Traffic Safety Fundamentals Handbook

Minnesota Department of Transportation
Office of Traffic, Safety and Technology
Published August 2008

Prepared by CH2M HILL, Inc.

Mn/DOT Traffic Safety Fundamentals Handbook – Introduction

The Minnesota Department of Transportation (Mn/DOT) published the original version of the Traffic Safety Fundamentals Handbook in April, 2001. Over 2,000 copies have since been distributed through Mn/DOT's education and outreach efforts to practicing professionals in both government agencies and the private sector. In addition, this handbook has been used as a resource in undergraduate and graduate traffic engineering classes at the University of Minnesota.

In the years since 2001, the field of traffic safety has witnessed several important changes. First, Federal Highway Legislation (SAFETEA-LU) raised the level of importance of highway safety by making it a separate and distinct program and by increasing the level of funding dedicated to safety. In response to this legislation, the Federal Highway Administration (FHWA) provided implementation guidelines that required the states to prepare Strategic Highway Safety Plans and encouraged their safety investments to be focused on low cost stand-alone projects that can be proactively deployed across both state and local highway systems.

Minnesota's Strategic Highway Safety Plan (SHSP) was prepared in accordance with the FHWA guidelines and was approved in July, 2006. The SHSP included identification of a statewide safety goal, safety emphasis areas and a list of high priority safety strategies. The SHSP also identified a new approach to distributing the funds associated with the Highway Safety Improvement Program – driven by the distribution of fatal and life changing injury crashes across Minnesota. As a result of this strategic safety planning effort and the hard work of safety professionals in both State and local

governments, dozens of highly effective safety projects have been implemented and the results are impressive – Minnesota met the initial safety goal of getting under 500 traffic fatalities (494 fatalities in 2005).

However, one fact remains constant – highway traffic fatalities are still the leading cause of death for Minnesotans under 35 years of age. This indicates there is still much work to do in order to move Minnesota Toward Zero Deaths.

This new edition of the handbook has been updated to reflect new safety practices, policies and research and is divided into four sections:

- Crash Characteristics – national and state crash totals including the basic characteristics as a function of roadway classification, intersection control, roadway design and access density.
- Safety Improvement Process – Black Spot Analysis + Systematic Analysis = Comprehensive Safety Improvement Process.
- Traffic Safety Toolbox – identification of safety strategies with an emphasis on effectiveness.
- Lessons Learned

For additional information regarding traffic safety, please contact Mn/DOT's Office of Traffic, Safety and Technology, Traffic Safety Engineer at (651) 234-7016.

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Funding: Provided by Mn/DOT Division of State Aid for Local Transportation

Published by: Mn/DOT Office of Traffic, Safety and Technology

The contents of this handbook reflect the views of the authors who are responsible for the facts and accuracy of the data presented. The contents do not necessarily reflect the views of or policies of the Minnesota Department of Transportation at the time of publication. This handbook does not constitute a standard, specification or regulation.

Table of Contents

Crash Characteristics—Contents

Minnesota Department of Transportation

Nationwide Historic Crash Trends

	1972	1979	1984	1989	1994	1999	2004	2006
Crashes								
Total (thousand)	N/A	N/A	N/A	6,700	6,500	6,300	6,181	5,973
Fatal (thousand)	N/A	N/A	N/A	41	36	37	38	39
Injury (thousand)	N/A	N/A	N/A	2,153	2,123	2,026	1,862	1,746
PDO (thousand)	N/A	N/A	N/A	4,459	4,337	4,226	4,281	4,189
Fatalities								
Total	54,589*	51,093	44,257	45,582	40,716	41,345	42,636	42,642
Traffic								
Registered Vehicles (million)	119	144	159	181	195	N/A	238	251
VMT (trillion)	1.3	1.5	1.7	2.1	2.4	2.7	3.0	3.0
Rates								
Crashes/100 MVM	N/A	N/A	N/A	317	276	235	206	198
Fatalities/100 MVM	4.3	3.3	2.6	2.2	1.7	1.5	1.4	1.4
Fatalities per million registered vehicles	458	355	278	252	209	195	180	170
Costs								
US Dollars (billion)	N/A	$19.4	N/A	N/A	$150.5	N/A	N/A	$230.6**

*1972 was the worst year for fatalities in U.S.
**Estimated for reported and unreported crashes in 2000

N/A = Not Available
PDO = Property Damage Only

VMT = Vehicle Miles Traveled
100 MVM = Hundred Million Vehicle Miles

Source: National Highway Traffic Safety Administration (NHTSA)

Highlights

- Nationally, over the past 10 years, there have been about 6.5 million crashes and between 40,000 and 45,000 deaths annually.
- Over that same period, VMT (exposure) has increased by almost 30%.
- The long-term trend is fewer crashes and fatalities, in spite of the increased exposure.
- As a result, there have been fairly dramatic decreases in both crash and fatality rates.
- Even though there have been significant decreases in both total crashes and fatalities, there have been large increases in the costs of those crashes.

Upper Midwest Area 2006 Crash Data

	Minnesota	North Dakota	South Dakota	Iowa	Wisconsin
Crashes					
Total	78,745	16,534	15,830	54,815	117,877
Fatal	456	101	172	386	659
Injury	24,663	4,141	4,296	16,950	35,296
PDO	53,626	12,292	11,362	37,479	81,922
Fatalities					
Total	494	111	191	439	712
Traffic					
Registered Vehicles (million)	4.8	N/A	1.0	3.4	5.3
VMT (billion)	56.6	7.7	8.5	31.7	59.4
Rates					
Crashes/MVM	1.4	2.0	1.9	1.7	2.0
Fatalities/100 MVM	0.9	1.5	2.3	1.2	1.2
Fatalities/MRV	103	N/A	191	129	134
Costs					
US Dollars (million)	$1,529	$399	$411	N/A	$2,715

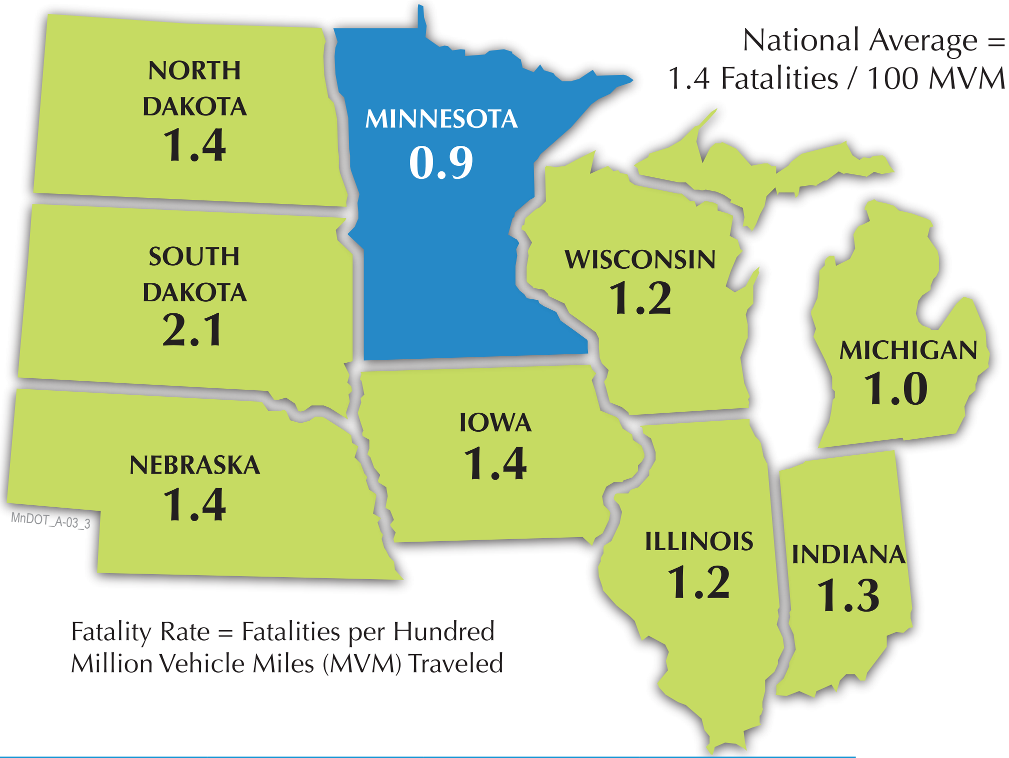
N/A = Not Available
PDO = Property Damage Only
VMT = Vehicle Miles Traveled
100 MVM = Hundred Million Vehicle Miles
MRV = Million Registered Vehicles

Source: 2006 State Publications of MN, ND, SD, IA and WI

Highlights

- Regionally, there is a wide variation from state to state in both the total number of crashes (15,000 to 118,000) and the number of fatalities (111 to 712).
- This variation is consistent with the state to state variation in exposure (VMT).
- Minnesota has averaged approximately 90,000 crashes and between 500 and 600 fatalities annually over the past several years.
- The trend in Minnesota is fewer crashes and fatalities, in spite of an increase in exposure (VMT).
- Minnesota has been a leader in the area of highway safety, with one of the lowest statewide average crash and fatality rates compared to other states in both the region and nationally.
- There is a relationship between the number of fatal crashes and fatalities. In general across the upper midwest area, the ratio was 1.1 fatalities per fatal crash.

Fatality Rates of Surrounding States—2006



National Average = 1.4 Fatalities / 100 MVM

Fatality Rate = Fatalities per Hundred Million Vehicle Miles (MVM) Traveled

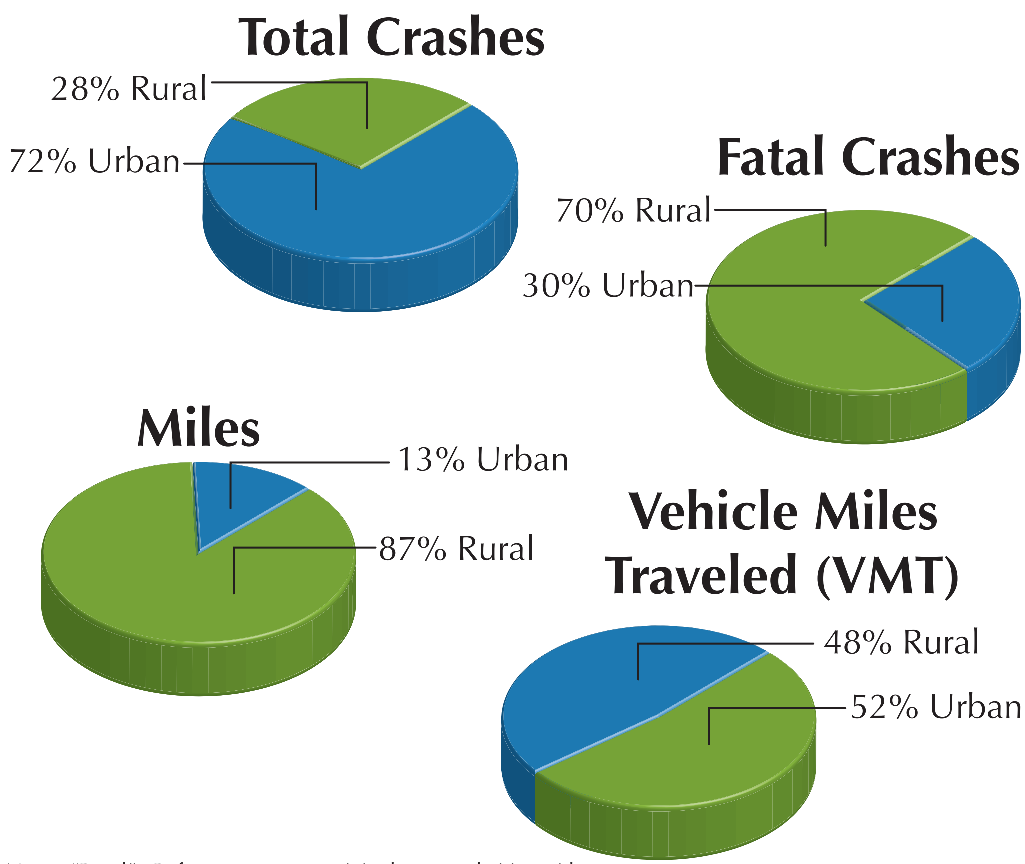
	Minnesota		Nationally
Year	Fatalities	Fatality Rate	Fatality Rate
1984	584	1.8	2.6
1989	605	1.6	2.1
1994	644	1.5	1.7
1999	626	1.2	1.5
2006	494	0.9	1.4

Source: National Highway Traffic Safety Administration (NHTSA)

Highlights

- Minnesota has the lowest fatality rate in the region and consistently one of the lowest fatality rates in the nation.
- National Fatality Rates
  - Average – 1.4
  - Range – 0.8 to 2.3
  - Trends – Lowest fatality rates in the northeast (mostly urban)
  - Highest rates in west, southwest, and southeast (most rural)
- Minnesota had the second lowest rate.
- Since 1994, Minnesota's fatality rate has dropped by almost 42%. This is the largest decline of any state.
- Traffic fatalities are still the leading cause of death for Minnesota residents under 35 years of age.
- The data suggests there are significant opportunities to move Toward Zero Deaths by focusing state safety efforts on the primary factors associated with severe crashes—safety belts, alcohol, young drivers, road edges, and intersections.

Minnesota Urban vs. Rural Crash Comparison



Note: “Rural” Refers to a non–municipal area and cities with a population less than 5,000.

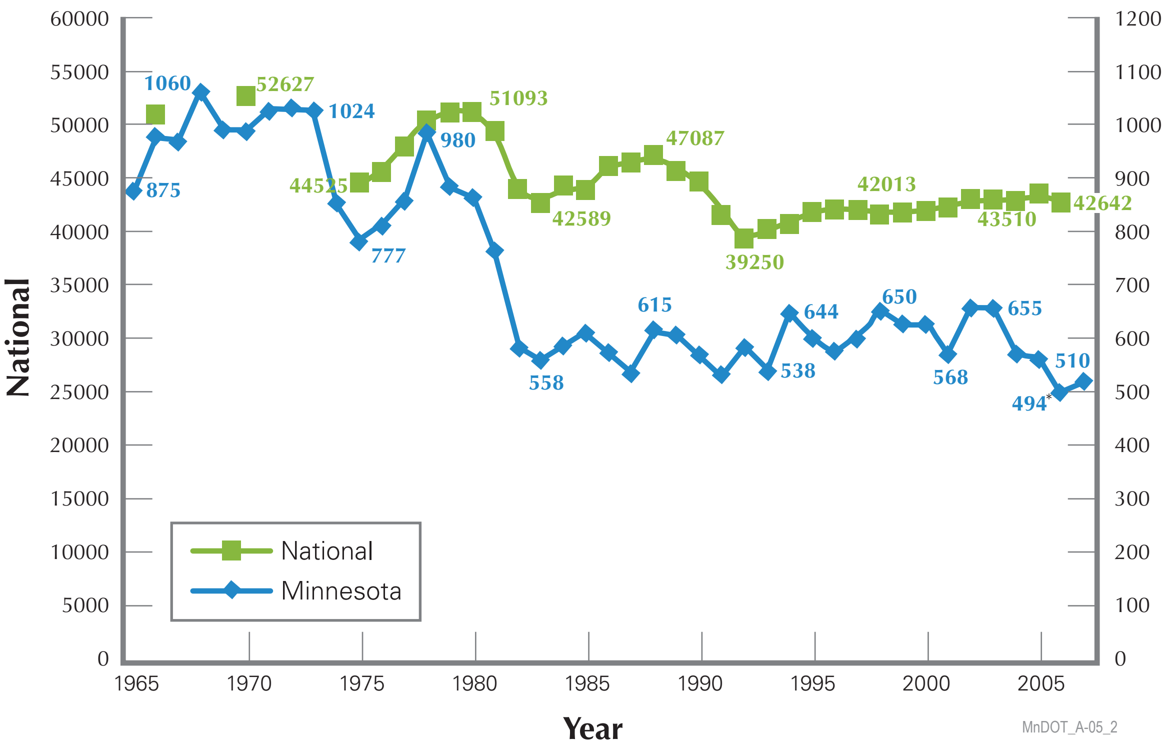
Source: 2004 - 2006 Minnesota TIS Crash Data

Highlights

- The total number of crashes is typically a function of exposure (VMT).
- In Minnesota, slightly more than one-half of the VMT is in urban areas and approximately 70% of the total number of statewide crashes are in urban areas.
- However, 70% of the fatal crashes in Minnesota are in the rural areas.
- On the average, rural crashes tend to be more severe than urban crashes – the fatality rate on rural roads is more than 2.5 times the rate in urban areas.
- The higher severity of rural crashes appears to be related to crash type, speed, and access to emergency services.

AASHTO's Strategic Highway Safety Plan

Persons Killed in Traffic Crashes

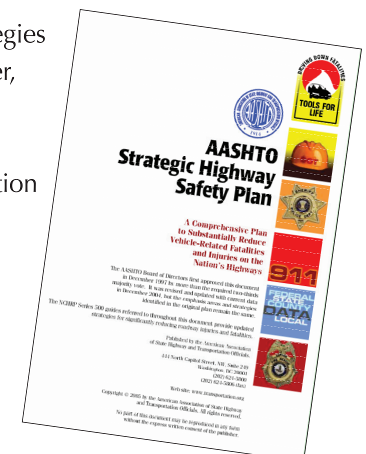


* The 494 traffic fatalities in 2006 is the lowest number in more than 50 years.

Source: Minnesota Department of Transportation (Mn/DOT) and National Highway Traffic Safety Administration (NHTSA)

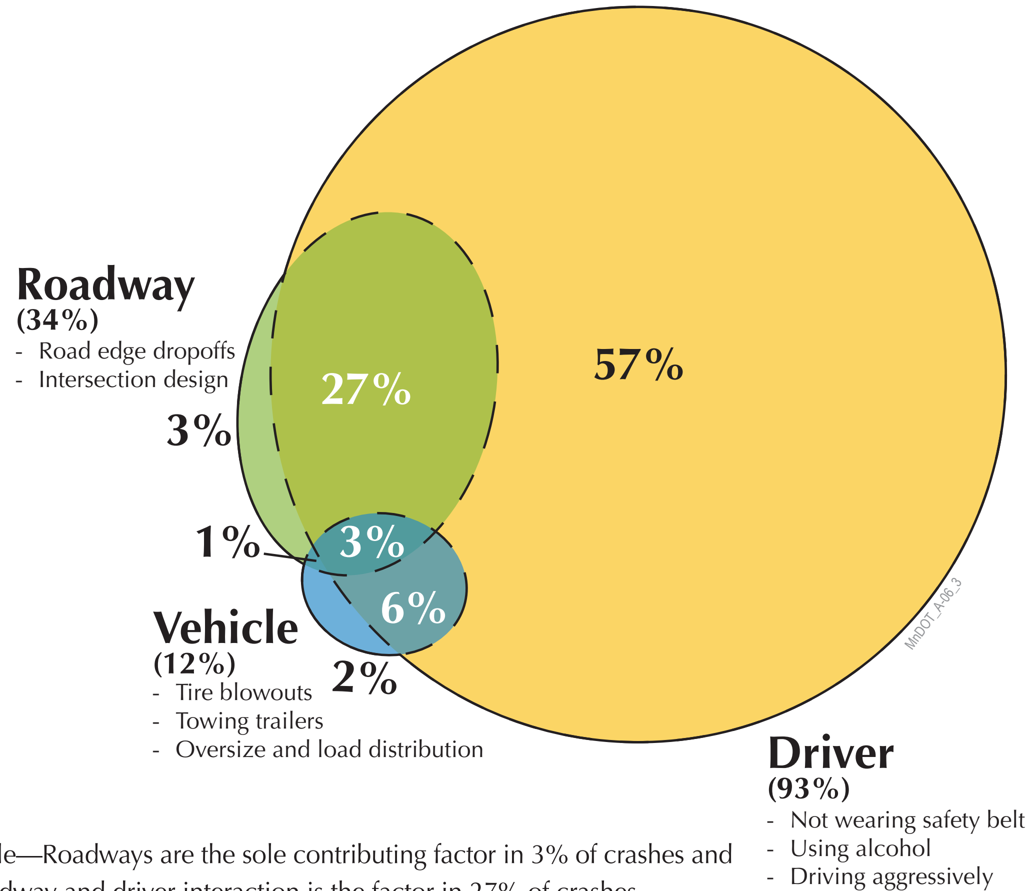
Highlights

- In the 1990's, AASHTO concluded that historic efforts to address traffic safety were not sufficient to cause a continued decline in the annual number of traffic fatalities.
- AASHTO's Strategic Highway Safety Plan was first published in 1997 and then updated in 2004.
- The plan suggested a new national safety performance measure – the number of traffic fatalities and setting a goal to reduce the nation's highway fatality rate to not more the one fatality per 100 million VMT by 2008.
- The plan introduced innovative ideas including:
  - Shared responsibility – all roads, all levels of road authorities
  - Safety Emphasis Areas
  - Focus on Proven Strategies
  - Consideration of Driver, Roadway and Vehicle interactions when analyzing crash causation
  - Development of State and Local Comprehensive Safety Plans



Role of Driver, Road, and Vehicle

Crash Causation Factors



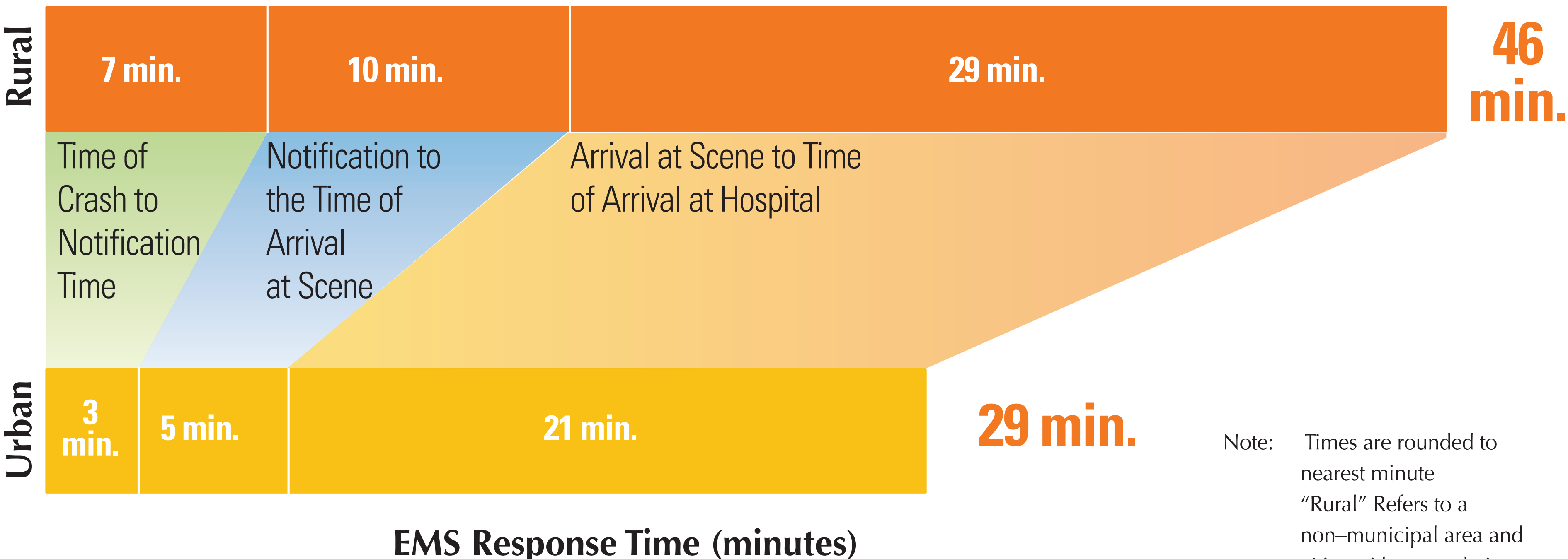
Example—Roadways are the sole contributing factor in 3% of crashes and the roadway and driver interaction is the factor in 27% of crashes.

