	0	0.740	--	--	--	--
		187.48	189.77	16	2	2.290	34500	201996034	0.12	0.99
	Manitowoc	135.62	148.68	64	8	13.060	21500	717909833	0.09	1.11
		148.68	156.02	88	4	7.340	18000	337797810	0.08	1.18
		156.02	169.52	64	8	13.500	17000	586774125	0.08	1.36
	Ozaukee	85.56	98.39	60	17	12.830	48000	1574548920	0.19	1.08
		98.86	110.86	90	7	12.000	25500	782365500	0.08	0.89
	Rock	0.00	0.63	12	1	0.630	17600	28349244	0.23	3.53
		0.63	11.62	66	12	10.990	15000	421480238	0.16	2.85
	Walworth	11.62	28.98	40	4	17.360	17450	774521391	0.03	0.52
		28.98	31.49	80	0	2.510	--	--	--	--
		31.49	33.97	90	0	2.480	--	--	--	--
		33.97	42.99	100	2	9.020	17300	398970611	0.03	0.50
	Waukesha	42.99	58.95	70	13	15.960	46500	1897466445	0.12	0.69
	Sheboygan	110.86	118.74	90	5	7.880	27000	543974130	0.09	0.92
		118.74	123.96	60	7	5.220	28000	373694580	0.19	1.87
		123.96	125.48	40	3	1.520	32000	124360320	0.28	2.41
		125.48	135.62	60	9	10.140	23000	596285235	0.13	1.51
	Milwaukee	64.61	64.89	36	0	0.280	65500	46890795	0.00	0.00

TABLE A-1 Homogeneous Median Width Segment Analysis (cont.)

Hwy	County	MP1	MP2	Median Width	CMCs	Length (miles)	ADT (vpd)	VMT	Crash Rates per mi/yr	Crash Rates per VMT
I-90	La Crosse	0.28	6.82	60	11	6.540	27000	451470915	0.24	2.44
		6.82	7.71	200	0	0.890	--	--	--	--
		7.71	8.34	60	2	0.630	22900	36886232	0.45	5.42
		8.34	9.21	80	1	0.870	26100	58056122	0.16	1.72
		9.21	10.45	300	0	1.240	--	--	--	--
		10.45	20.28	60	12	9.830	21200	532816473	0.17	2.25
	Monroe	20.28	27.75	60	3	7.470	15000	286483838	0.06	1.05
		27.75	28.61	140	1	0.860	17000	37379685	0.17	2.68
		32.13	37.17	70	3	5.040	16000	206176320	0.09	1.46
		37.17	37.82	250	1	0.650	15000	24928312	0.22	4.01
		37.82	52.18	60	7	14.360	25000	917873250	0.07	0.76
I-90/ I-94	Columbia	203.23	207.73	120	4	4.500	36000	414193500	0.13	0.97
		207.73	211.04	100	3	3.310	51000	431604837	0.13	0.70
		211.04	212.94	150	1	1.900	56000	272038057	0.08	0.37
	Juneau	153.98	179.35	60	25	25.370	31500	2043239546	0.14	1.22
		179.35	180.69	120	0	1.340	--	--	--	--
		180.69	185.52	60	3	4.830	34000	419869398	0.09	0.71
		185.52	187.83	70	2	2.310	35000	206713148	0.12	0.97
	Sauk	187.83	189.21	60	3	1.380	37000	130547655	0.31	2.30
		189.21	191.60	90	3	2.390	36900	225482245	0.18	1.33
		191.60	203.23	60	13	11.630	38000	1129929998	0.16	1.15
I-94	Dunn	31.48	34.50	50	2	3.020	29200	225464442	0.09	0.89
		35.86	56.58	50	49	20.720	30500	1615763730	0.34	3.03
	Eau Claire	56.58	61.73	60	6	5.150	26000	342348825	0.17	1.75
		61.73	64.42	120	4	2.690	22700	156122825	0.21	2.56
		64.42	67.78	60	7	3.360	28700	246552516	0.30	2.84
		67.78	68.66	175	0	0.880	--	--	--	--
		68.66	72.59	60	11	3.930	24000	241152660	0.40	4.56
		72.59	74.63	255	1	2.040	28000	146041560	0.07	0.68
		74.63	80.66	60	3	6.030	28000	431681670	0.07	0.69
		80.66	81.27	155	0	0.610	--	--	--	--
		81.27	83.49	60	2	2.220	30000	170279550	0.13	1.17
		83.49	84.18	150	1	0.690	30000	52924725	0.21	1.89
	Jackson	94.09	100.84	60	6	6.750	22000	379677375	0.13	1.58
		102.58	104.46	85	2	1.880	22000	105747180	0.15	1.89
		104.82	116.17	100	7	11.350	23500	681949144	0.09	1.03
		117.77	126.02	350	2	8.250	23800	502017863	0.03	0.40
		126.02	131.95	90	3	5.930	25000	379038188	0.07	0.79
	Monroe	131.95	146.90	60	12	14.950	25000	955585313	0.11	1.26
	St. Croix	2.67	3.43	28	6	0.760	64000	124360320	1.13	4.82
		3.43	5.37	50	6	1.940	52000	257924940	0.44	2.33
		5.37	7.15	76	0	1.780	--	--	--	--
		7.15	8.63	110	4	1.480	39700	150224403	0.39	2.66
		8.63	10.91	50	3	2.280	40000	233175600	0.19	1.29
		10.91	12.45	150	0	1.540	--	--	--	--
	St. Croix	12.45	25.27	50	26	12.820	35000	1147213725	0.29	2.27
		25.27	27.30	100	0	2.030	--	--	--	--
		27.30	31.48	50	4	4.180	28500	304585628	0.14	1.31
	Dane	233.77	234.35	60	0	0.580	58000	86009070	0.00	0.00
		239.05	240.06	450	0	1.010	--	--	--	--
		240.27	253.22	60	17	12.950	35000	1158846938	0.19	1.47