Source: Human Factors & Highway Safety, Elizabeth Alicandri

Highlights

- Crashes are caused by a variety of factors involving drivers, the roadway, and vehicles
  - Driver behaviors that attribute to crashes include not wearing a safety belt, using alcohol, and driving aggressively. Driver behaviors are a factor in a total of 93% of crashes.
  - Roadway features focus on road edges and intersections. Roadway features are a factor in 34% of crashes.
  - Vehicle equipment failures, including tire blowouts, towing trailers, over size and load distribution. Vehicle failures are a factor in 12% of crashes.
- Studies have shown that Safety Programs that address multiple factors of the four Safety E's – Education, Enforcement, Engineering, and Emergency Services—will be the most effective.
- Examples of education and enforcement programs include the Department of Public Safety's Project Night Cap (alcohol) and CLICK IT or Ticket (safety belt usage).

Emergency Response Time Comparison



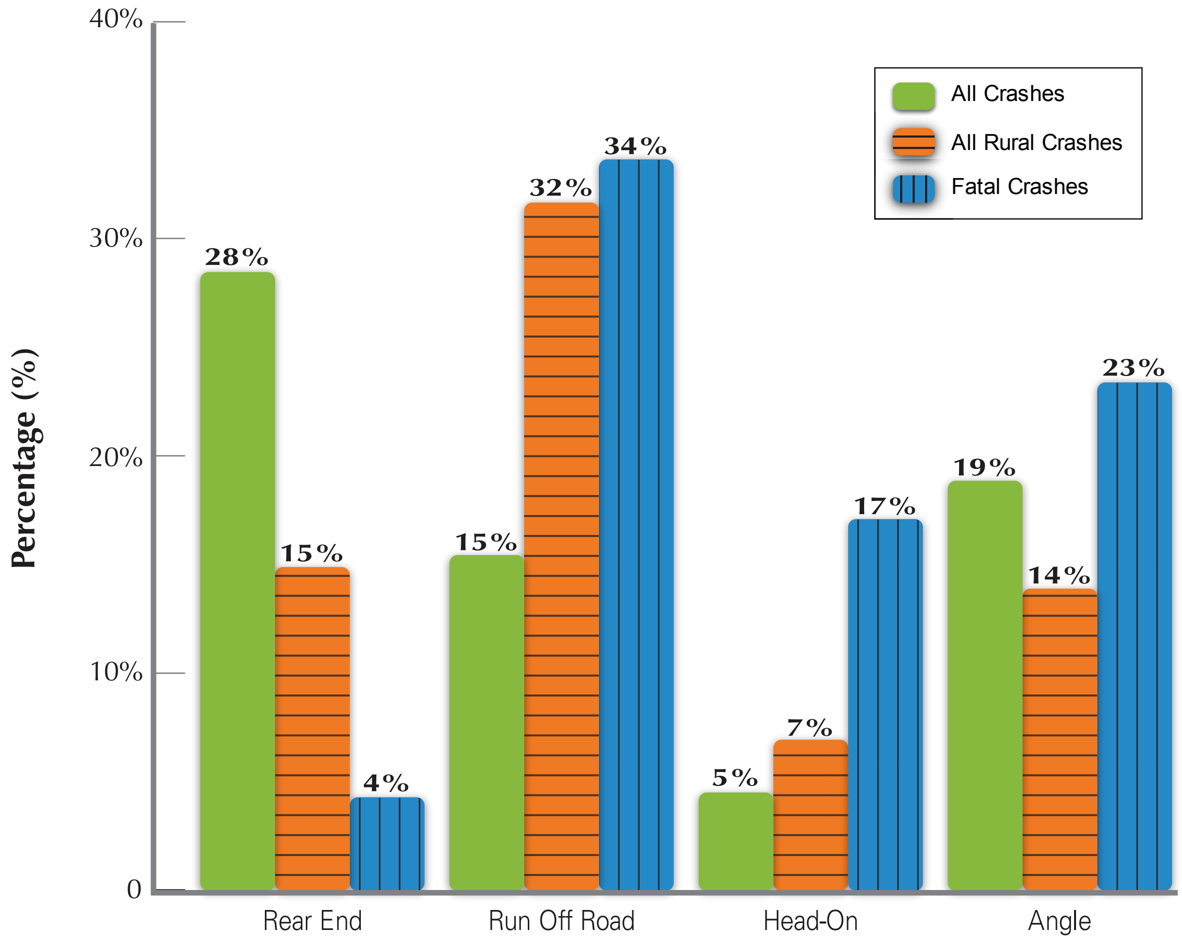
Note: Times are rounded to nearest minute
"Rural" Refers to a non–municipal area and cities with a population less than 5,000

Source: National Highway Traffic Safety Administration (NHTSA)

Highlights

- It appears that Emergency Response time may be a significant contributing factor to the higher frequency of fatal crashes in rural areas.
- Response times in rural areas are more than 50% longer than in urban areas.
- The higher frequency of fatal crashes in rural areas combined with the large EMS response times has lead to the research currently underway, in both Minnesota and nationally, regarding an automatic emergency notification system (MayDay) and enhancing the 511 (roadway information) system to provide first responders with real-time routing information to trauma centers

Fatal Crashes are Different

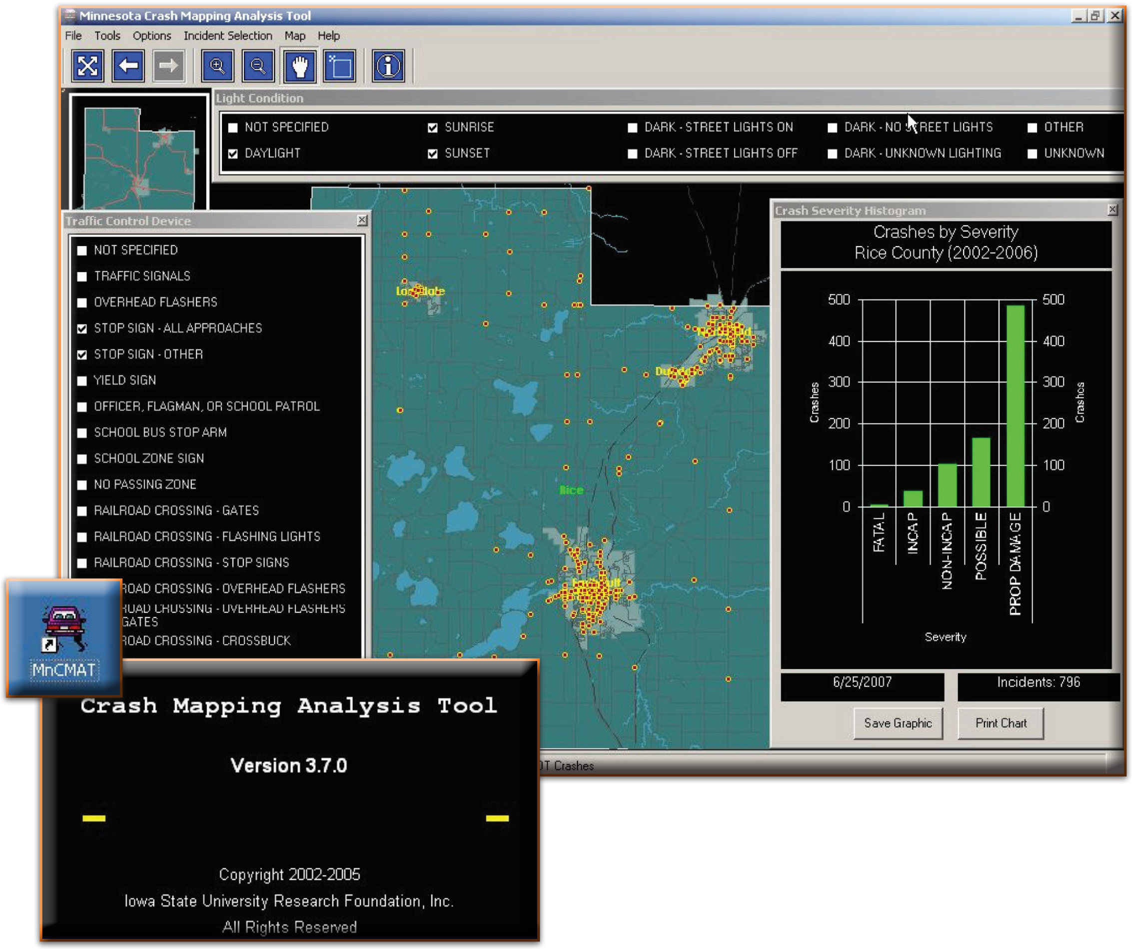


Source: 2004 - 2006 Minnesota TIS Crash Data

Highlights

- For the past 30 years, the primary safety performance measure was the total number of crashes. This resulted in safety investments being focused on locations with the highest number of crashes, which also have larger numbers of the most common types of crashes.
- The most common types of crashes in Minnesota are Rear End (28%) and Right Angle (19%). These crashes occur most frequently at signalized intersections along urban/suburban arterials – which ended up being the focus of safety investment.
- One problem with directing safety investments towards signalized urban/suburban intersections is that there was little effect on reducing fatalities – only about 10% of fatal crashes occur at these locations.
- The advent of Minnesota's Toward Zero Deaths (TZD) program and the recent adoption of a fatality-based safety performance measure lead to research that first identified that fatal crashes are different than other less severe crashes.
- Fatal crashes are overrepresented in **rural areas** and on the **local road system**. The most common types of fatal crashes are **Run Off Road (34%)**, Right Angle (23%), and Head-On (17%).
- These facts about fatal crashes have changed Mn/DOT's safety investment strategies – which are now focused on road departures in rural areas and on local systems.

Minnesota's Crash Mapping Analysis Tool (MnCMAT)



MnCMAT(1 of 2)

Highlights

- In order to assist cities and counties in gaining a better understanding of crash characteristics on their systems, Minnesota Local Road Research Board and Minnesota County Engineers Association (MCEA) have made a new tool available – the Minnesota Crash Mapping Analysis Tool (MnCMAT).
- MnCMAT is a map–based computer application that provides 10 years of crash data for every county in Minnesota.
- Individual crashes are spatially located by reference point along all roadways in each county.
- Up to 73 pieces of information are provided for each crash, including route, location (reference point), date/day/time, severity, vehicle actions, crash causation, weather, road characteristics, and driver condition.
- Analysts can select specific intersections or roadway segments for study. An overview of the entire county can also be generated.
- For more information about MnCMAT, consult the website: **http://www.dot.state.mn.us/stateaid/sa_crash_map_tool.html**

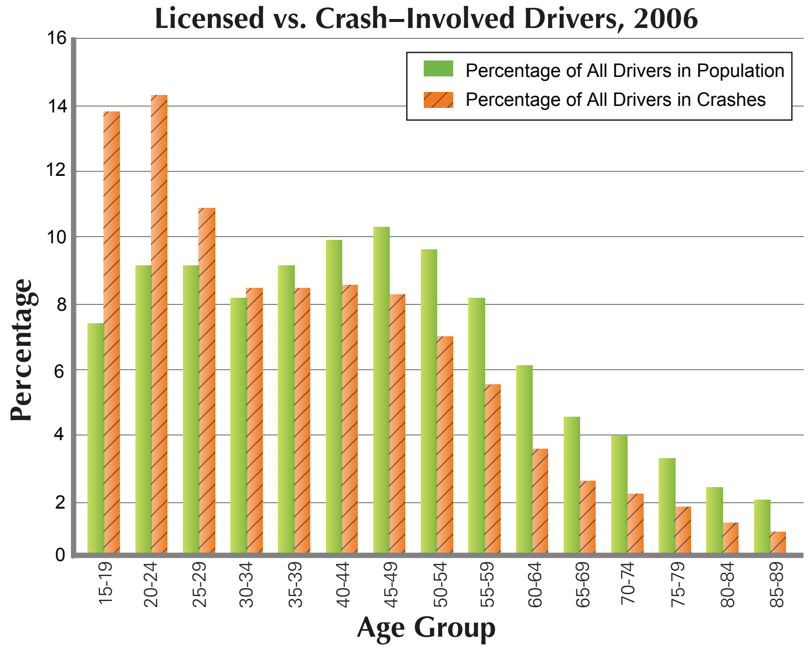
Minnesota's Crash Mapping Analysis Tool (MnCMAT)

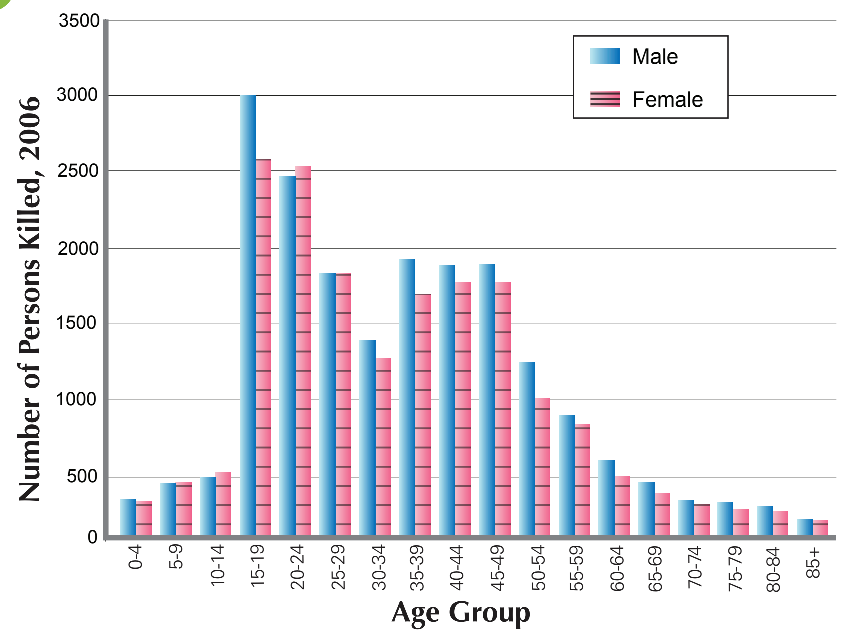
MnCMAT(2 of 2)

Highlights

- The recommended analytical process for conducting a safety/crash study is to compare Actual conditions at a specific location (intersection or segment of highway) compared to Expected conditions (based on documenting the average characteristics for a large system of similar facilities).
- MnCMAT supports this analytical process by providing both the data for individual locations and for larger systems – individual or multiple counties.
- These graphs provide summaries of crash data for the City of Brooklyn Park.
- The data indicates crashes predominately occur on dry surface conditions and are more likely to occur during the week. Additionally, the graph shows the distribution of crashes by severity.

Crash Involvement by Age and Gender





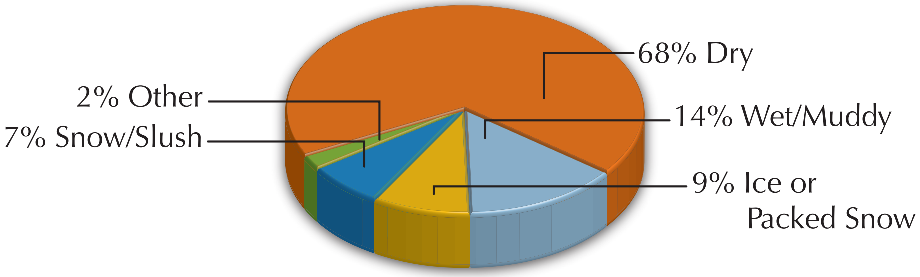
Source: 2004 - 2006 Minnesota Crash Facts

Highlights

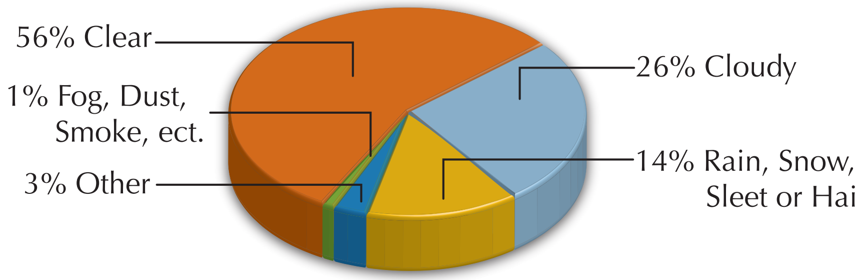
- The distribution of fatal crashes and total crashes by age indicates that young people are overrepresented.
- A recent analysis of crashes found that Minnesota has the highest percentage of young drivers (under 19 years of age) involved in fatal crashes of any state (approximately 14%), and those drivers only make up about 8% of the driving population.
- Minnesota's Strategic Highway Safety Plan has documented that young drivers (under 21 years old) are involved in 24% of fatal crashes. As a result, addressing young driver safety issues has been adopted as one of Minnesota's main safety emphasis areas.
- One strategy has been found to be particularly effective at reducing the crash involvement rate of young drivers – adoption of a comprehensive Graduated Drivers License (GDL) program. The Minnesota Legislature took a step in this direction in 2008 by adding provisions that prohibit driving between midnight and 5 a.m. during the first 6 months of licensure and limiting the number of unrelated teen passengers during the first 12 months of licensure.

Total Crashes by Road, Weather, & Lighting Conditions

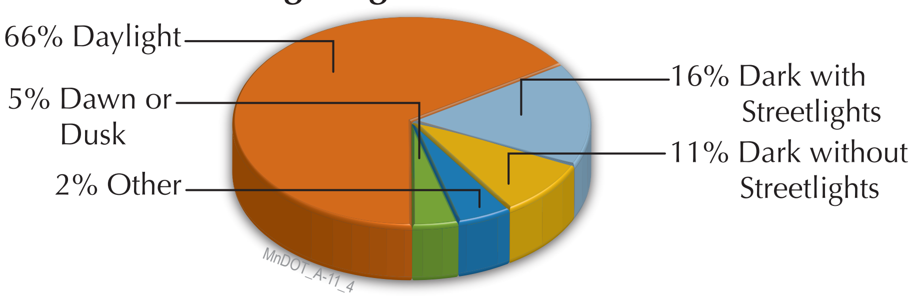
Road Conditions



Weather Conditions



Lighting Conditions

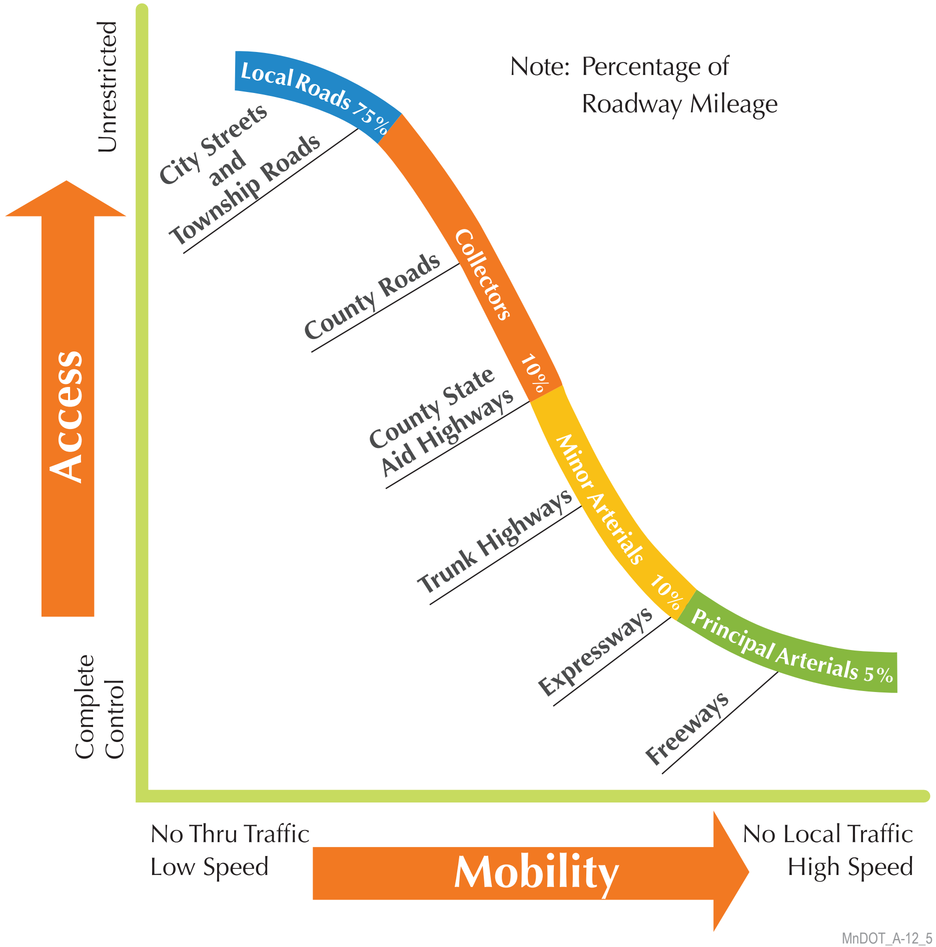


Source: 2004 - 2006 Minnesota TIS Crash Data

Highlights

- Some elements of traffic safety are counter-intuitive. Many people think that most crashes occur at night during bad weather.
- However, the data clearly indicates that crash frequency is a function of exposure. Most crashes occur during the day on dry roads in good weather conditions.
- It should be noted that some recent research has looked at safety issues during night time hours and during snow events. This research concludes that these conditions represent a significant safety risk because low level of exposure results in very high crash rates.
- In addition, the new focus on fatal crashes reinforces the concern about night time hours being more at risk—11% of all crashes occur during dark conditions but 26% of fatal crashes occur during hours of darkness.

Access vs. Mobility—The Functional Class Concept



Functional Classification System (1 of 2)

Source: FHWA Publication No. FHWA-RD-91-044 (Nov 1992)

Highlights

- One of the key concepts in transportation planning deals with the functional classification of a road system. The basic premise is that there are two primary roadway functions—Access and Mobility—and that all roadways serve one function or the other, or in some cases, both functions.
- The four components of most functionally classified systems include Local Streets, Collectors, Minor Arterials, and Principal Arterials.
- The primary function of local streets is land access and the primary function of principal arterials is moving traffic. Collectors and minor arterials are usually required to serve some combination of both access and mobility functions.
- Key reasons supporting the concept of a functionally classified system include the following:
  - It is generally agreed that systems that include the appropriate balance of the four types of roadways provide the greatest degree of safety and efficiency.
  - It takes a combination of various types of roadways to meet the needs of the various land uses found in most urban areas around the state.
  - Most agencies could not afford a system made up entirely of principal arterials. A region could be gridlocked if it was only served by a system of local streets.
  - Roadways that only serve one function are generally safer and tend to operate more efficiently. For example, freeways only serve the mobility function and as a group have the lowest crash rates and the highest level of operational efficiency.
  - Functional classification can be used to help prioritize roadway improvements.
- The design features and level of access for specific roadways should be matched to the intended function of individual roadways.
- The appropriate balance point between the competing functions must be determined for each roadway based on an analysis of specific operational, safety, design, and land features.

Typical Functionally Classified Urban System

ADT – Average Daily Traffic

VMT – Vehicle Miles Traveled

MPH - Miles Per Hour

2K - 2,000

1M - 1,000,000

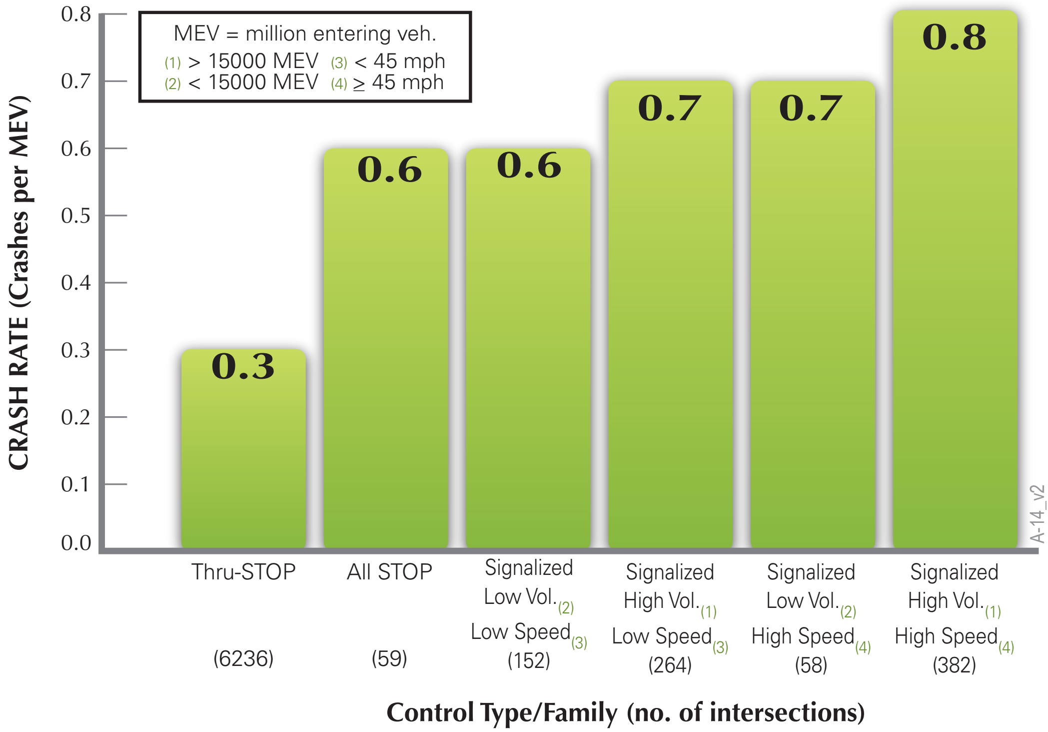
Functional Classification System (2 of 2)

Source: FHWA Publication No. FHWA-RD-91-044 (Nov 1992)

Highlights

- Local Streets
  - Low volumes (less than 2K ADT)
  - Low speeds (30 MPH)
  - Short trips (less than one mile)
  - Two lanes
  - Frequent driveways and intersections
  - Unlimited access
  - 75% system mileage / 15% VMT
  - Jurisdiction - Cities and Townships
  - Construction cost: $250K to $500K/mile
- Collectors
  - Lower volumes (1K to 8K ADT)
  - Lower speeds (30 or 35 MPH)
  - Shorter trips (1 to 2 miles)
  - Two or three lanes
  - Frequent driveways
  - Intersections to 1/8th mile spacing
  - 10% system mileage / 10% VMT
  - Jurisdiction - Cities and counties
  - Construction cost: $1M to $2M / mile
- Minor Arterials
  - Moderate volumes (5K to 40K ADT)
  - Moderate speeds (35 to 45 MPH)
  - Medium length trips (2 to 6 miles)
  - Three, four, or five lanes
  - Only major driveways
  - Intersections at 1/4 mile spacing
  - 10% system mileage / 25% VMT
  - Jurisdiction - Counties and Mn/DOT
  - Construction cost: $2.5M to $7M / mile
- Principal Arterials
  - High volumes (greater than 20K ADT)
  - High speeds (greater than 45 MPH)
  - Longer trips (more than 6 miles)
  - 4 or more lanes - access control
  - Intersections at 1/2 mile spacing and Interchanges 1+ mile spacing
  - 5% system mileage / 50% VMT
  - Jurisdiction - Mn/DOT
  - Construction cost: $10M to $50M / mile

Intersection Crash Rates (MN) by Control Type and Family



Note: Only for Trunk Highway Intersections

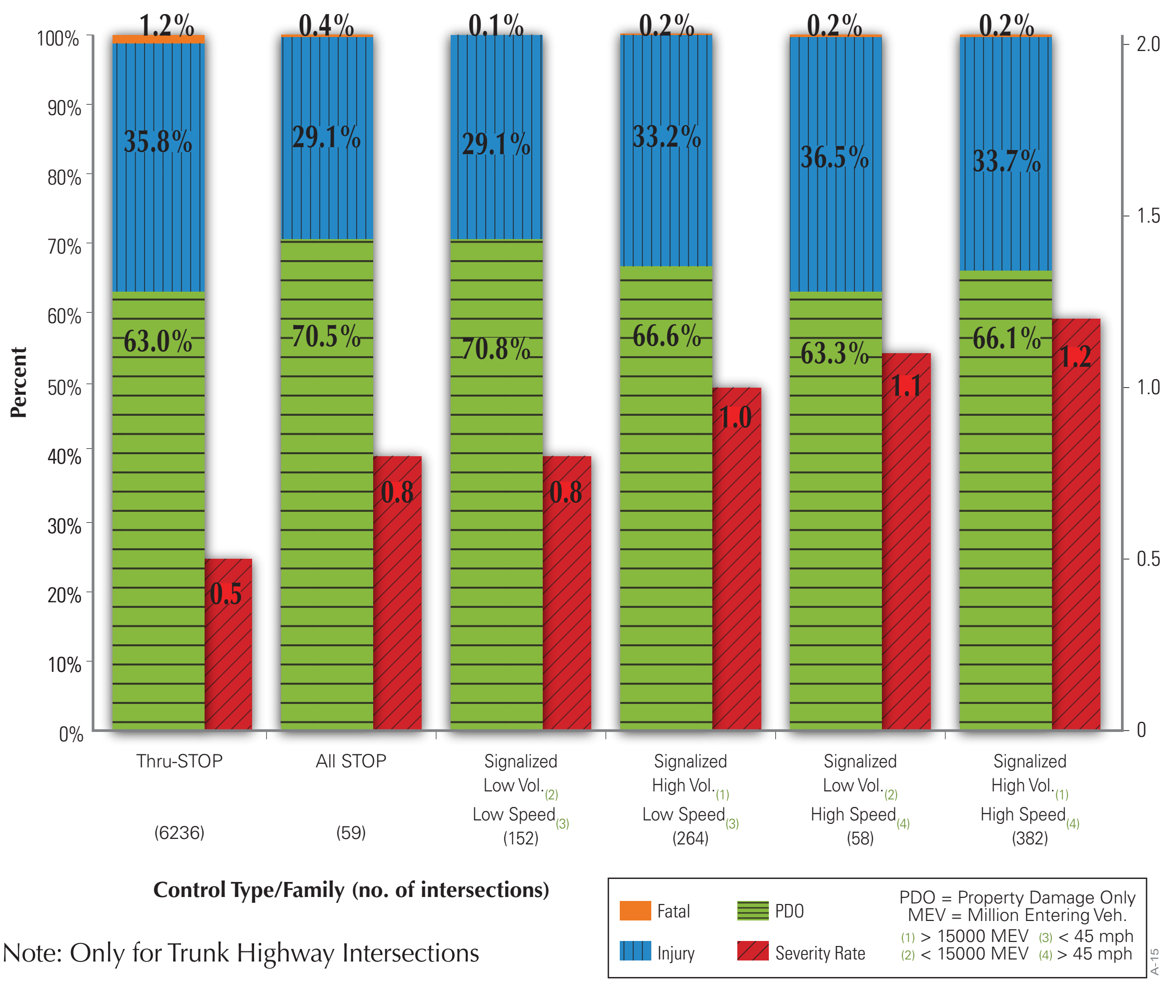
Intersection Crashes (1 of 2)

Source: 2004-2006 Minnesota TIS Crash Data

Highlights

- Crash frequency at intersections tends to be a function of exposure —the volume of traffic traveling through the intersection. As a result, the most commonly used intersection crash statistic is the crash rate—the number of crashes per million entering vehicles (MEV).
- Crash frequency also tends to be a result of the type of traffic control at the intersection. Contrary to the popularly held opinion that increasing the amount of intersection control results in increased safety, the average crash rate at signalized intersections (0.7 per MEV) is more than 150% higher than average crash rate at stop sign–controlled intersections (0.3 per MEV). In addition, the average severity rate and the average crash density is also greater for signalized as opposed to stop sign controlled intersections.
- It should be noted that approximately 40% of the Thru-STOP intersections had no crashes in the 2004-2006 time period. At those intersections with crashes, the average crash rate is approximately equal to the all STOP condition.
- A wealth of research also supports the conclusion that traffic signals are only rarely safety devices. Most Before vs. After studies of traffic signal installations document increases in the number and rate of crashes, a change in the distribution of the type of crashes, and a modest decrease in the fraction of fatal crashes.
- As a result of crash characteristics associated with signalized intersections, installing traffic signals is NOT one of Minnesota's high priority safety strategies.
- There is also data to support a conclusion that some type of left turn phasing (either exclusive or exclusive/permitted), addressing clearance intervals and providing coordination helps to minimize the number of crashes at signalized intersections.

Intersection Crash Severity (MN) by Control Type and Family



Note: Only for Trunk Highway Intersections

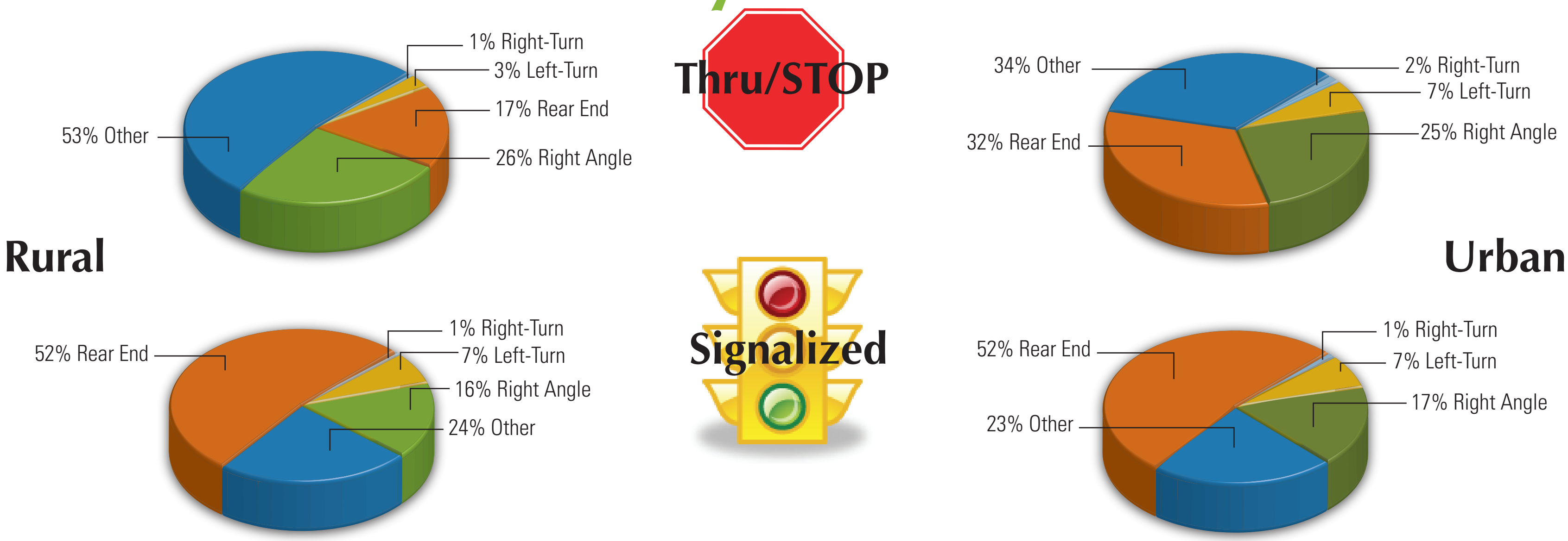
Source: 2004-2006 Minnesota TIS Crash Data

Intersection Crashes (2 of 2)

Highlights

- The distribution of intersection crash severity appears to be a result of the type/degree of intersection control methods. Based on a review of over 31,000 crashes at more than 7,100 intersections, All-Way STOP–controlled and low speed/volume signalized intersections were found to have the highest percentage of property damage only crashes (71%) and the lowest percentage of injury crashes (29%). Intersections with traffic signal controls had the lowest percentage of fatal crashes (0.2%).
- The data also suggests that (on average) the installation of a traffic signal does not result in a reduction in crash severity. The severity rate at signalized intersections (1.1) is about 120% higher than at intersections with Thru/STOP controls (0.5).
- This data supports the theory that increasing the amount of intersection controls does not necessarily result in a higher level of intersection safety.

Intersection Crash Distribution by Rural vs. Urban



Other – Sideswipe (Passing/Opposing), Runoff Road, Head–On, and Other/Unknown Crashes.

Note: "Rural" Refers to a non–municipal area and cities with a population less than 5,000.

Highlights

- The crash type distribution that can be expected at an intersection is primarily a function of the type of intersection control.
- At stop–controlled intersections, in both rural and urban areas, the most common types of crashes are right angle and rear end collisions.
- At signalized intersections, the most common types of crashes are rear end, right angle, and left turn collisions.

Several Key Points:

- Traffic signals appear to reduce but not eliminate right angle crashes.
- Right turns present a very low risk of a crash (1% to 2% of intersection crashes).
- Left turns present a very low risk of a crash (3% to 7% of intersection crashes).
- Crossing conflicts present a very high risk of a crash (16% to 26% of intersection crashes).
- Rear end conflicts present the highest risk of a crash (17% to 52% of intersection crashes).

Roadway Segment Crash and Fatality Rates by Jurisdictional Class

Roadway Jurisdiction Classification	Miles	Crashes	Fatalities	Crash Rate*	Fatality Rate**
Interstate	914	9,689	43	0.8	0.3
Trunk Highway	10,956	22,583	196	1.1	1.0
CSAH /County Roads	44,997	22,768	185	1.6	1.3
City Streets	19,105	21,423	41	2.7	0.5
Other (Township, etc.)	59,387	2,282	29	1.9	2.4
State Total	135,359	78,745	494	1.4	0.9

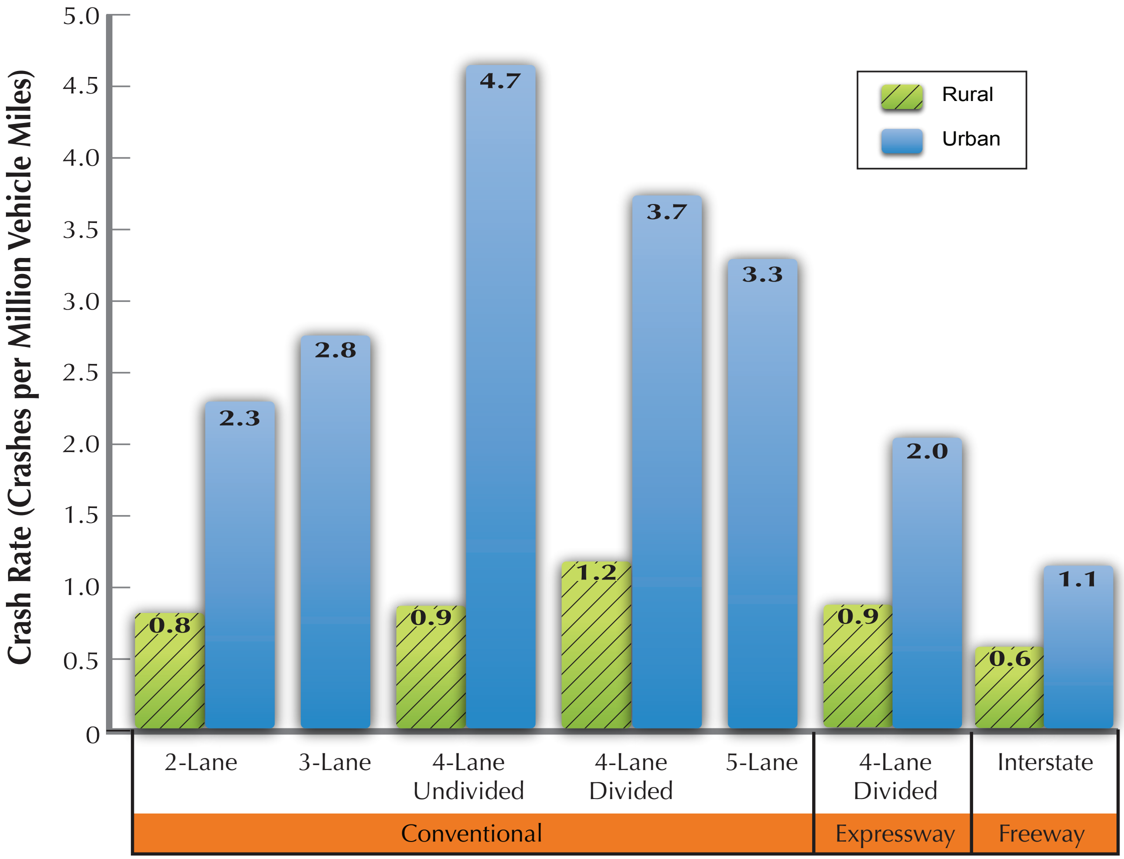
* per million vehicle miles (MVM)
** per 100 million vehicle miles (100 MVM)

Source: Minnesota Motor Vehicle Crash Facts (2006)

Highlights

- As a class, interstates had lower crash and fatality rates than conventional roadways. This is likely due to three factors:
  - Interstates only serve a mobility function
  - Interstates tend to have a consistently high standard of design
  - Interstates have very strict control of access
- Of the conventional roadways, Trunk Highways had the lowest crash rate and the second lowest fatality rate.
- City streets had the highest crash rate and a low fatality rate.
- County and township roads had moderately high crash rates and the highest fatality rates.
- This distribution of crashes generally supports the idea that greater numbers of crashes occur in urban areas and greater numbers of fatal crashes occur in rural areas.
- Crash rates and fatality rates by roadway jurisdiction (and for the state as a whole) are interesting, however, there is a great deal of evidence to suggest that crash rates are more a function of roadway design than who owns the road.

Roadway Segment Crash Rates
Facility Type by Rural vs. Urban



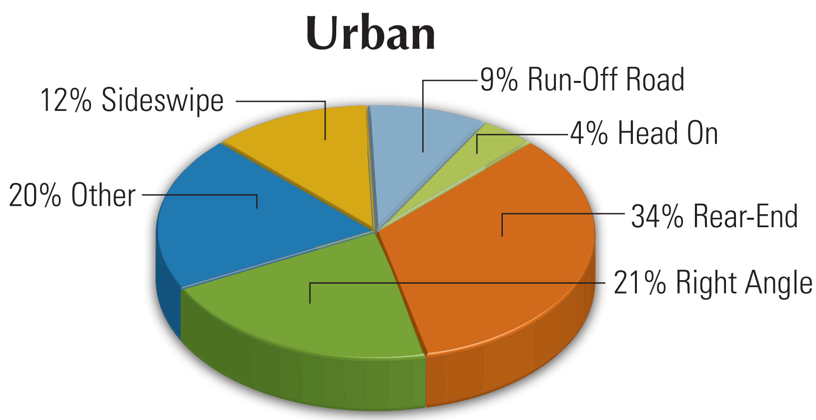
Note: Only for Trunk Highway Segments
"Rural" Refers to a non–municipal area and cities with a population less than 5,000.