TABLE A-1 Homogeneous Median Width Segment Analysis (cont.)

Hwy	County	MP1	MP2	Median Width	CMCs	Length (miles)	ADT (vpd)	VMT	Crash Rates per mi/yr	Crash Rates per VMT
I-94	Jefferson	253.22	256.24	60	3	3.020	35000	270248475	0.14	1.11
		256.24	259.19	100	1	2.950	35000	263984437	0.05	0.38
		259.19	277.77	60	28	18.580	36000	1710158940	0.22	1.64
	Waukesha	277.77	289.52	60	24	11.750	60000	1802508750	0.29	1.33
STH 172	Brown	5.51	6.48	60	2	0.970	12000	29760570	0.29	6.72
		7.94	11.63	60	5	3.690	39000	367941893	0.19	1.36
STH 23	Iowa	23.65	27.14	57	1	3.490	12500	111538219	0.04	0.90
		27.14	27.76	80	0	0.620	--	--	--	--
	Sheboygan	198.51	208.78	60	7	10.270	19750	518591994	0.10	1.35
STH 29	Chippewa	78.45	79.80	26	0	1.350	--	--	--	--
		79.80	82.37	40	4	2.570	18000	118275255	0.22	3.38
		82.37	103.32	60	19	20.950	13250	709721841	0.13	2.68
	Clark	103.32	120.64	60	9	17.320	10000	442829100	0.07	2.03
		121.83	133.54	60	16	11.710	10250	306880311	0.20	5.21
	Marathon	133.54	156.44	60	19	22.900	11300	661610198	0.12	2.87
		156.44	161.53	50	7	5.090	14000	182194005	0.20	3.84
		162.19	165.99	84	0	3.800	--	--	--	--
		165.99	166.46	40	0	0.470	17900	21509938	0.00	0.00
		171.59	172.31	90	0	0.720	--	--	--	--
		172.31	185.54	60	5	13.230	14000	473561235	0.05	1.06
		190.02	193.42	60	1	3.400	10100	87798795	0.04	1.14
	Shawano	193.42	248.91	60	27	55.490	9700	1376178358	0.07	1.96
	Brown	248.91	258.04	60	10	9.130	22300	520551743	0.16	1.92
STH 30	Dane	0.00	0.48	20	1	0.480	32000	39271680	0.30	2.55
		0.48	0.62	34	2	0.140	37000	13243965	2.04	15.10
		0.62	2.71	260	2	2.090	32000	170995440	0.14	1.17
STH 35	St. Croix	255.04	256.65	42	4	1.610	10900	44868406	0.35	8.91
		256.65	262.81	30	14	6.160	11000	173245380	0.32	8.08
STH 441	Calumet	4.38	7.08	64	3	2.700	6750	46596769	0.16	6.44
	Outagamie	7.08	8.49	64	1	1.410	8000	28840140	0.10	3.47
	Winnebago	2.37	4.38	64	1	2.010	44000	226118970	0.07	0.44
STH 54	Portage	116.98	124.86	60	3	7.880	10700	215574933	0.05	1.39
STH 57	Brown	130.92	132.96	24	2	2.040	10400	54244008	0.14	3.69
	Ozaukee	15.90	19.20	28	1	3.300	24000	202494600	0.04	0.49
		31.33	41.62	50	2	10.290	8500	223626137	0.03	0.89
	Sheboygan	41.62	42.51	50	0	0.890	--	--	--	--
		42.51	50.70	60	7	8.190	9000	188458043	0.12	3.71
		50.70	54.71	120	2	4.010	10600	108677216	0.07	1.84
		54.71	65.79	60	3	11.080	10000	283287900	0.04	1.06
USH 10	Portage	179.89	182.60	20	4	2.710	13900	96310216	0.21	4.15
	Waupaca	196.81	201.88	99	0	5.070	--	--	--	--
		201.88	203.03	30	3	1.150	6800	19993785	0.37	15.00
		203.03	219.39	60	16	16.360	14000	585598020	0.14	2.73
	Winnebago	240.29	243.33	60	2	3.040	13650	106094898	0.09	1.89
		244.92	245.64	48	1	0.720	--	--	--	--
		245.64	247.56	64	2	1.920	46400	227775744	0.15	0.88
	Calumet	249.80	252.98	60	1	3.180	11400	92687301	0.04	1.08