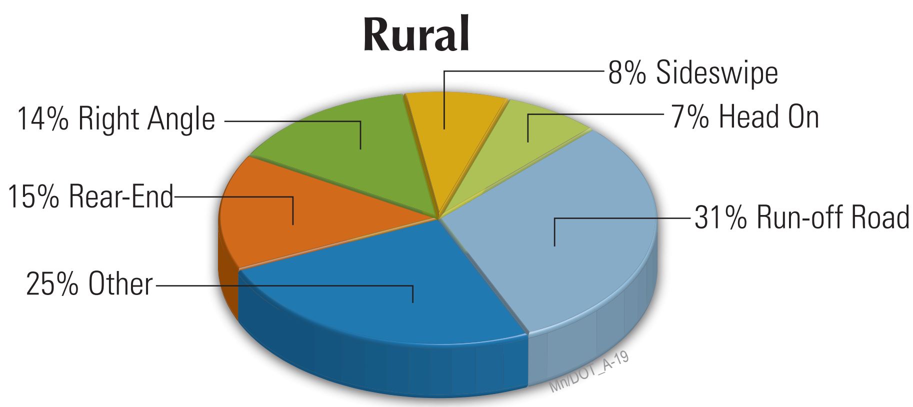
Source: 2004-2006 Minnesota TIS Crash Data

Highlights

- Average crash rates vary by location (Rural vs. Urban) and type of facility.
- Freeways have the lowest crash rates and are the safest roadway system in the state.
- Rural roadways have lower crash rates than similar urban roads.
- Urban conventional roadways-often minor arterials which serve both a mobility and land access function—have the highest crash rates.
- Four–lane undivided roadways have the highest crash rate—these facilities are usually found in commercial areas with high turning volumes and with little or no management of access. Over the years, this average has been lowered (from a rate of 8.0 in 1990), due to Mn/DOT's efforts to convert the worst segments to either three-lane, four-lane divided or five-lane roads. The addition of left turn lanes to segments of urban conventional roadways typically reduces crashes by 25% to 40%.
- The distribution of crash rates by facility type points to the relationship between access density and safety—highways with low levels of access (freeways) have low crash rates and highways with higher levels of access (conventional roads) have comparatively higher crash rates.

Roadway Segment Crash Distribution by Rural vs. Urban





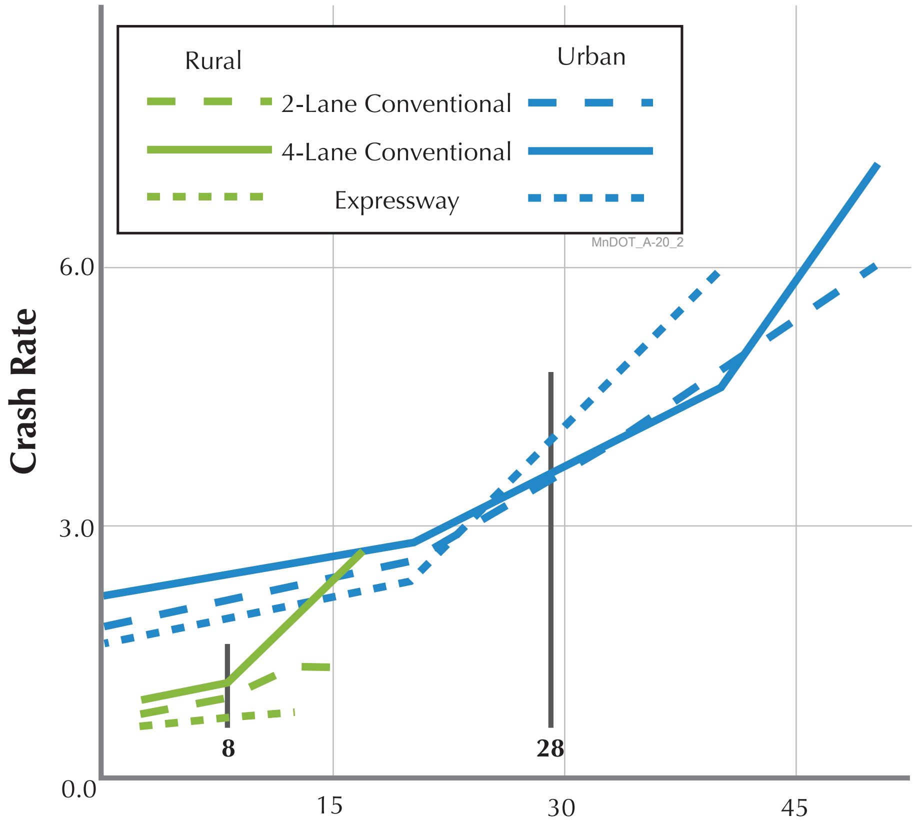
Note: Only for Trunk Highway Segments
"Rural" Refers to a non–municipal area and cities with a population less than 5,000.
Percentages are rounded.

Source: 2004 - 2006 Minnesota TIS Crash Data

Highlights

- There is a significant difference in the types of crashes that occur on urban versus rural roads.
- Urban crashes are predominately two vehicle (about 85%) and rural crashes are predominately single vehicle (about 55%).
- The most common types of urban crashes include:
  - Rear-End (34%)
  - Right Angle (21%)
- The most common types of rural crashes include:
  - Run off the Road (31%)
  - Rear-End (15%)
  - Right Angle (14%)
- Some types of crashes are more severe than others. Only 7% of all rural crashes involve head-on collisions, but they account for 20% of the fatal crashes.
- Deer hits are underreported because they rarely result in injury to vehicle occupants. A conservative estimate is that as many as 24% of rural crashes involve hitting a deer. For more information about collisions involving a deer, see www.deercrash.com

Roadway Segment Crash Rates as a Function of Facility Type and Access Density (MN)



Note: "Rural" Refers to a non–municipal area and cities with a population less than 5,000.

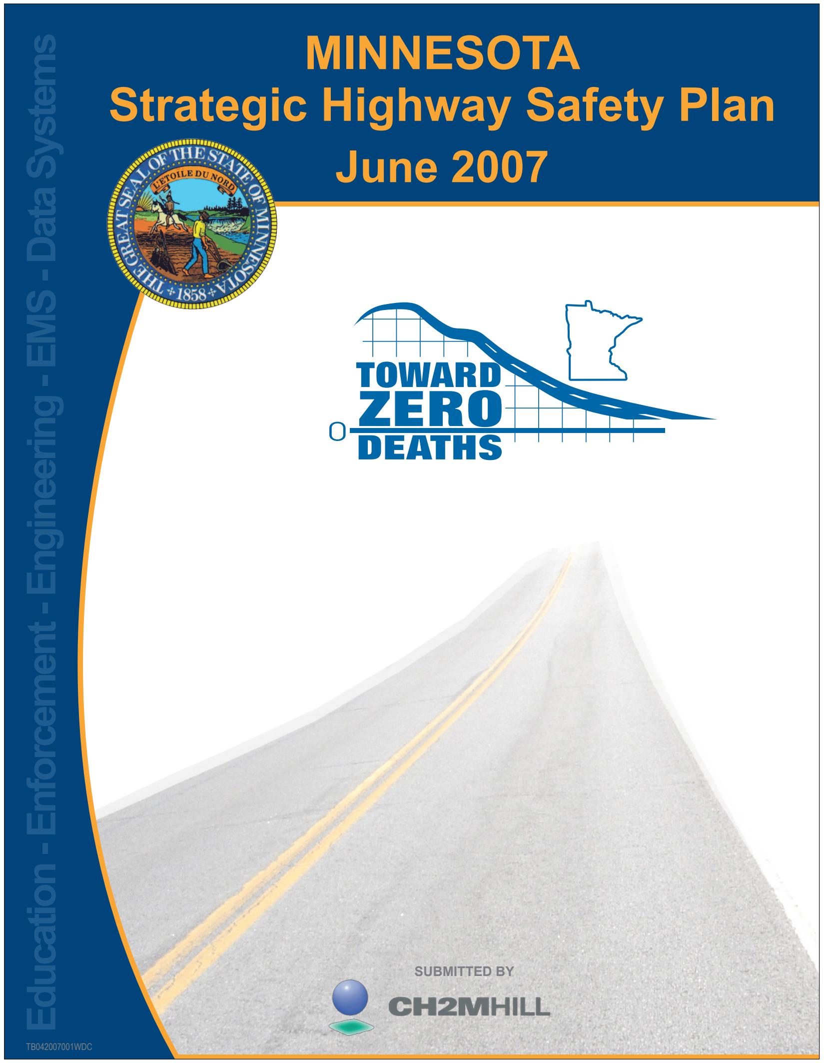
Source: Mn/DOT Research Report 1998-27 "Statistical Relationship between Vehicular Crashes and Highway Access"

Highlights

- Previous safety research going back 30 years indicated a potential relationship between access density and crash rates. However, this research did not account for other factors that are known to affect crash rates (rural vs. urban, design type of facility, etc.) and none of the data was from Minnesota.
- As a result, in 1998, Mn/DOT undertook a comprehensive review of the relationship between access and safety on Minnesota' s Trunk Highway System. This effort ended with the publication of Research Report No. 1998-27, "Statistical Relationship Between Vehicular Crashes and Highway Access."
- The key components of the research included:
  - Conducting a detailed analysis of a 766-mile sample of the state's 12,000 mile Trunk Highway System.
  - Documenting the density of access and the crash characteristics on over 430 segments of roadway.
  - Conducting rigorous statistical tests in order to achieve a high degree of statistical reliability.
  - Dividing the roadway segments into 11 separate categories in order to account for the primary factors that account for the crash rate variability.
- The significant results include:
  - Documenting for the first time the actual access density (an average of 8 per mile in rural areas and 28 per mile in urban areas).
  - Observing a statistical relationship between access density and crash rates in 10 of 11 categories.
  - Identifying a statistically significant tendency (in 5 out of 6 categories with sufficient sample size) for segments with higher access densities to have higher crash rates in both urban and rural areas.

Safety Improvement Process

Minnesota's Strategic Highway Safety Plan (SHSP)



Highlights

- Minnesota Strategic Highway Safety Plan (SHSP) is a data driven document that addresses the following issues:
  - Comprehensive: Addressed Four Safety E's
  - Systematic: Considered all roads
- Identifies a new safety performance measure: Fatal and life-changing injury crashes
- Documents a new safety goal: 400 or fewer fatalities by 2010
- Identifies a need to focus safety investments on rural areas and on local systems in order to achieve the goal
- Identifies the Critical Emphasis Areas (CEAs) and Critical Strategies
  - Driver behavior based emphasis areas
    - Unbelted vehicle occupants
    - Alcohol related
    - Speeding related
    - Young driver involved
  - Infrastructure-based emphasis areas
    - Intersection
    - Single vehicle road departure
    - Head-on and sideswipe
- Includes both Proactive & Reactive Elements

http://www.dot.state.mn.us/trafficeng/safety/shsp/index.html

Minnesota's Safety Emphasis Areas

Statewide Fatalities (2001-2005)			
Total Vehicle Occupant Fatalities			2,429
Total Nonvehicle Occupant Fatalities (i.e., Pedestrian, Bicyclist)			579
Total Fatalities			3,008
Driver Behavior Based Emphasis Areas	**Number**	**Percentage***	**Rank**
Unbelted (Based on Veh. Occ. Fatalities)	1,271	(52%)	1
Alcohol-Related	1,068	(36%)	2
Speeding-Related	850	(28%)	5
Involved Drivers Under 21	718	(24%)	6
Infrastructure-Based Emphasis Areas	**Number**	**Percentage***	**Rank**
Intersection	1,004	(33%)	3
Single Vehicle Run Off Road	965	(32%)	4
Head-On and Sideswipe	611	(20%)	7

Source: Minnesota Strategic Highway Safety Plan

*Note: Crashes may have more than one factor - percentages total more than 100%

Highlights

- Guidance provided by Federal Highway and AASHTO suggest that state and local safety programs will be the most effective if their implementation efforts are focused on mitigating the factors that cause the greatest number of fatal crashes.
- An analysis of Minnesota's crash data documented the factors causing fatal crashes; the results support designating seven safety emphasis areas in two basic categories: Driver Behavior and Infrastructure.
- Mn/DOT has taken the lead in addressing the Infrastructure based Emphasis Area by adopting a focus on lane departure crashes in rural areas, establishing goals for proactively deploying low cost treatments widely across systems of roadways, and revising the Highway Safety Improvement Program in order to direct more resources to those elements of the system that are most at risk—rural highways and local roads.
- The Minnesota Department of Public Safety has taken the lead in addressing the Driver Behavior–based emphasis areas, mostly through education and enforcement programs such as Click It or Ticket, Safe & Sober, HEAT (High Enforcement of Aggressive Traffic), Safe Communities, and a comprehensive set of limitations (hours of operation, number of unrelated passengers, etc.) for the most at risk group in Minnesota—teenager drivers.

Minnesota's Safety Emphasis Areas (1 of 2)

Safety Emphasis Areas—Greater Minnesota vs. Metro

	Total Fatalities	Driver Behavior Based Emphasis Areas: Unbelted	Alcohol-Related	Speeding-Related	Young Driver Involved	Infrastructure Based Emphasis Areas: Single Vehicle Run Off Road	Intersection	Head-on and Sideswipe
Statewide								
	3,008	1,271 (52%)	1,068 (36%)	850 (28%)	718 (24%)	965 (32%)	1,004 (33%)	611 (20%)
Greater Minnesota Districts (2001-2005 Fatalities)								
State Trunk Highway	1,089 (53%)	476 (49%)	284 (26%)	262 (24%)	224 (21%)	282 (26%)	360 (33%)	295 (27%)
Local Roads	974 (47%)	492 (63%)	460 (47%)	284 (29%)	263 (27%)	459 (47%)	298 (31%)	129 (13%)
Greater Minnesota Districts Total	2,063	968 (55%)	744 (36%)	546 (26%)	487 (24%)	741 (36%)	658 (32%)	424 (21%)
Metro District (2001-2005 Fatalities)								
State Trunk Highway	465 (49%)	162 (45%)	167 (36%)	145 (31%)	103 (22%)	108 (23%)	126 (27%)	112 (24%)
Local Roads	480 (51%)	141 (45%)	157 (33%)	159 (33%)	128 (27%)	116 (24%)	221 (46%)	76 (16%)
Metro District Total	945	303 (45%)	324 (34%)	304 (32%)	231 (24%)	224 (24%)	347 (37%)	188 (20%)

Source: Minnesota Strategic Highway Safety Plan

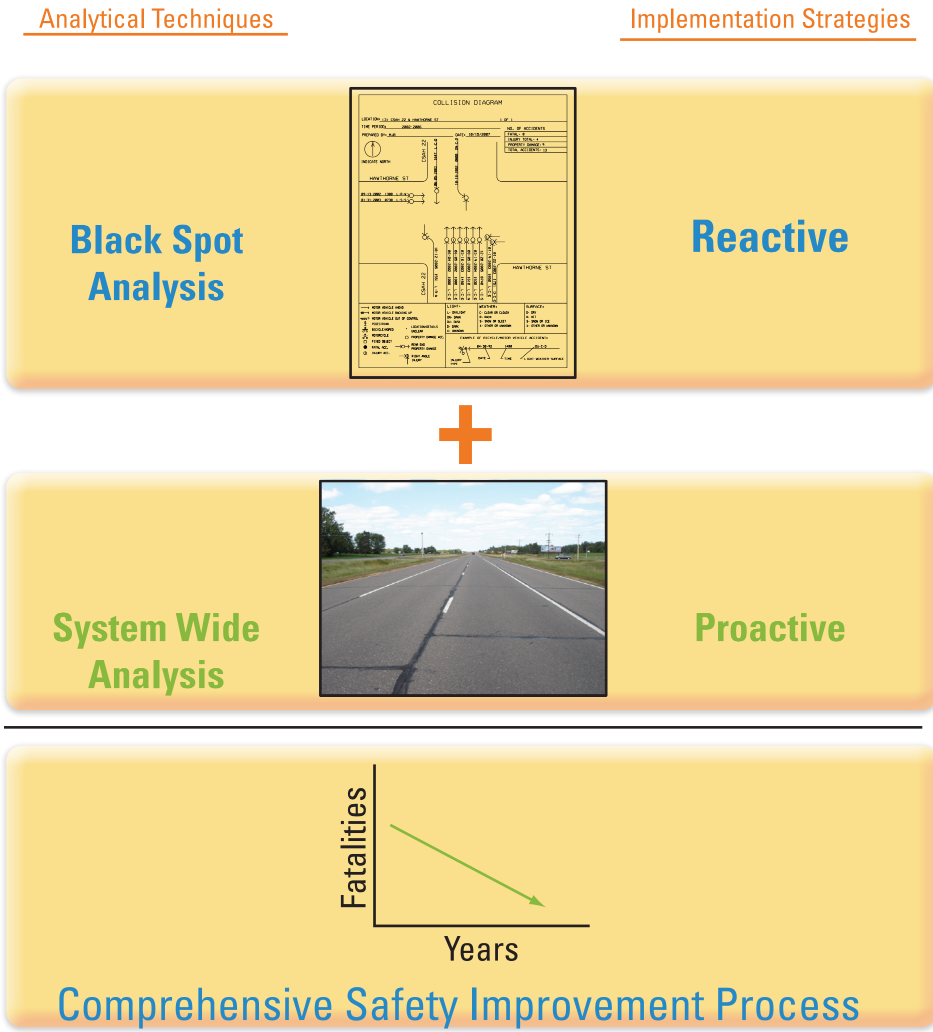
Represents at least 3% greater than statewide average

Highlights

- Almost 70% of the fatalities in Minnesota are in the 79 counties outside of the 8 county Minneapolis – St. Paul Metropolitan Area.
- Fatal crashes are split almost evenly between the state and local roadway systems – which results in higher fatality rates on the local system.
- In Urban areas, the primary factors associated with fatal crashes are intersections and speeding.
- In Rural areas, the primary factors associated with fatal crashes are not using safety belts, alcohol, and road departure crashes.

Minnesota's Safety Emphasis Areas (2 of 2)

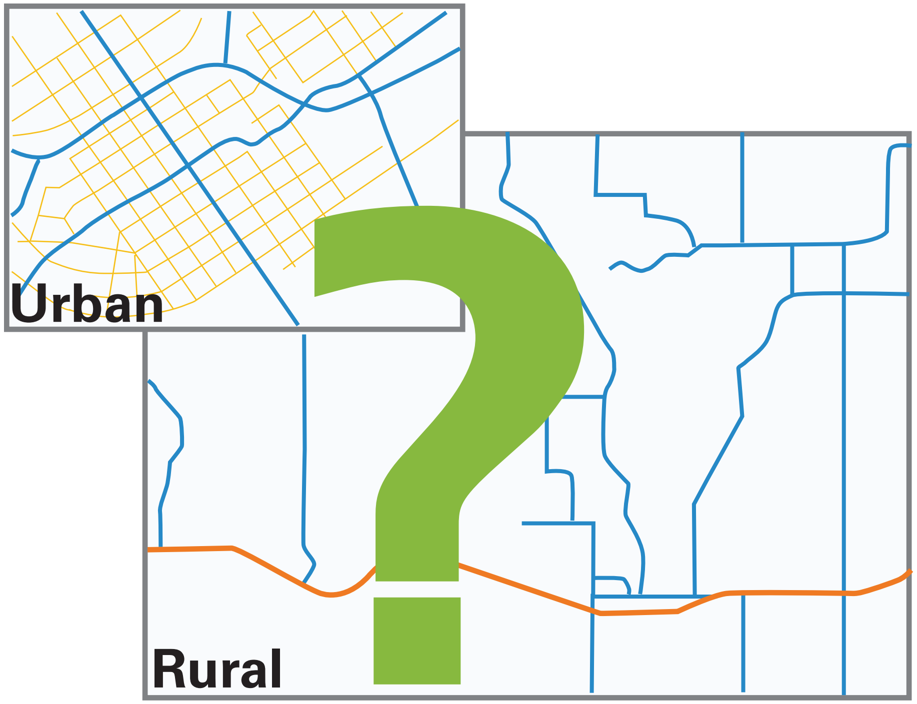
Comprehensive Safety Improvement Process



Highlights

- For the past 30 years, most safety programs have been focused on identifying locations with a high frequency or rate of crashes – Black Spots – and then reactively implementing safety improvement strategies.
- The result of making Black Spots the highest priority in the safety program was to focus safety investments primarily on urban and suburban signalized intersections—the locations with the highest number of crashes. However, these Black Spot intersections were found to account for fewer than 10% of fatal crashes.
- A new, more systematic based analysis of Minnesota's crash data combined with the adoption of a goal to reduce fatal crashes has led to a more comprehensive approach to safety programming—a focus on Black Spots in urban areas where there are intersections with high frequencies of crashes and a systems-based approach for rural areas where the total number of severe crashes is high but the actual number of crashes at any given location is very low.

Why Have a Black Spot Identification Process?



"Rural" Refers to a non–municipal area and cities with a population less than 5,000

Highlights

- Conducting periodic Black Spot reviews of your system supports project development activities and are an integral part of a best practices approach to risk management. Monitoring the safety of your system is good practice and is the industry "norm" against which you will be evaluated.

Project Development

- Crashes are one measurable indicator of how well a system of roadways and traffic control devices is functioning.
- Understanding safety characteristics can assist in the prioritization and development of roadway improvement projects by helping document Purpose and Need.

Risk Management

- Actively identifying potentially hazardous locations is better than being in the mode of reacting to claims of potentially hazardous locations by the public (or plaintiff's attorneys).
- Knowledge (actual or constructive) of hazardous conditions is one of the prerequisites for proving government agency negligence in tort cases resulting from motor vehicle crashes.
- All crash analysis performed as part of a safety improvement program is not subject to discovery in tort lawsuits.

Data Systems

- In order to be able to develop countermeasures to mitigate the effects of crashes, agencies need a monitoring system to identify crash locations and the key characteristics and contributing factors associated with the crashes. MnCMAT provides virtually all of the data necessary to support Black Spot analyses.

Alternative Methods for Identifying Potentially Hazardous Locations

Highlights

- There are three primary methods for identifying potentially hazardous locations.

1 Number of Crashes annually is greater than X crashes per year.

- The first method would involve setting an arbitrary threshold value of X crashes per year at any particular location. This is the simplest approach with the least data requirements. However, the selection of the threshold value is subjective and this methodology does not account for variations in traffic volume or roadway design/traffic control characteristics.
  This method is better than nothing and would be most applicable in systems consisting of similar types of roads with only small variations in traffic volumes.

2 Crash Rate is greater than Y crashes per million vehicles annually.

- The second method consists of computing crash rates and then comparing them to an arbitrarily selected threshold value of Y crashes per unit of exposure (a crash rate).

Advantage:
- Allows comparison of facilities with different traffic volumes.

Disadvantages:
- Subjective selection of the threshold value.
- Requires more data (traffic volumes).
  Does not account for known variation in crash rates among different types of road designs.
- Does not account for the random nature of crashes.

Conclusion:
- Limited applicability, better than just using crash frequency.

3 Critical Rate is a statistically adjusted Crash Rate to account for random nature of crashes.

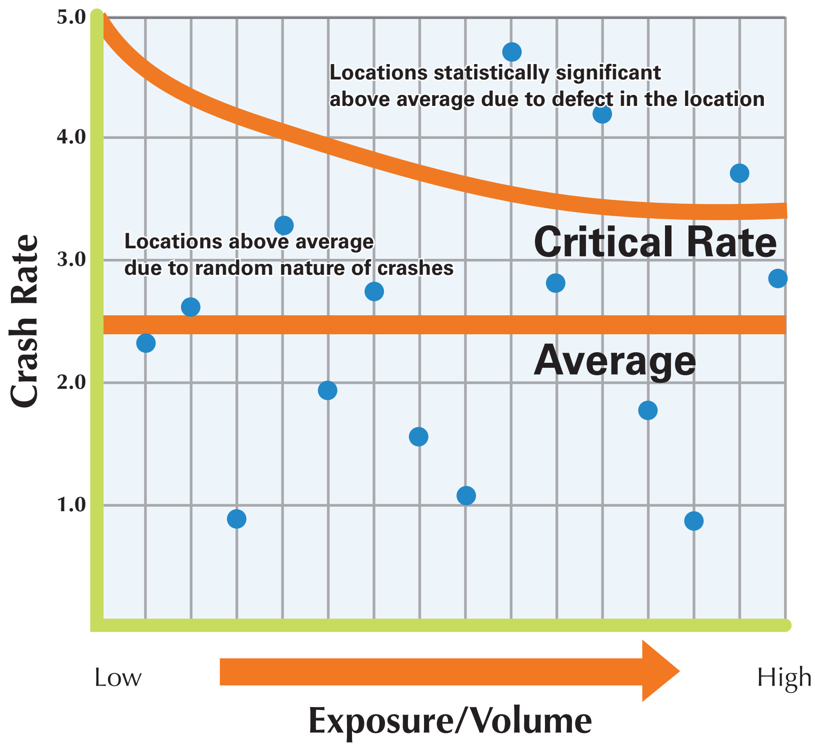
- The third method involves using a statistical quality control technique called "Critical Crash Rate"

Advantage:
- Only identifies those locations as hazardous if they have a crash rate statistically significantly higher than at similar facilities.

Disadvantage:
- Most data intensive methodology (volumes and categorical averages).

Conclusion:
- Of these three methods, critical crash rate is the most accurate, and statistically reliable method for identifying hazardous locations.

Effect of Random Distribution of Crashes



Highlights

The Concept of "Critical Crash Rate"

- The technique that uses the critical crash rate is considered to be the best for identifying hazardous locations.
- The critical crash rate accounts for the key variables that affect safety, including:
  - The design of the facility
  - The type of intersection control
  - The amount of exposure
  - The random nature of crashes
- The concept suggests that any sample or category of intersections or roadway segments can be divided into three basic parts:
  - Locations with a crash rate below the categorical average: These locations are considered to be SAFE because of the low frequency of crashes and can be eliminated from further review.
  - Locations with a crash rate above the categorical average, but below the critical rate: These locations are considered to be SAFE because there is a very high probability (90-95%) that the higher than average crash rate is due to the random nature of crashes.
  - Locations with a crash rate above the critical rate: These locations are considered to be UNSAFE and in need of further review because there is a high probability (90-95%) that conditions at the site are contributing to the higher crash rate.
- The other advantage of using the critical crash rate is that it helps screen out 90% of the locations that do not have a problem and focuses an agency's attention and resources on the limited number of locations that do have a documented problem (as opposed to a perceived problem).

Calculating Crash Rates

Intersection Rates:

$$\text{Rate per MEV} = \frac{(\text{number of crashes}) \times (1 \text{ million})}{(\text{number of years}) \times (ADT) \times (365)}$$

Segment Rates:

$$\text{Rate per MVM} = \frac{(\text{number of crashes}) \times (1 \text{ million})}{(\text{segment length}) \times (\text{number of years}) \times (ADT) \times (365)}$$

MEV – Million Entering Vehicles
MVM – Million Vehicle Miles
ADT – Average Daily Traffic on each leg entering an intersection or the daily two-way volume on a segment of roadway

Critical Rate:

$$R_c = R_a + K \times (R_a/m)^{1/2} + 0.5/m$$

R_c = Critical Crash Rate
for intersections: crashes per MEV
for segments: crashes per MVM

R_a = System Wide Average Crash Rate by Intersection or Highway Type

m = Vehicle Exposure During Study Period
for intersections: years x ADT x (365/1 million)
for segments: length x years x ADT x (365/1 million)

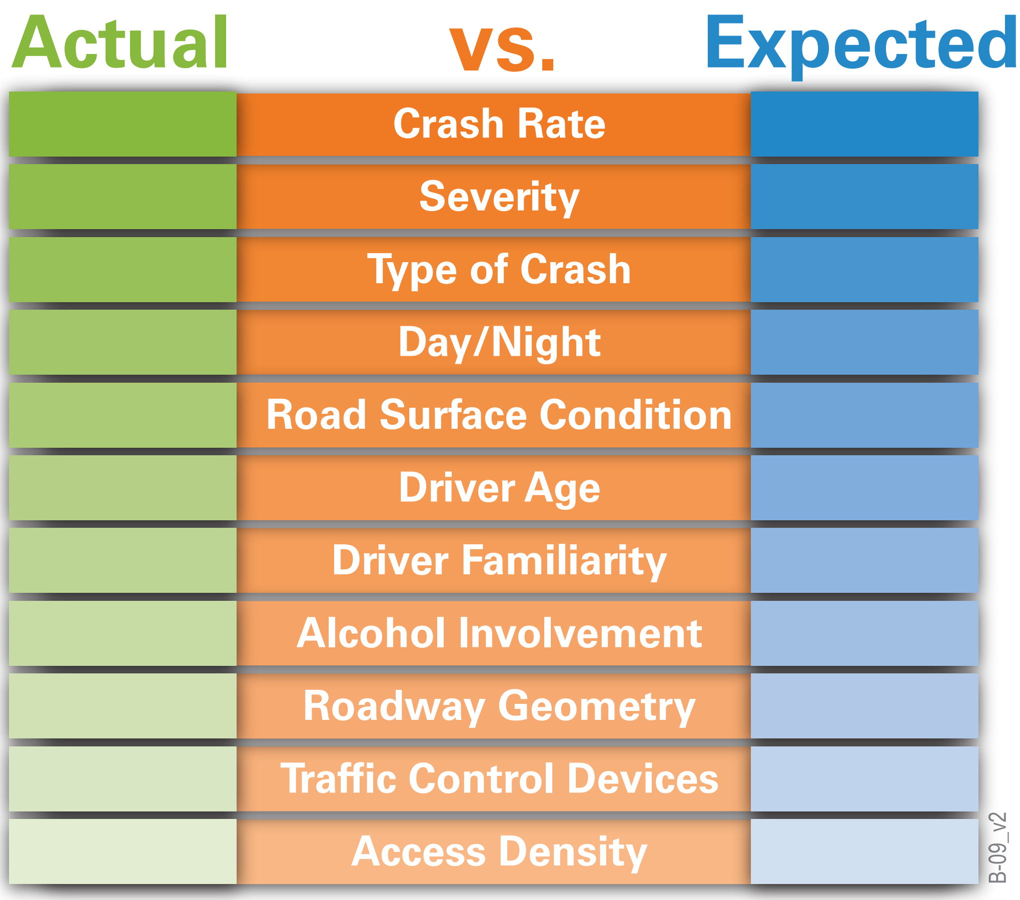
k = Constant based on Level of Confidence

Level of Confidence	0.995	0.950	0.900
K	2.576	1.645	1.282

Highlights

- The number of crashes at any location is usually a function of exposure. As the number of vehicles entering an intersection or the vehicle miles of travel along a roadway segment increase, the number of crashes typically increase.
- The use of crash rates (crash frequency per some measure of exposure) accounts for this variability and allows for comparing locations with similar designs but different volumes.
- Intersection crash rates are expressed as the number of crashes per million entering vehicles.
- Segment crash rates are expressed as the number of crashes per million vehicle miles (of travel)
- The Critical Crash Rate is calculated by adjusting the systemwide categorical average based on the amount of exposure and desired statistical level of confidence.
- The difference between the systemwide categorical average and the critical rate increases as the volume decreases.
- When computing the critical crash rate, the term m (vehicle exposure) is the denominator in the equations used in the calculation of either the intersection or segment crash rate.
- The same formulas can be used to calculate fatality or injury rates, or the rate at which a particular type of crash is occurring.
- A good rule of thumb is to use three years of crash data when available. More data is almost always useful, but increases the concern about changed conditions. Using only one or two years of data presents concerns about sample size and statistical reliability.

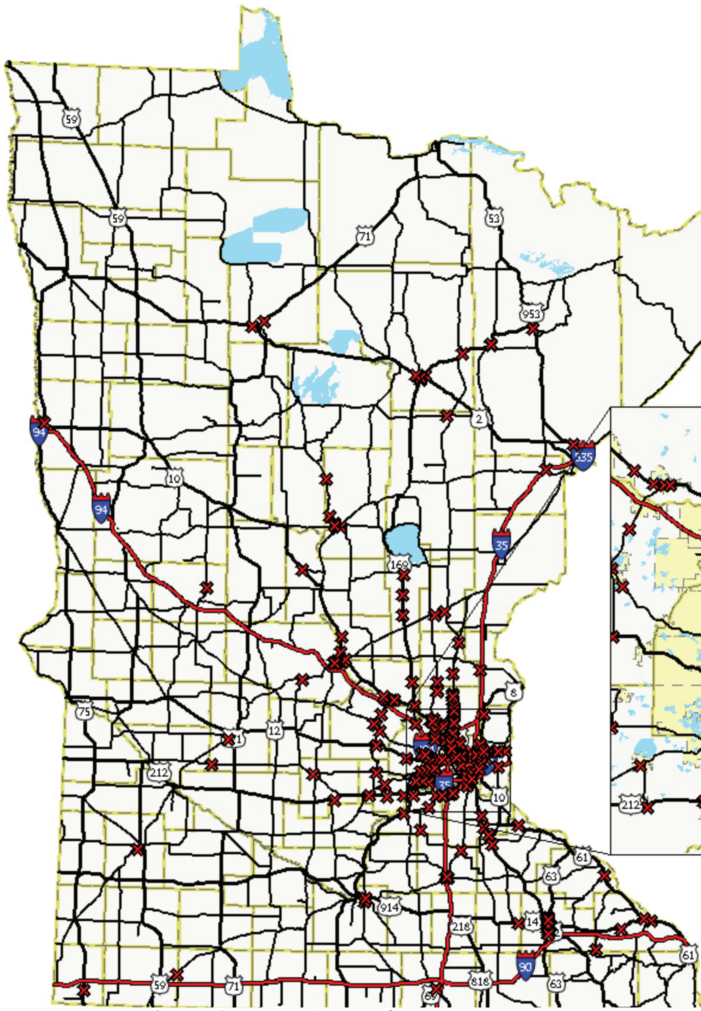
Supplemental Analysis: More Detailed Record Review

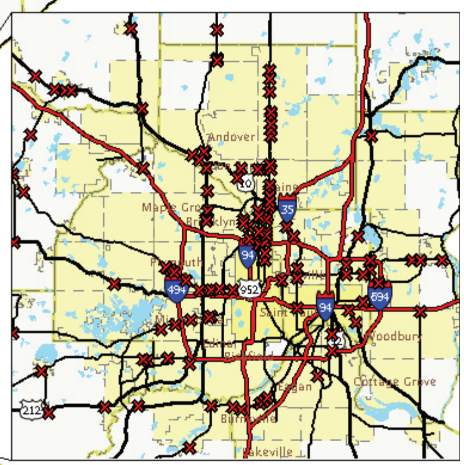


Highlights

- After identifying hazardous locations, the next step is to conduct supplemental analyses in order to better understand the nature of the problem and to help develop appropriate mitigative strategies.
- A more detailed understanding of the contributing factors is necessary to develop countermeasures because there is currently no expert system in place that allows mapping from a high crash rate to the base safety solution. Traffic engineers need to know more about the particular problems at specific locations because our "Tool Kit" is far less developed than other areas of roadway engineering.
- The supplemental analysis of crash data involves comparing ACTUAL crash characteristics to EXPECTED characteristics and then evaluating for differences. These differences document crash causation factors, which help identify effective countermeasures.
- It is important to remember that roads that are similar in design, with similar volumes will operate in a similar manner and will probably have similar crash characteristics.

Mn/DOT's High Crash–Cost Trunk Highway Intersections





Top 200 Intersections
Trunk Highway High Crash-Cost Intersections
January 1, 2004 - December 31, 2006

Source: 2004 – 2006 Minnesota TIS Crash Data

Highlights

- Mn/DOT uses a number of techniques to identify potentially hazardous locations, including critical crash rate, crash frequency, crash severity, and crash cost.
- Mn/DOT publishes a Top 200 list of high crash intersections along the state's 12,000 mile trunk highway system on an annual basis.
- The list ranks intersections by crash cost, frequency, severity, and rate.
- Intersections on the list generally have the following characteristics:
  – Crash frequencies between 1 and 63 per year.
  – Crash rates between 0.2 and 5.7 crashes per million entering vehicles.
  – Crash costs between $0.26 million and $1.2 million per year.
- Listed intersections are overwhelmingly signalized (70%) and in urban areas (69%).
- In general, this approach does NOT adequately identify intersections with safety deficiencies in rural areas.
- This approach also does not necessarily identify locations with fatal crashes (fewer than 10% of fatal crashes in Minnesota occurred at intersections in the Top 200 list).
- The key point is that a black spot analysis should continue to be a necessary part of a comprehensive safety program, but a systematic evaluation should also be performed.

Systematic Analysis—State Highways

Crash Summary by Facility Types – Greater Minnesota Districts

Area	Facility Type		Miles	Crashes: Fatal	Crashes: Serious Injury	Crash Rate	Severity Rate	Fatal Rate	Crash Density	Priority
Rural	Freeway		702	54	77	0.6	0.8	0.6	3.7	✓
Rural	4-Lane Expressway		712	49	94	0.8	1.2	0.8	3.5	✓
Rural	4-Lane Undivided		27	0	4	0.9	1.4	0	2.5	
Rural	4-Lane Divided Conventional (Non expressway)		123	11	24	1.2	1.9	1.2	4.4	
Rural	2-Lane	ADT < 1,500	3,774	48	74	0.8	1.4	1.9	0.3	✓
Rural	2-Lane	1,500 ≤ ADT < 5,000	3,916	110	185	0.7	1.2	1.4	0.7	✓
Rural	2-Lane	5,000 ≤ ADT < 8,000	583	45	52	0.9	1.4	1.7	2.0	✓
Rural	2-Lane	ADT ≥ 8,000	198	24	35	0.9	1.4	1.5	3.5	✓
Rural	**Sub Total**		**10,034**	**341**	**545**					
Urban	Freeway		21	2	7	1.4	1.9	0.3	21.3	
Urban	4-Lane Expressway		41	4	19	2.4	3.5	0.9	12.6	
Urban	4-Lane Undivided		43	1	20	3.9	5.6	0.3	16.9	
Urban	4-Lane Divided Conventional (Non expressway)		66	8	45	3.3	5.1	1.2	17.6	
Urban	Three-Lane		30	0	10	2.8	3.8	0.0	10.1	
Urban	Five-Lane		12	2	4	2.8	3.9	1.6	13.7	
Urban	2-Lane	ADT < 1,500	81	1	4	1.9	3.0	1.8	0.7	
Urban	2-Lane	1,500 ≤ ADT < 5,000	238	0	22	2.1	3.0	0.0	2.4	
Urban	2-Lane	5,000 ≤ ADT < 8,000	111	10	19	2.0	2.8	1.9	4.6	
Urban	2-Lane	ADT ≥ 8,000	75	5	19	2.6	3.7	0.8	10.5	
Urban	**Sub Total**		**718**	**33**	**169**					

Crash Summary by Facility Types – Metro District

Area	Facility Type		Miles	Crashes: Fatal	Crashes: Serious Injury	Crash Rate	Severity Rate	Fatal Rate	Crash Density	Priority
Rural	Freeway		122	22	24	0.6	0.9	0.5	11.1	✓
Rural	4-Lane Expressway		111	17	65	1.0	1.5	0.7	10.3	✓
Rural	4-Lane Undivided		0	0	0	2.5	3.1	0.0	14.8	
Rural	4-Lane Divided Conventional (Non expressway)		1	0	0	1.3	2.0	0.0	9.2	
Rural	2-Lane	ADT < 1,500	13	0	2	0.0	0.0	0.0	0.5	
Rural	2-Lane	1,500 ≤ ADT < 5,000	89	5	8	1.0	1.5	2.0	1.3	
Rural	2-Lane	5,000 ≤ ADT < 8,000	98	8	18	1.2	2.0	1.8	2.7	✓
Rural	2-Lane	ADT ≥ 8,000	137	17	33	1.3	2.0	1.2	6.9	✓
Rural	**Sub Total**		**571**	**69**	**150**					
Urban	Freeway		267	43	128	1.2	1.6	0.2	41.7	✓
Urban	4-Lane Expressway		124	17	81	1.9	2.7	0.5	23.9	✓
Urban	4-Lane Undivided		20	2	25	5.8	7.8	0.7	41.3	✓
Urban	4-Lane Divided Conventional (Non expressway)		21	3	19	5.0	6.8	0.9	38.6	✓
Urban	Three-Lane		9	0	2	3.1	4.3	0.0	16.8	
Urban	Five-Lane		2	0	3	5.6	8.8	0.0	52.4	
Urban	2-Lane	ADT < 1,500	1	0	0	4.0	6.3	0.0	2.1	
Urban	2-Lane	1,500 ≤ ADT < 5,000	9	0	0	2.8	3.9	0.0	3.7	
Urban	2-Lane	5,000 ≤ ADT < 8,000	26	2	2	2.3	3.3	1.6	5.5	
Urban	2-Lane	ADT ≥ 8,000	54	6	20	3.0	4.2	1.1	15.6	✓
Urban	**Sub Total**		**533**	**73**	**280**					

Source: Mn/DOT SHSP Crash Records, 2004-2005

Highlights

- Historically, the absence of Black Spots in a system of roads was interpreted to mean that there were no safety deficiencies and that there were no opportunities to effectively make investments to reduce crashes.
- However, a new interpretation of the crash data by the Federal Highway Adminitration (FHWA) and an increasing number of state departments of transportation suggests that neither of these assumptions is correct.
- A review of Minnesota's crash data, conducted as part of the Strategic Highway Safety Plan, provides several insights in support of a systematic approach for addressing safety deficiencies.
- On the state's highway system, the facility types that present the greatest opportunity to reduce fatal crashes (based on the total number of fatal crashes) are rural two-lane roads (50%) and freeways (22%). However, until recently there have been few projects on these facilities because the process of filtering the data failed to identify any Black Spots.
- Further analysis of these priority facilities shows that neither the overall crash rate nor the fatality rate are at all unusual, but the pool of fatal crashes susceptible to correction is still large and represents the greatest opportunity for reduction: addressing road departure crashes on rural two–lane roads and cross-median crashes on freeways.
- The final point in support of a systematic approach to address safety in rural areas is the very low density of crashes along rural two-lane highways – 61% of fatal crashes occur on the 87% of the system that averages less than one crash per mile per year.