TABLE A-1 Homogeneous Median Width Segment Analysis (cont.)

Hwy	County	MP1	MP2	Median Width	CMCs	Length (miles)	ADT (vpd)	VMT	Crash Rates per mi/yr	Crash Rates per VMT
USH 12	Dane	252.13	254.15	50	3	2.020	34700	179212835	0.21	1.67
		254.15	258.15	60	7	4.000	49175	502912725	0.25	1.39
		258.15	259.18	48	8	1.030	76725	202051643	1.11	3.96
		268.04	273.50	50	7	5.460	45360	633219023	0.18	1.11
	Walworth	321.89	339.45	60	15	17.560	13000	583654890	0.12	2.57
USH 14	Dane	132.26	132.98	16	1	0.720	28000	51544080	0.20	1.94
		132.98	138.48	60	7	5.500	18900	265774163	0.18	2.63
USH 141	Oconto	28.46	36.43	60	6	7.970	12000	244527570	0.11	2.45
USH 151	Dane	94.10	99.80	24	3	5.700	50000	728673750	0.08	0.41
		101.36	107.25	60	14	5.890	29000	436718468	0.34	3.21
		107.25	111.16	110	2	3.910	18000	179944065	0.07	1.11
		111.16	115.07	500	3	3.910	20000	199937850	0.11	1.50
	Columbia	115.07	121.87	900	5	6.800	16000	278174400	0.11	1.80
	Dodge	122.87	148.30	60	31	25.430	15000	975272288	0.17	3.18
	Iowa	36.15	49.06	57	6	12.910	8000	264061140	0.07	2.27
USH 18	Iowa	57.74	74.82	50	22	17.080	19000	829716510	0.18	2.65
	Dane	74.82	96.58	50	29	21.760	20200	1123824576	0.19	2.58
USH 41	Washington	55.36	61.64	24	3	6.280	56000	899157840	0.07	0.33
		61.64	74.23	40	25	12.590	32000	1030063440	0.28	2.43
		75.41	83.58	37	11	8.170	29000	605770778	0.19	1.82
	Dodge	83.58	90.84	50	8	7.260	32200	597696561	0.16	1.34
	Fond du Lac	90.84	98.20	50	24	7.360	32000	602165760	0.47	3.99
		99.92	101.90	30	4	1.980	35000	177182775	0.29	2.26
		101.90	110.38	50	29	8.480	33800	732825912	0.49	3.96
	Winebago	110.38	121.12	48	35	10.740	44300	1216455629	0.47	2.88
		121.12	121.99	30	10	0.870	64250	142915933	1.64	7.00
		121.99	126.42	50	23	4.430	56000	634278540	0.74	3.63
		126.42	128.14	60	8	1.720	56600	248904726	0.66	3.21
		128.14	130.90	50	12	2.760	61000	430454430	0.62	2.79
		130.90	131.77	60	2	0.870	64000	142359840	0.33	1.40
	Outagamie	140.64	142.20	52	4	1.560	55400	220964562	0.37	1.81
		142.20	156.59	60	29	14.390	46500	1710810911	0.29	1.70
	Brown	156.59	181.71	60	62	25.120	48800	3134207328	0.35	1.98