Note: Crash rate is crashes per million vehicle miles; fatality rate is fatal crashes per 100 million vehicle miles

Implementation Guidance for State Highways

Reactive → **Proactive**

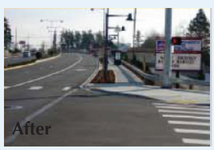
GOAL FOR METRO DISTRICT

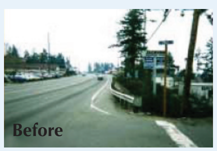
High-Cost Improvements

Interchanges

Roundabouts

Road Reconstruction



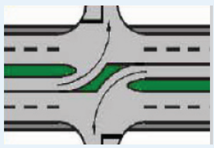


Moderate-Cost Intersection Improvements

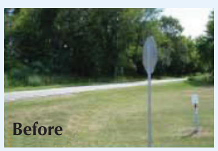
Improve Traffic Signal Operations

Accel/Decel Lanes

Indirect Turns



Improve Sight Distance



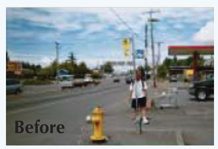
50/50 GOAL

Corridor Management and Technology Improvements

Employ ITS Technologies

Elec. Speed Enforcement in School Zones

Access Management



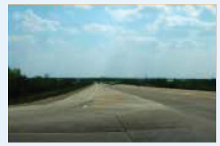
Road Safety Audit

GOAL FOR GREATER MINNESOTA DISTRICTS

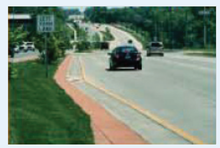
Low-Cost Intersection Improvements

Red Light Enforcement

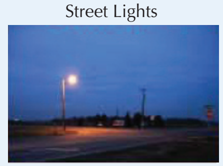
Turn Lane Modifications



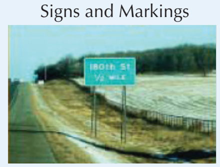
Channelization



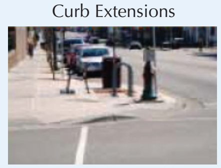
Street Lights



Enhance Traffic Signs and Markings



Curb Extensions



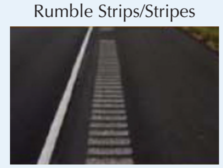
Road Departure Improvements

Edge Treatments

Enhanced Del. of Curves

Safety Edge

Paved Shoulders Rumble Strips/Stripes



Cable Median Barrier

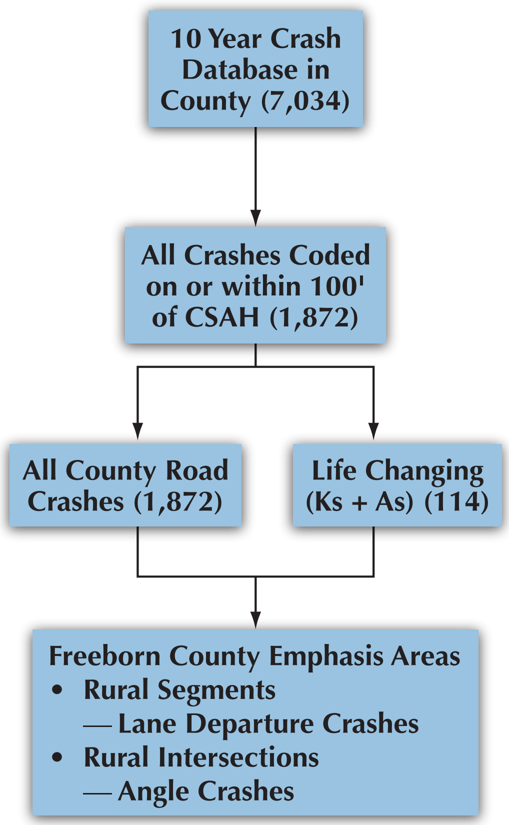
Upgrade Roadside Hardware

Highlights

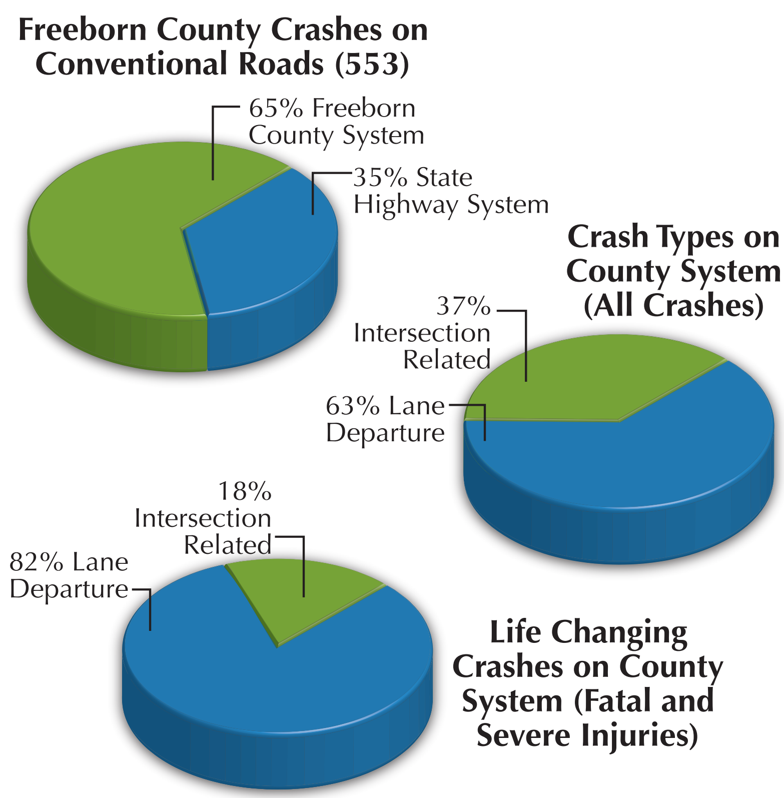
- As part of the Strategic Highway Safety Plan, Mn/DOT developed implementation guidance for the districts.
- The goal for districts in greater Minnesota is to have a safety program that is primarily focused on proactively deploying (relatively) low-cost safety strategies broadly across their systems of rural two-lane roads and freeways.
- The goal for the Metropolitan District is to base their safety program primarily on deploying generally higher cost safety strategies at their Black Spot locations, while reserving a small fraction of their resources for widely deploying low-cost new technologies or innovations across their system.

Systematic Analysis—County Highways

Freeborn County Road Safety Audit Review Analysis Model



Additional Analysis to Support Priorities of CEAs in Freeborn County (2002–2006 Crash Data)



Systematic Analysis of County Highways (1 of 2)

Source: Freeborn County Road Safety Audit Report, 2008

Highlights

- An example of safety planning at the local level is the work done by Freeborn County.
- The County's crash data was analyzed using the MnCMAT tool – this analysis identified Lane Departure crashes along rural segments on the county system and Angle crashes at rural intersections as the highest safety priorities.
- A review of crash data for the 2002 to 2006 timeframe found 65% of the crashes on conventional roads occurred on the county system.
- The most relevant type of crash is lane departure and 63% of these occurred on the county system.
- Lane departures accounted for 82% of the severe crashes and 92% of these occurred on the county system.

Implementation Guidance for County Highways

High Priority Locations on the Local System–Horizontal Curves:

- No individual curves identified as Black Spots
- 48% of severe crashes in curves
- 17 of 72 (24%) curves identified as visual traps

Lane Departure Crashes

Key Objectives:
Keep Vehicles in Their Lane

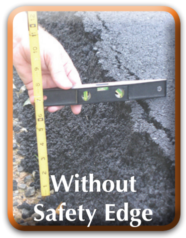
Key Strategies:

- Improved curve delineation
- Improved lane markings

Key Objectives:
Improve Shoulders

Key Strategies:

- Safety edge
- Paved shoulders
- Shoulder rumble strips



Key Objectives:
Improve Roadsides

Key Strategies:

- Clear roadside of fixed objects
- Breakaway sign and mailbox supports
- Flatten slopes


Examples of implementations not compliant with current standards

Systematic Analysis of County Highways (2 of 2)

Source: Freeborn County Road Safety Audit Report, 2008

Highlights

- The objective of the safety analysis conducted by Freeborn County was to identify the primary causes of their severe crashes and to conduct a mapping exercise linking crash causation with a shortlist of high priority safety strategies.
- The review of county crash data found no Black Spots on the county system, but did find a pool of life-changing crashes (fatal+severe injury) that would be susceptible to correction.
- The safety analysis found that lane departure crashes accounted for 87% of all life-changing crashes and that 48% of these crashes occurred in curves – which make up only about 6% of the county's highway system.
- A field review of a sample of the county's system found that about one-quarter of the curves (17 of 72) constituted a "visual trap" – a horizontal curve that followed a crest vertical curve or where there was a township road on the extended tangent.
- A shortlist of high priority strategies was developed to address lane departure crashes and a method was developed to assist in prioritizing horizontal curves based on the number of crashes, curve radius, presence of a visual trap, and proximity to other high priority curves.

Safety Planning at the Local Level

Highlights

- Federal highway legislation requires all states to prepare Strategic Safety Plans, and all of the states have complied.
- However, both national and Minnesota crash data indicate that between 40 and 50% of traffic fatalities occur on local roads – this clearly indicates the need for local road authorities to undertake their own strategic safety planning in order to support the statewide effort.
- Mn/DOT has supported safety planning at the local level by increasing levels of financial assistance and technical support. The 2009-2010 Highway Safety Improvement Program allocated almost $12M for 45 projects on the local system (including several projects that involve the preparation of county strategic safety plans).
- The single most important practice to support safety at the local level is for agencies to dedicate a portion of their annual capital improvement program to implementing low-cost strategies on their system.
- The preparation of a data driven Safety Plan will assist in identifying the primary factors contributing to serious crashes, and this will assist in identifying the high priority safety strategies. The overall objective is to develop a multi-year list of safety improvement projects.
- In addition to improvements to roadways, other local safety based practices could include:
  - Initiating/participating in a Safe Communities program
  - Initiating/participating in a Safe Routes to School program
  - Initiating a fatal crash review process
  - Participating in road safety audits
  - Support law enforcement initiatives to reduce speeding, improve seat belt compliance and reducing drinking and driving.

Traffic Safety Tool Box—Contents

Minnesota Department of Transportation

Traffic Safety Tool Box—Then vs. Now

Highlights

THEN: Only a few sources of information about the effectiveness of safety projects were available, none were comprehensive and there were concerns about the statistical reliability of the conclusions because of the analytical techniques that were used. Most of the information available was based on observations of a limited number of locations.

NOW: Better and more comprehensive set of references are available:

- NCHRP Series 500 Reports – Implementation of AASHTO's Strategic Highway Safety Plan
  http://safety.transportation.org/guides.aspx
- Report No. FHWA-SA-07-015 Desktop Reference for Crash Reduction Factors
  www.transportation.org/sites/safetymanagement/docs/Desktop%20Reference%20Complete.pdf
- Safety Analyst –
  www.safetyanalyst.org

Traffic Safety Tool Box (1 of 2)

Traffic Safety Tool Box—Then vs. Now

Education

- Older Drivers
- Distracted/Fatigued Drivers
- Motorcycles
- Alcohol

Enforcement

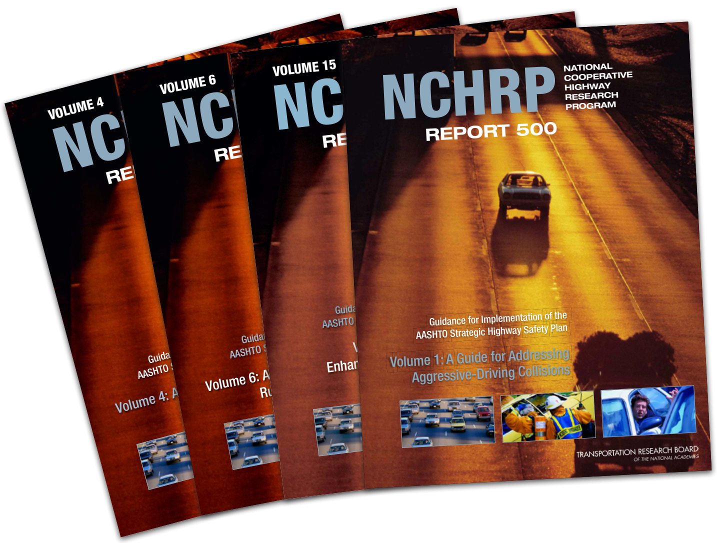
- Aggressive Driving
- Unlicensed/ Suspended/Revoked Drivers License
- Unbelted Occupants
- Heavy Trucks

Engineering

- Trees in Hazardous Locations
- Head-On Crashes
- Unsignalized Intersections
- Run-Off-Road Crashes
- Pedestrians
- Horizontal Curves
- Signalized Intersections
- Utility Poles
- Work Zones

Emergency Services

- Rural Emergency Medical Services



Traffic Safety Tool Box (2 of 2)

Highlights

- The National Corporative Highway Research Program (NCHRP) developed a series of guides to assist state and local agencies reduce the number of severe crashes in a number of targeted areas.
- The guides correspond to the 22 safety emphasis areas outlined in AASHTO's Strategic Highway Safety Plan.
- Each guide includes a description of the problem and a list of suggested strategies/countermeasures to address the problem.
- The list of strategies in each guide was generated by an expert panel that consisted of both academics and practitioners in order to provide a balance and a focus on feasibility.
- In addition to describing each strategy, supplemental information is provided, including the following;
  - Expected Effectiveness (crash reduction factors)
  - Implementation Costs
  - Challenges to Implementation
  - Organizational and Policy Issues
  - Designation of Each Strategy as either Tried, Experimental, or Proven

http://safety.transportation.org/guides.aspx

Effectiveness of Safety Strategies

Proven

Education

- Graduated Drivers Licensing
- Safety Belt Enforcement Campaigns
- DWI Checkpoints
- Street Lights at Rural Intersections

Enforcement

- Access Management
- Roadside Safety Initiatives
- Pave/Widen Shoulders
- Roundabouts
- Exclusive Left Turn Signal Phasing
- Shoulder Rumble Strips
- Improved Roadway Alignment
- Cable Median Barrier

Engineering

- Removing Unwarranted Traffic Signals
- Removing Trees in Hazardous Locations
- Pedestrian Crosswalks, Sidewalks, and refuge Islands
- Left Turn Lanes on Urban Arterial

Tried

Engineering

- Rumble Strips (on the approach to intersections)
- Neighborhood Traffic Control (Traffic Calming)
- Overhead Red/Yellow Flashers
- Increased Levels of Intersection Traffic Control
- Indirect Left Turn Treatments
- Restricting Turning Maneuvers
- Pedestrian Signals
- Improve Traffic Control Devices on Minor Intersection Approaches

Experimental

Engineering

- Turn and Bypass Lanes at Rural Intersections
- Dynamic Warning Devices at Horizontal Curves
- Static/ Dynamic Gap Assistance Devices
- Delineating Trees in Hazardous Locations
- Marked Pedestrian Crosswalks at Unsignalized Intersections

Highlights

- Traffic Engineers have historically had a "tool box" of strategies that could be deployed to address safety concerns. The results of recent safety research studies suggest that the process for originally filling the tool box appears to have been primarily based on anecdotal information.
- The recent research efforts have subjected a number of safety measures to a comprehensive package of comparative and before vs. after analyses and rigorous statistical tests. The results of this research indicate that some safety measures should be kept in the tool box, some removed, some new measures added, and some continued to be studied.
- The 22 volumes that make up the NCHRP Series 500 Reports – Implementation of AASHTO's Strategic Highway Safety Plan – identify over 600 possible safety strategies in categories including driver behavior (speeding, safety belt usage and alcohol), infrastructure related improvements (to reduce head-on, road departure and intersection crashes) and providing emergency medical services.
- These NCHRP Reports have designated each of the strategies as either Proven (as a result of a rigorous statistical analysis), Tried (widely deployed but no statistical proof of effectiveness) or Experimental (new techniques or strategies and no statistical proof).
- It should be noted that virtually all of the strategies that have been designated in the NCHRP Series 500 Reports as either Proven, Tried, or Experimental are associated with engineering activities. This is due to the lack of published research quantifying the crash reduction effects of strategies dealing with Education, Enforcement, and Emergency Services.

Roadside Safety Strategies

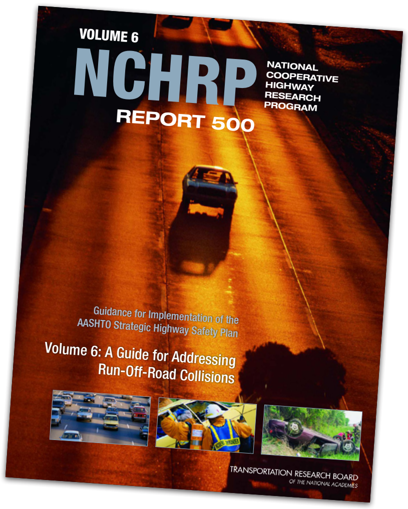
Emphasis Area Objectives and Strategies	
Objectives	**Strategies**
15.1 A—Keep vehicles from encroaching on the roadside	• 15.1 A1—Install shoulder rumble strips • 15.1 A2—Install edgeline “profile marking,” edgeline rumble strips, or modified shoulder rumble strips on section with narrow or no paved shoulders • 15.1 A3—Install midlane rumble strips • 15.1 A4—Provide enhanced shoulder or in-lane delineation and marking for sharp curves • 15.1 A5—Provide improved highway geometry for horizontal curves • 15.1 A6—Provide enhanced pavement markings • 15.1 A7—Provide skid-resistant pavement surfaces • 15.1 A8—Apply shoulder treatments – Eliminate shoulder drop-offs – Widen and/or pave shoulders
15.1 B—Minimize the likelihood of crashing into an object or overturning if the vehicle travels off the shoulder	• 15.1 B1—Design safer slopes and ditches to prevent rollovers • 15.1 B2—Remove/relocate objects in hazardous locations • 15.1 B3—Delineate trees or utility poles with retroreflective tape
15.1.C—Reduce the severity of the crash	• 15.1 C1—Improve design of roadside hardware (e.g., light poles, signs, bridge rails) • 15.1 C2—Improve design and application of barrier and attenuation systems

Roadside Safety Strategies (1 of 6)

Source: NCHRP Report 500 Series (Volume 6)

Highlights

- Single vehicle road departure crashes have been identified as being one of Minnesota’s Safety Emphasis Areas.
- Single vehicle road departure crashes account for 32% of all fatal crashes in Minnesota and as much as 47% of fatal crashes on local roads in rural areas.
- The guidance in the NCHRP Service 500 Report – Volume 6 suggests a three step process for addressing road departure crashes:
  1. Keep Vehicles on the Road
  2. Provide Clear Recovery Areas
  3. Install/Upgrade Highway Hardware
- This three step priority is based on cost considerations, feasibility, and logic. The strategies associated with keeping vehicles on the road are generally low cost, can easily be implemented because additional right-of-way and detailed environmental analyses are not required, and treating road edges directly addresses the root cause of the problem – vehicles straying from the lane.



- Providing clear recovery areas is considered to be the second priority even though the strategies have been proven effective, because of implantation challenges – costs are generally higher than for edge treatments, and additional right-of-way may be required as well as more detailed environmental review.
- Installing / upgrading highway hardware is the third priority because it can be expensive to construct and maintain, it can cause injuries when hit, and it does not address the root cause of the problem.

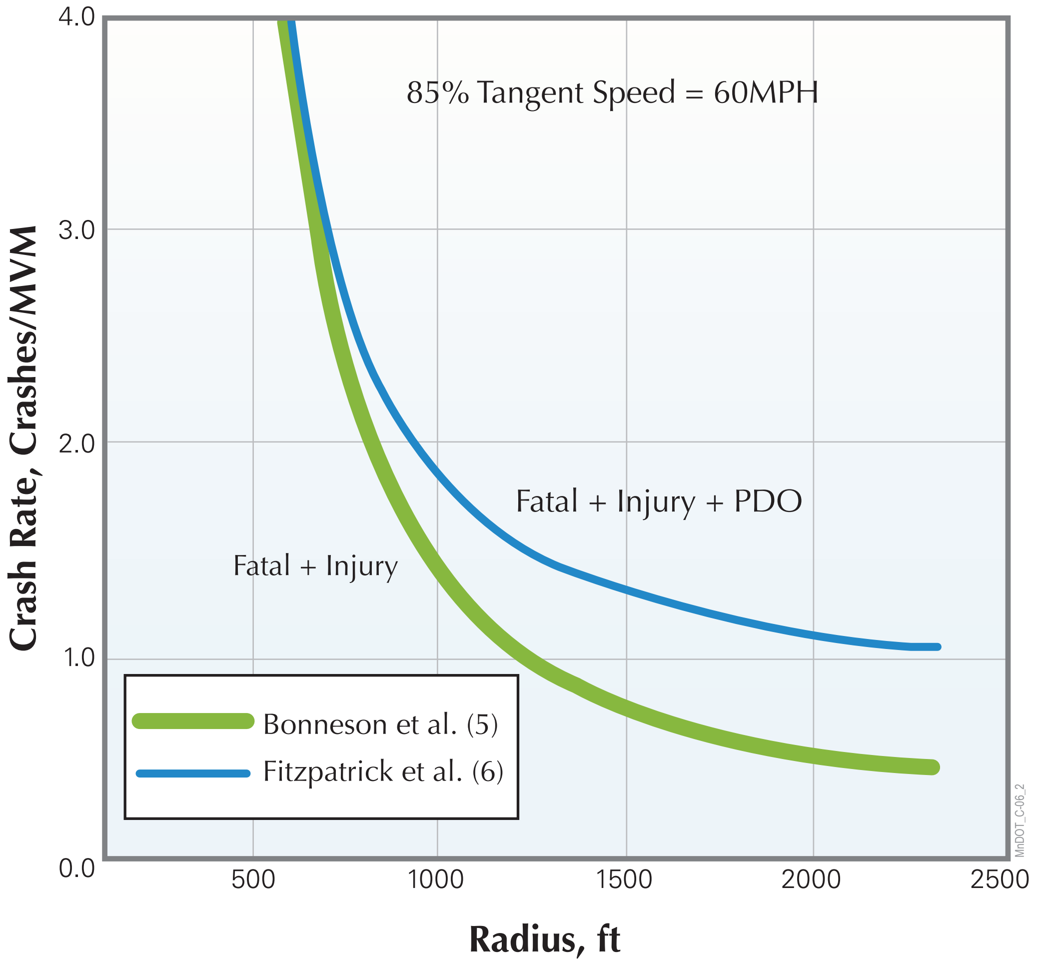
Edge Treatments

Roadside Safety Strategies (2 of 6)

Highlights

- Typical edge treatments include shoulder/edgeline rumble strips, enhanced pavement markings, and eliminating shoulder drop offs.
- Implementation costs vary from no cost (safety edge) to several thousand dollars per mile for rumble strips/stripEs.
- National safety studies have documented crash reductions in the range of 20 to 50% for road departure crashes.
- An unexpected benefit has been observed on projects where edgelines have been painted over the edgeline rumble strips – night time visibility in wet pavement conditions was improved (the reflective beads applied to the nearly vertical face of the rumble strip remain above the film of water on the pavement surface) and the life of the pavement marking was extended (snow plows cannot scrap away the beads on the vertical faces).