	Oconto	181.71	198.96	60	24	17.250	17000	749766938	0.20	3.20
USH 45	Milwaukee	32.50	35.15	28	4	2.650	41200	279145965	0.22	1.43
	Washington	60.24	73.58	50	21	13.340	28000	954997260	0.22	2.20
		73.58	73.91	30	1	0.330	31000	26155552	0.43	3.82
USH 51	Dane	48.69	54.08	50	4	5.390	34000	468550005	0.11	0.85
		54.08	54.57	40	1	0.490	48000	60134760	0.29	1.66
		54.57	55.63	22	0	1.060	14000	37942170	0.00	0.00
		56.48	57.09	10	0	0.610	--	--	--	--
		57.09	60.13	50	4	3.040	18500	143791620	0.19	2.78
		60.13	61.17	40	0	1.040	--	--	--	--
		61.17	62.54	60	0	1.370	--	--	--	--
	Lincoln	205.00	211.16	96	4	6.160	13200	207894456	0.09	1.92
		211.16	224.52	70	9	13.360	13000	444056340	0.10	2.03
		224.52	236.10	60	10	11.580	17000	503321805	0.12	1.99
	Marathon	188.36	192.70	50	3	4.340	43000	477140685	0.10	0.63
		192.70	194.74	40	2	2.040	43000	224278110	0.14	0.89
		194.74	204.41	90	1	9.670	22700	561229636	0.01	0.18

TABLE A-1 Homogeneous Median Width Segment Analysis (cont.)

Hwy	County	MP1	MP2	Median Width	CMCs	Length (miles)	ADT (vpd)	VMT	Crash Rates per mi/yr	Crash Rates per VMT
USH 53	Barron	136.87	154.50	84	8	17.630	10000	450755025	0.06	1.77
	Washburn	154.50	160.38	84	7	5.880	9700	145826793	0.17	4.80
		160.38	176.92	50	9	16.540	8500	359453483	0.08	2.50
		177.76	180.91	100	0	3.150	--	--	--	--
		180.91	192.42	150	4	11.510	4850	142726734	0.05	2.80
	Douglas	192.42	195.64	150	3	3.220	6100	50219684	0.13	5.97
		196.92	203.25	33	2	6.330	6300	101960633	0.05	1.96
		203.25	208.35	40	6	5.100	6100	79540492	0.17	7.54
		209.41	210.08	70	0	0.670	--	--	--	--
		210.08	219.58	100	1	9.500	5800	140876925	0.02	0.71
		223.06	236.52	80	1	13.460	16000	550621680	0.01	0.18
		237.59	238.24	20	0	0.650	16000	26590200	0.00	0.00
	Chippewa	93.02	96.07	25	2	3.050	33000	257336888	0.09	0.78
		96.07	96.56	32	1	0.490	39000	48859493	0.29	2.05
		98.35	106.02	60	3	7.670	14000	274543815	0.06	1.09
		106.02	115.25	80	2	9.230	--	--	--	--
	La Crosse	3.23	4.35	39	1	1.120	31000	88770360	0.13	1.13
		4.35	5.71	60	2	1.360	31600	109878888	0.21	1.82
		5.71	16.75	50	18	11.040	20000	564530400	0.23	3.19