Horizontal Curves



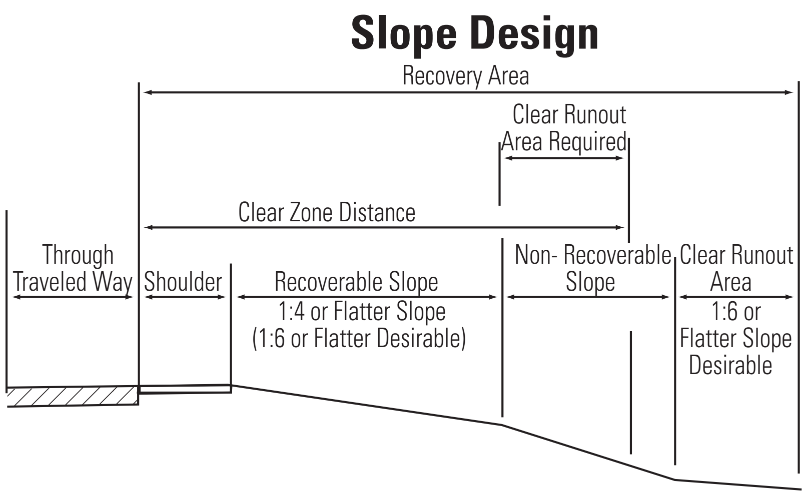
MVM – Million Vehicle Miles

Source: Texas Transportation Institute (FHWA/TX-07/0-5439-1)
Roadside Safety Strategies (3 of 6)

Highlights

- A number of previously published research reports have identified horizontal curves as at-risk elements of rural road systems, however, the degree of risk was not quantified.
- A recent report prepared by the Texas Transportation Institute (FHWA/TX-07/0-5439-1) related actual crash rates on rural roads to the radius of curvature. The results of this research indicates that the crash rate on curves with radii greater then 2,500 feet is approximately equal to the crash rate on tangent sections.
- On curves with radii of 1,000 feet, the crash rate is twice the rate on tangents and curves; curves with radii of 500 feet have crash rates eight times higher than on tangents.
- A number of safety studies that were focused on local, rural systems in Minnesota have found road departure crashes are overrepresented on horizontal curves – 40 to 50% of the road departure crashes in the selected counties occurred on curves, and curves made up less than 10% of the county's system.
- The same studies also documented that over 60% of the horizontal curves on the county system have radii less than 1,000 feet – from a system perspective, these curves are more at risk.

Slope Design/Clear Recovery Areas



Example #1
- 6:1 Slope (Fill Slope)
- 60 MPH
- 5,000 ADT

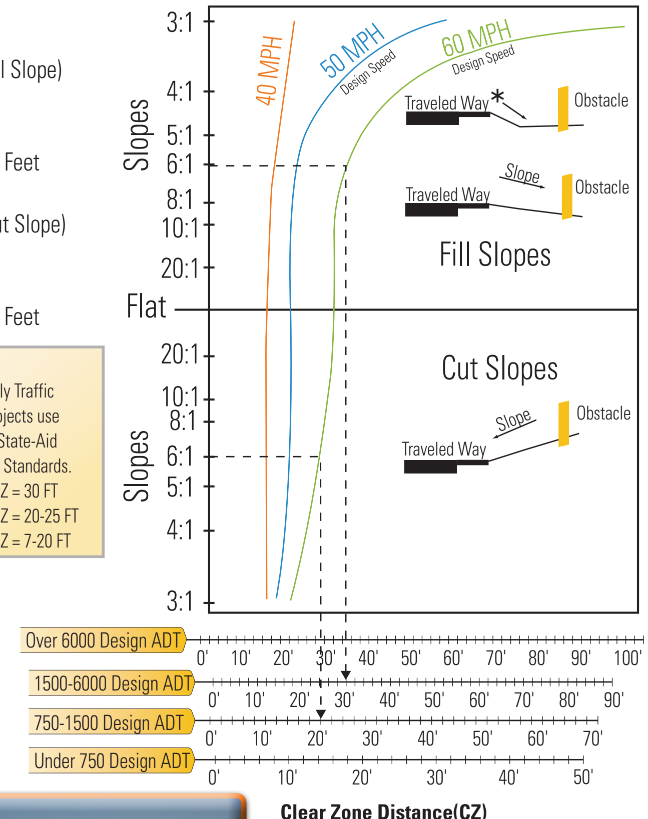
Answer: CZ = 30 Feet

Example #2
- 6:1 Slope (Cut Slope)
- 60 MPH
- 750 ADT

Answer: CZ = 20 Feet

CZ = Clear Zone
ADT = Average Daily Traffic
Note: State-Aid projects use the Mn/Dot State-Aid Rural Design Standards.

Over 1,500 ADT;	CZ = 30 FT
750-1,500 ADT;	CZ = 20-25 FT
0-750 ADT;	CZ = 7-20 FT



* See Mn/DOT Road Design Manual section 3.3.4 for a discussion on variable slope determination

Highlights

- Providing clear recovery areas has been proven to reduce severe road departure crashes by removing obstacles in hazardous locations and flattening shoulder slopes that cause vehicles to roll over.
- The recommended clear zone distance is a function of speed, slope, volume, and horizontal curvature.
- Generally, higher speeds, steeper fill slopes, higher volumes, and locations along the outsides of horizontal curves require larger clear zones.
- The concept of providing clear recovery areas is primarily intended for rural roadways. However, the concept can be applied to suburban or urban roadways if road departure crashes are a concern.

Note: "Rural" Refers to a non–municipal area and cities with a population less than 5,000.

Source: Mn/DOT Road Design Manual

Roadside Safety Strategies (4 of 6)

Upgrade Roadside Hardware

Example implementations not compliant with current standards (NCHRP 350)

Highlights

- Upgrading roadside hardware is a part of a comprehensive package of safety strategies aimed at reducing the severity of road departure crashes.
- Typical treatments and their installation costs include the following:
  - Impact attenuator = $20,000
  - Guardrail terminal = $1,500
  - Guardrail transition = $1,000
  - W-Beam or Cable Guardrail = $75,000 - $150,000 per mile
- Safety Benefits associated with using modern hardware involve reducing the severity of collisions with guardrail.

Roadside Safety Strategies (5 of 6)

Effectiveness of Roadside Safety Initiatives

TH 6		TH 38
11.2	Length (Miles)	11.2
23	Total Crashes (5 Years) +122%	51
11	PDO Crashes	25
12	Injury Crashes +117%	26
0	Fatal Crashes	0
1,100	Volume (VPD)	1,100
22.48	MVM	22.48
1.0	Crash Rates (Crashes/MVM) +130%	2.3
1.5	Severity Rate +173%	4.1
1.3	Critical Crash Rates	1.3
10 (43%)	SVRD Crashes	37 (73%)
3	Hit Trees +1000%	30
8 (35%)	Passing Crashes	3 (6%)
2	Angle Crashes	4
6	Deer Hits	1
10 (43%)	Night	21 (41%)

Source: Mn/DOT District 1, Traffic Engineering *Roadside Safety Strategies (6 of 6)*

Highlights

- An estimate of the safety implications by evaluating two very similar segments of two-lane rural trunk highways in northern Minnesota: TH 6 and TH 38.
- Both roads have the following similar characteristics:
  - Have virtually identical volumes
  - Serve similar functions (recreational and logging).
  - Traverse the Chippewa National Forest.
  - Have scenic qualities.
- TH 6 has been reconstructed and TH 38 has not. (Note: This segment of TH38 has recently been reconstructed but a Before vs. After Study has not been completed)
- The results are obvious. TH 38 has the following characteristics:
  - More than twice as many crashes.
  - More than twice as many injuries.
  - A crash rate more than twice the average for two-lane rural roads (and 30% greater than the critical rate).
  - Almost four times as many SVRD crashes (and more than three the average for similar roads).
  - Ten times as many tree hits.
  - More than twice as many night time crashes.

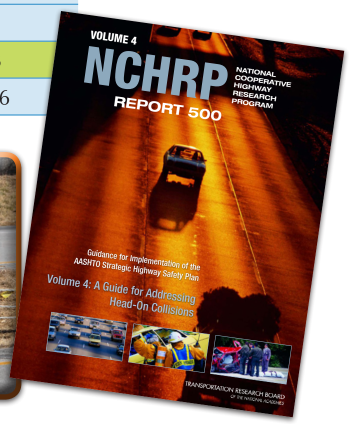
PDO – Property Damage Only
VPD – Vehicles Per Day
MVM – Million Vehicle Miles
SVRD – Single Vehicle Road Departure

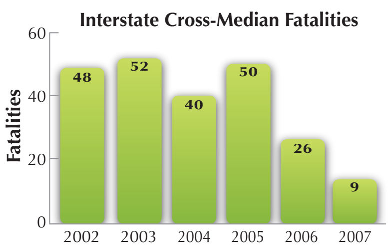
Addressing Head-On Collisions

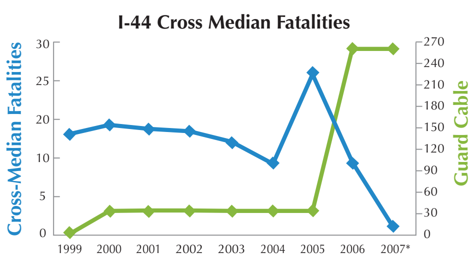
Head–On Crashes on a Two–Lane Rural Highway in Delaware Before and After Use of Centerline Rumble Stripe

Severity of Crash	Head–On Crash Frequency: 36 Months Before	Head–On Crash Frequency: 24 Months After
Fatal	6	0
Injury	14	12
Damage Only	19	6
Total	39	18
Crashes per Month	1.1	0.76

Source: NCHRP 500 Series (Volume 4)







Source: AASHTO, "Driving Down Lane Departure Crashes", April 2008

Highlights

- Head-on crashes account for approximately 20% of the traffic fatalities in Minnesota.
- Addressing head-on crashes is one of Minnesota's Critical Safety Emphasis areas.
- Minnesota averages approximately 120 fatal head-on crashes per year, 90% are passing related on two-lane facilities, slightly less than one-half are on the State system, and about 75% are in rural areas.
- Centerline rumble strips have been found to reduce head-on crashes along two-lane roads – data from 98 sites in 7 states (including Minnesota) indicated significant reductions for injury crashes (15%) as well as for head-on and opposing sideswipe injury crashes (25%).
- Additional strategies for two-lane roads include conducting field surveys to confirm that designated passing zones meet current guidelines for sight distance and the use of thermoplastic markings where passing is not permitted.
- The construction of "Passing Lanes" along two-lane roads has been found to be a convenience for motorists (providing opportunities to pass slower moving vehicles). However, there is no evidence that the passing lanes have reduced head-on crashes.
- A number of states have begun to address cross-median head-on crashes on divided highways by installing cable median barriers. Reported reductions in severe head-on crashes have ranged from 70 to 95%.
- Mn/DOT has installed approximately 150 miles of cable barrier, with plans to install an additional 80 miles. A preliminary analysis of Mn/DOT's first cable median barrier installation (along I-94 in Maple Grove) found a 100% reduction in fatalities and a 90% reduction in overall crash severity.

Intersection Safety Strategies

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
A-Improve access management	A1-Implement intersection or driveway closures, relocations, and turning restrictions using signing or by providing channelization.	Low to Moderate	Tried	Medium (1-2yrs.)
B-Reduce the frequency and severity of intersection conflicts through geometric design improvements	B1-Provide left-turn lanes at intersections; provide sufficient length to accommodate deceleration and queuing; and use offset turn lanes to provide better visibility if needed.	Moderate to High	Proven	Medium (1-2yrs.)
	B2-Provide bypass lanes on shoulders at T-intersections.	Low	Tried	Short (<1 yr.)
	B3-Provide right-turn lanes at intersections; provide sufficient length to accommodate deceleration and queuing; use offset turn lanes to provide better visibility if needed; and provide right-turn acceleration lanes.	Moderate to High	Proven	Medium (1-2yrs.)
	B4-Realign intersection approaches to reduce or eliminate intersection skew.	High	Proven	Medium (1-2yrs.)
C-Improve driver awareness of intersections as viewed from the intersection approach.	C1-Improve visibility of intersections by providing enhanced signing. This may include installing larger regulatory, warning, and guide signing and supplementary stop signs.	Low	Tried	Short (<1 yr.)
	C2-Improve visibility of intersections by providing lighting (install or enhance) or red flashing beacons mounted on stop signs.	Low to Moderate	Proven	Medium (1-2yrs.)
	C3-Improve visibility of intersections by providing enhanced pavement markings, such as adding or widening stop bar on minor-road approaches, supplementary messages (i.e., STOP AHEAD).	Low	Tried	Short (<1 yr.)
	C4-Improve visibility of traffic signals using overhead mast arms and larger lenses.	Moderate	Tried	Short (<1 yr.)
	C5- Deploy mainline dynamic flashing beacons to warn drivers of entering traffic.	Low	Experimental	Short (<1 yr.)
D-Improve sight distance at intersections.	D1-Clear sight triangles approaches to intersections; in addition to eliminating objects in the roadside, this may also include eliminating parking that restricts sight distance.	Low to Moderate	Tried	Short (<1 yr.)
E-Choose appropriate intersection traffic control to minimize crash frequency and severity	E1-Provide all-way stop control at appropriate intersections.	Low	Proven	Short (<1 yr.)
	E2-Provide roundabouts at appropriate intersections.	High	Proven	Long (>2 yrs.)
F-Improve driver compliance with traffic control devices and traffic laws at intersections	F1-Enhance enforcement of red-light running violations using automated enforcement (cameras) or adding confirmation lights on the back of signals to assist traditional enforcement methods.	Moderate	Proven/Tried	Medium (1-2yrs.)
G-Reduce frequency and severity of intersection conflicts through traffic signal control and operational improvements.	G1-Employ multiphase signal operation, signal coordination, emergency vehicle preemption optimize clearance intervals; implement dilemma zone protection; on high speed roadways, install advance warning flashers to inform driver of need to stop; and retime adjacent signals to create gaps at stop-controlled intersections.	Low to Moderate	Proven/Tried	Medium (1-2yrs.)

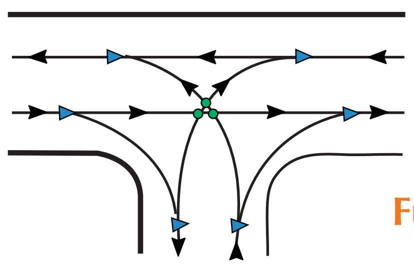
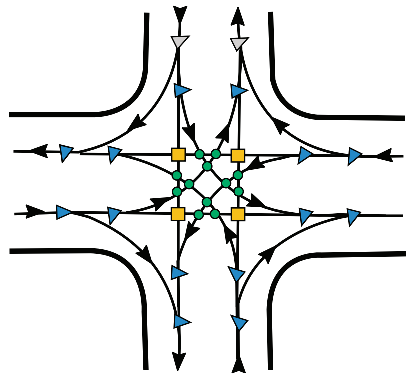
Source: Mn/DOT Strategic Highway Safety Plan

Highlights

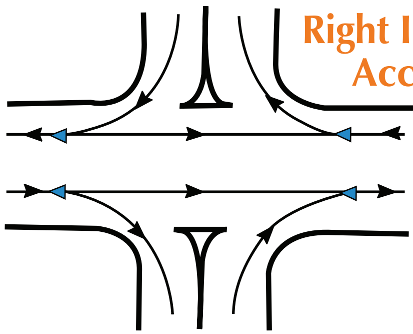
- Addressing crashes at intersections is one of Minnesota's Safety Emphasis Areas.
- Intersection related crashes account for more then 50% of all crashes and about one-third of fatal crashes.
- Approximately two-thirds of fatal intersection crashes occur in Greater Minnesota and slightly more than one-half are on the local system.
- STOP controlled intersections average slightly less than 1 crash per year and signalized intersections average almost 7 crashes per year.
- The high priority safety strategies for unsignalized intersections involve managing access and conflicts, enhancing signs and markings, improving intersection sight distance and providing roundabouts.
- The high priority strategies for signalized intersections include reducing red light violations and optimizing signal operations.

- On the state system, about 55% of intersection crashes occur at locations with STOP control. However, there are 7 times as many STOP controlled as compared to signal controlled intersections.
- The density of severe crashes (Fatals & A Injuries) is four times higher at signalized intersections than at STOP controlled intersections.

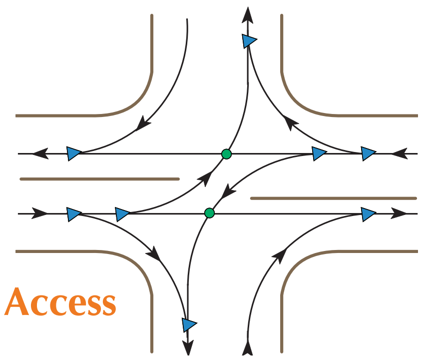
Conflict Points—Traditional Intersection Design

Full Access



Right In/Out Access



3/4 Access

	Crossing	Turning	Merge/ Diverge	Total	Typical Crash Rate (crashes per mil. entering vehicles)
Full Access +	4	12	16	32	0.3 [1]
Full Access T	0	3	6	9	0.3 [2]
3/4 Access	0	2	8	10	0.2 [3]
Right In/Out Access	0	0	4	4	0.1 [3]

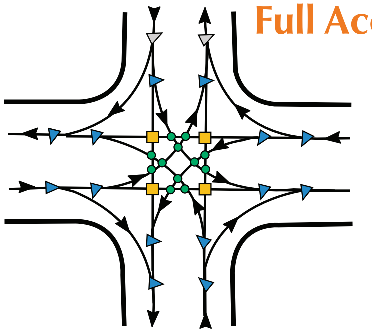
Intersections (2 of 8)

Highlights

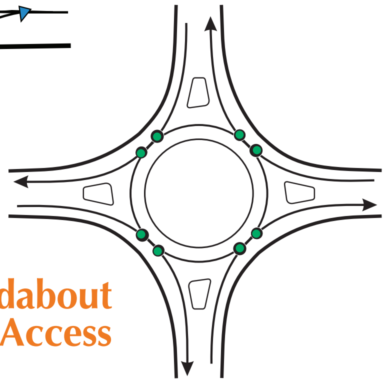
- A review of the safety research suggests that intersection crash rates are related to the number of conflicts at the intersection.
- Conflict points are locations in or on the approaches to an intersection where vehicle paths merge, diverge, or cross.
- The actual number of conflicts at an intersection is a function of the number of approaching legs ("T" intersection have fewer conflicts than 4-legged intersections) and the allowed vehicle movements (intersections where left turns are prohibited/prevented have fewer conflicts than intersections where all movements are allowed).
- A preliminary review of intersection crash data indicates two key points:
  - Some vehicle movements are more hazardous than others. The data indicates that minor street crossing movements and left turns onto the major street are the most hazardous (possibly because of the need to select a gap from two directions of on-coming traffic). Left turns from the major street are less hazardous than the minor street movements, and right turn movements are the least hazardous.
  - Crash rates at restricted access intersections (3/4 design and right in/out) are typically lower than at similar 4-legged intersections. Prohibiting/preventing movements at an intersection will likely reduce the crash rate.

[1] 2004-2006 Minnesota TIS Crash Data
[2] Estimated based on Publication FHWA-RD-91-048
[3] Estimated based on a limited sample of Mn/DOT data

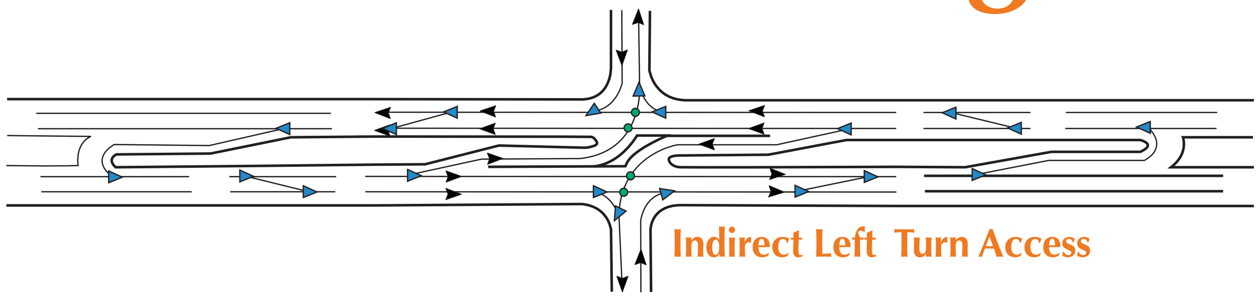
Conflict Points—New Intersection Design



Full Access



Roundabout Access



Indirect Left Turn Access

	Crossing	Turning	Merge/Diverge	Total	Typical Crash Rate (crashes per mil. entering vehicles)
Full Access	4	12	16	32	0.3 [1]
Roundabout	0	0	8	8	0.2 [2]
Indirect Left Turn	0	4	20	24	0.1 [3]

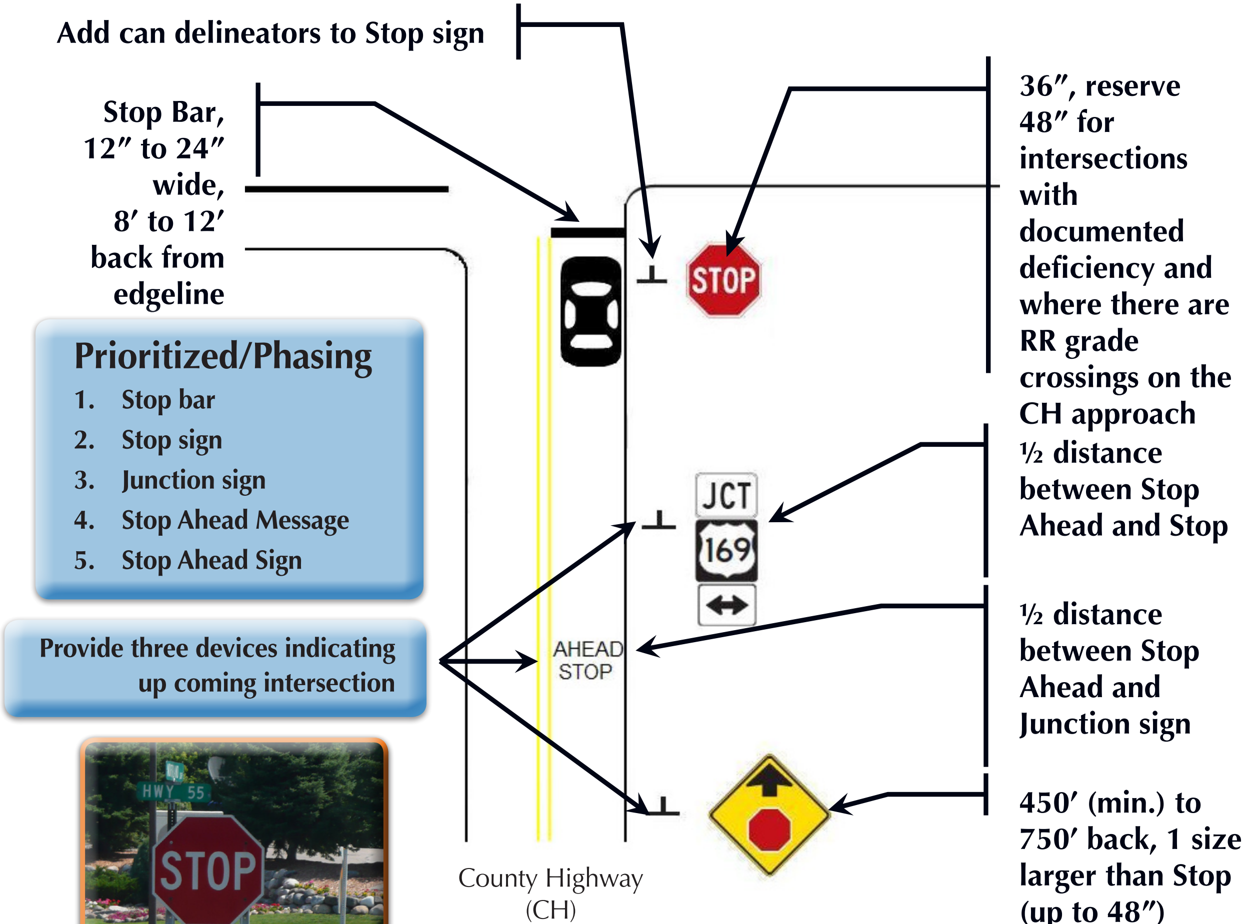
[1] 2004-2006 Minnesota TIS crash data [2] Estimated based on a limited sample of Mn/DOT data [3] NCHRP 15–30 Preliminary Draft

Highlights

- Analysis of crash data proves that the most frequent type of severe intersection crash is a right angle – vehicle maneuvers that involve crossing conflicts.
- In response to this data, highway agencies are beginning to implement intersection designs that reduce or eliminate the at-risk crossing maneuvers by substituting lower-risk turning, merging and diverging maneuvers. Two examples of these new designs include Roundabouts and Indirect Turn Treatments.
- Roundabouts have been implemented at a sufficient number of intersections in Minnesota and around the County, such that follow-up studies have documented a Proven effectiveness of reducing both the frequency and severity of crashes. More information regarding Roundabouts can be found at – Roundabouts: An Informational Guide (Report No. FHWA-RD-00-067 **www.tfhrc.gov/safety/00-0675.pdf**)
- The concept of Indirect Turns has primarily been applied to divided roadways where there is sufficient room in the median to construct the channelization necessary to restrict crossing maneuvers and to accommodate U-turns. This design technique has been implemented at approximately a dozen intersections in Maryland and North Carolina and as a result is considered Tried. Before/After studies at these locations have documented close to a 90% reduction in total crashes and a 100% reduction in angle crashes. More information about Indirect Turns can be found in NCHRP 15-30: Median Intersection Design for Rural High Speed Divided Highways (currently in draft form at **http://www.ctre.iastate.edu/educweb/nchrp%20final%20report/**)

Intersections (2 of 8)

Enhanced Signs and Markings



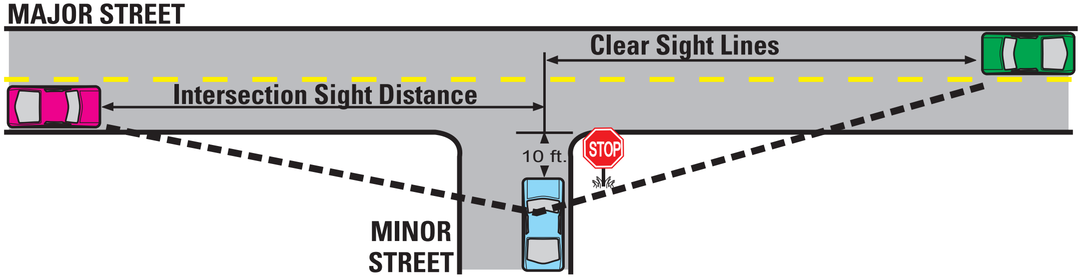
Source: Mn/DOT Dist 3-13 County RSA - CH2M HILL 2006 Intersections (3 of 8)

Highlights

- The most common type of crash at STOP controlled intersections is a right angle crash.
- Research performed in Minnesota (Reducing Crashes at Controlled Rural Intersections – Mn/DOT No. 2003-15) found that approximately 60% of these angle crashes involved vehicles on the minor road stopping and then pulling out and 26% involved vehicles running through the STOP sign.
- This same study also found that increasing the conspicuity of traffic control devices by using bigger, brighter or additional signs and markings (such as the STOP AHEAD message and a STOP bar) are associated with decreasing Run the STOP crashes.
- A more recent – Safety Evaluation of STOP AHEAD Pavement Markings (FHWA-HRT-08-043) – documents the effects of adding STOP AHEAD pavement markings. The study looked at 175 sites in Arkansas, Maryland and Minnesota. The study found crash reductions in the range of 20 to 40%, benefit/cost ratios greater than 2 to 1 and concluded that this strategy has the potential to reduce crashes at signalized intersections.

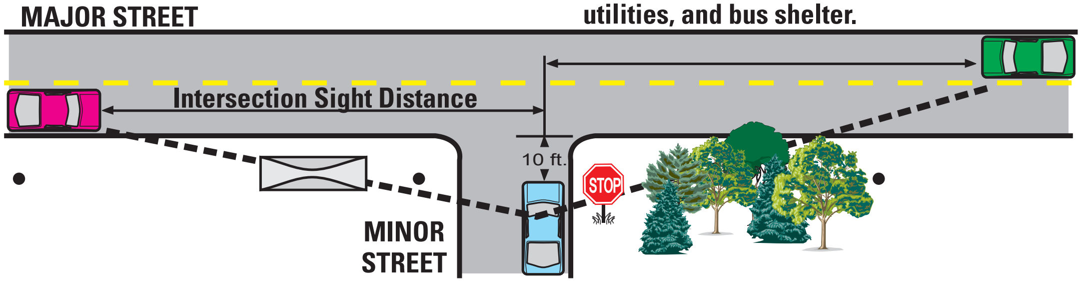
Intersection Sight Distance

Adequate Sight Distance



Speed	30	35	40	45	50	55	60	65
Intersection Sight Distance	325 ft 7 sec.	400 ft 8 sec.	475 ft 8 sec.	550 ft 8 sec.	650 ft 9 sec.	725 ft 9 sec.	880 ft 10 sec	950 ft 10 sec

Inadequate Sight Distance



Source: NCHRP Report 383 – Intersection Sight Distance Iowa Highway Safety Management System, and AASHTO Green Book

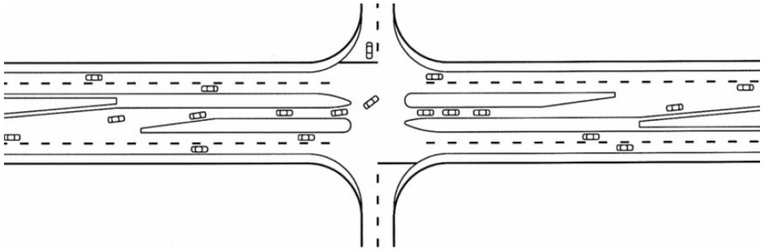
Intersections (4 of 8)

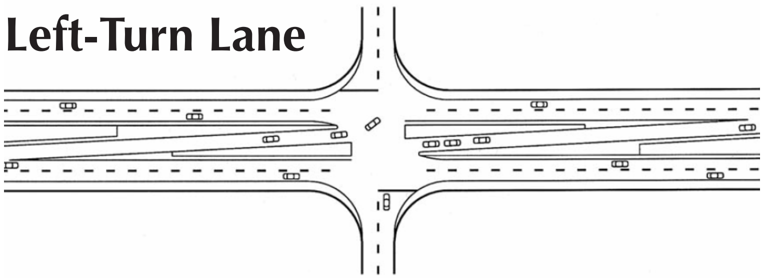
Highlights

- Intersection sight distance refers to the length of the gap along the major roadway sufficient to allow a minor street vehicle to either safely enter or cross the major traffic system.
- A reasonable intersection sight distance allows for adequate driver perception reaction time (2.5 seconds) and either sufficient time to clear the major street, or to turn onto the major street and accelerate to the operating speed without causing approaching vehicles to reduce speed by more than 10 mph.
- The actual length of the recommended intersection distance is a function of the major street operating speed. However, the size of the gap varies from 7 seconds at 30 mph to 10 seconds at speeds of 60 mph and above.
- When dealing with Mn/DOT's Trunk Highways, refer to Section 5-2.02.02 of the *Road Design Manual* for additional guidance regarding intersection sight distance.
- It is important to note that intersection sight distance is always greater than stopping sight distance, by as much as 30 to 60%.
- The ten second "Rule of Thumb," 10 seconds of intersection sight distance, is a good estimate regardless of conditions.
- Removal of vegetation and on–street parking are cost–effective safety improvements for intersections.

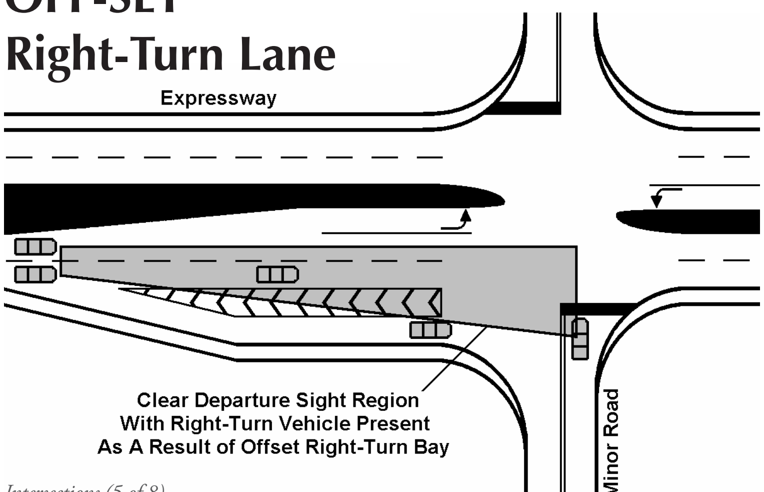
Turn Lane Designs

OFF-SET Left-Turn Lane





OFF-SET Right-Turn Lane

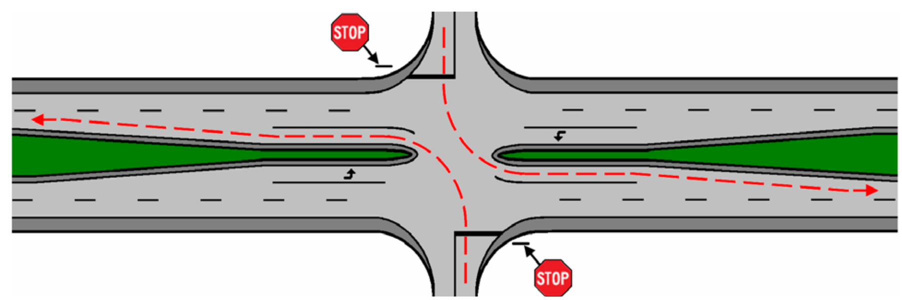


Intersections (5 of 8)
Source: NCHRP 15-30 Preliminary Draft

Highlights

- Providing right and left turn lanes at intersections are included in Minnesota's list of High Priority strategies.
- However, there are locations where vehicles are stopped or decelerating in the turn lane and can block the line of sight for other vehicles waiting at the intersections. In these cases the use of Off-set left and right turn lanes will improve the line of sight for vehicles waiting to complete their crossing or turning maneuvers.
- Off-set turn lanes are considered Tried (as opposed to Proven). A Before vs. After Study of Off-set Left Turn lanes in North Carolina reported a 90% reduction in Left Turn crashes. A similar study of Off-set Right Turn lanes in Nebraska found a 70% reduction in near-side right angle crashes.
- The Median Acceleration Lane (MAL) has been used at a number of locations in Minnesota and is also considered Tried – Before vs. After studies indicate a 75% reduction in same direction sideswipe crashes, a 35% reduction in far-side right angle crashes and a 25% reduction involving left turn crashes from the minor road.

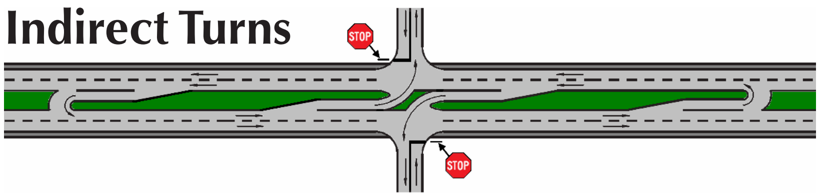
Median Acceleration Lane



Roundabouts and Indirect Turns

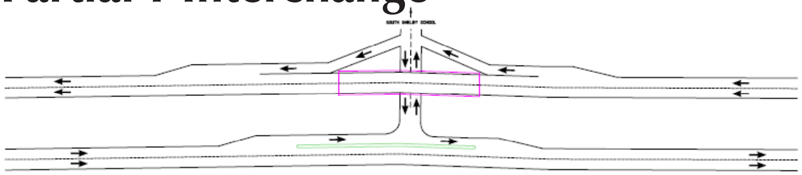
Minnesota TH13 at Scott County Highway 2 Source: Mn/DOT Metro District Before: After Study

Indirect Turns



Source: NCHRP 15-30

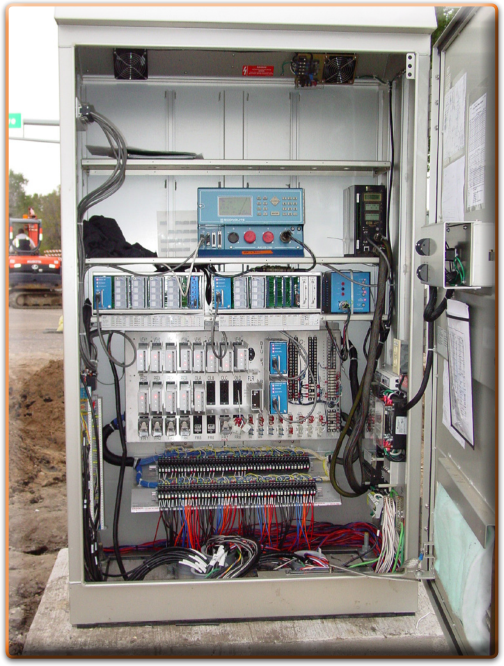
Partial T-Interchange



Highlights

- The most common and most severe type of crash at STOP controlled intersections is a Right Angle which involves a vehicle on the minor road attempting to select a safe gap along the major highway in order to cross.
- A proven strategy to reduce gap selection related angle crashes involves redesigning the intersection or median cross-over to eliminate crossing conflicts (which have the highest probability of a crash) by substituting merging, diverging or turning conflicts (which have a lower probability of a crash).
- The primary examples of reduced conflict intersection designs include; Roundabouts, J-Turns and special application for “T” intersections – the Partial Interchange.
- Roundabouts are considered to be Proven effective (there is virtually no possibility of an angle crash) with statistically significant crash reductions – 38% for all crashes, 76% for injury crashes and for serious injury and fatal crashes. Not withstanding the superior safety performance, care must be taken when considering conversion to a Roundabout – implementation costs are in the range of $1,000,000 and all entering legs are treated equally. The key question is do the traffic characteristics and function classification support the degrading of mainline traffic operations.
- The concept behind indirect-turns is that merge, diverge and turning conflicts result in fewer and less severe crashes. An example of the indirect turn applied to a divided roadway is the J-Turn. This application involves constructing a barrier in the median cross-over and forcing minor street crossing traffic to instead make a right turn, followed by a downstream U-Turn, followed by another right turn. J-Turns have been Tried at about a dozen locations in Maryland and North Carolina – implementation costs are in the range of $500,000 to $750,000 and a preliminary crash analysis found a 100% reduction in angle crashes and a 90% reduction in total crashes.
- The partial interchange is an interesting concept for “T” intersections along divided roadways – the construction of one bridge on the “near-side” of the intersection eliminates all crossing maneuvers. This concept is being considered for several locations in Minnesota, but deployment has not been sufficiently wide spread to be able to identify typical implementation costs or document crash reductions.

Traffic Signal Operations

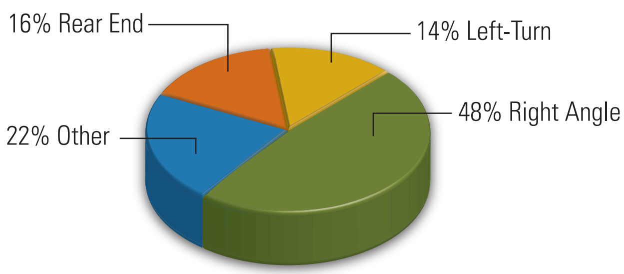


Highlights

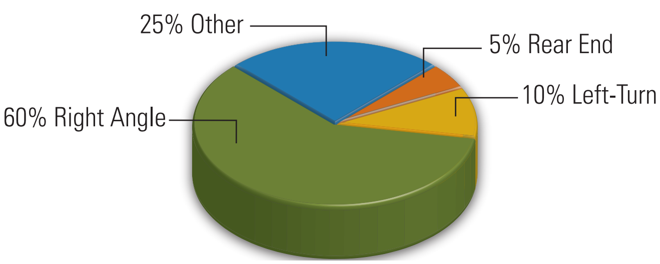
- Installing traffic signals is NOT considered to be a High Priority Intersection Safety Strategy because of the results of studies done at both the national level and in Minnesota. At most intersections, the installation of a traffic signal will increase the number of crashes, along with increasing crash and severity rates. Also, as a category signalized intersections have a higher average crash density, crash rate and severity rate than the average for STOP controlled intersections.
- However, if a traffic signal must be installed to address intersection delay and congestion, there are several suggested High Priority strategies to reduce frequency and severity of intersection crashes. These include:
  - Use of multiphase signal operation combined with left turn lanes.
  - Provide a coordinated signal system along urban arterials
  - Use overhead indications–one per through lane mounted at the center of each lane
  - Provide dilemma zone protection and optimize clearance intervals
  - Use advance warning flashers to supplement static signs where a signal may be unexpected.
  - Pedestrian indications including the use of count down timers.

Red Light Enforcement

Signalized



Thru-Stop or Yield Controlled



Other – Sideswipe (Passing/Opposing), Runoff Road, Right Turn, and Head-On Crashes

Intersections (6 of 8)

Highlights

- The most common type of severe crash at signalized intersections is a Right Angle. Even though signals are intended as a mitigation for angle crashes they have proven to be only marginally effective. In the Minneapolis-Saint Paul Metropolitan area, the annual number of severe angle crashes at signalized intersections (160) exceeds the number at STOP controlled intersections (120), even though the number of STOP controlled intersections exceeds the number of signalized intersections by a factor of 4.
- Crash analysis indicates that most angle crashes at signalized intersections are caused by red light violations.
- As a result, one of Minnesota's adopted High Priority Safety Strategies involves enhancing the enforcement of red-light violations.
- A number of states are using technology to supplement traditional enforcement of red light violations. This involves the use of Red Light Camera Systems in states with enabling legislation (Not Minnesota).
- Studies of RLC systems (including Safety Evaluation of Red Light Cameras, FHWA-HRT-05-048) have documented 40% reductions in red light violations, 25% reductions in angle crashes and a 15% overall reduction in total intersection crashes. The studies also noted a modest increase in rear end crashes, but these tended to be less severe so the average value of crash reduction approached $50,000 per site per year.
- Florida is a state that does not allow RLC systems, so they developed a strategy that uses confirmation lights mounted on the signal mast arms combined with a partnership with local law enforcement. The confirmation light allows one officer to safely observe and pursue red light violators (instead of one officer to observe and an additional officer to pursue). Confirmation lights are inexpensive ($500 to $1,000 per mast arm) and a preliminary evaluation of installations in Florida found a 50% decrease in violations and a 10% overall decrease in crashes.
- For more information see www.stopredlightrunning.com

Safety Effects of Street Lighting at Rural Intersections

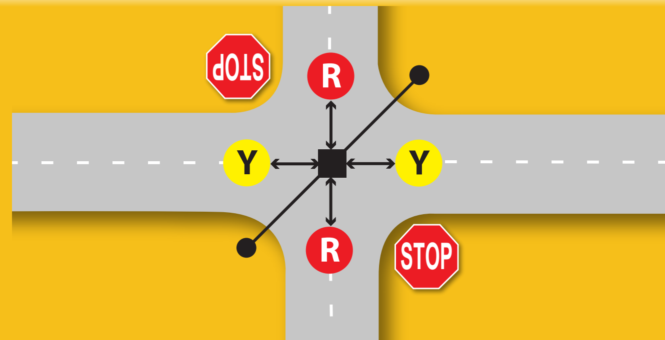
System-Wide Comparative Analysis				
Item	**Intersections without Street Lights**	**Intersections with Street Lights**	**Reduction**	**Statistical Significance**
Intersections	3236	259		
Night Crashes	34%	26%	26%	Yes
Night Crash Rate	0.63	0.47	25%	Yes
Night Single Vehicle Crashes	23%	15%	34%	Yes
Night Single Vehicle Crash Rate	0.15	0.07	53%	Yes

Before vs. After Crash Analysis				
Item	**Before**	**After**	**Reduction**	**Statistical Significance**
Intersections	12	12		
Number of Night Crashes	47	28	40%	Yes
Night Crashes/Intersection/Year	1.31	0.78	40%	
Total Crashes/Intersection/Year	2.44	2.08	15%	
Night Crash Rate	6.06	3.61	40%	Yes
Total Crash Rate	2.63	2.24	15%	Yes
Severity Index	43%	32%	26%	Yes
Night Single Vehicle Crash Rate	4.0	2.84	29%	Yes
Night Multiple Vehicle Crash Rate	2.06	0.77	63%	Yes

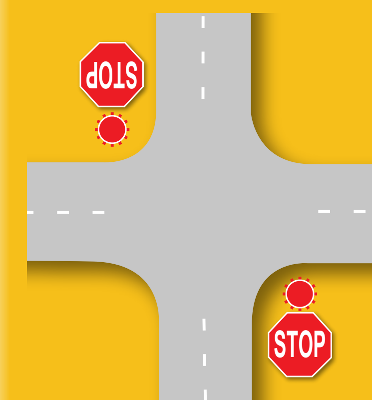
Highlights

- The installation of street lights is considered to be a "Proven" effective strategy for reducing crashes.
- Research has found that the installation of street lights at rural intersections reduced:
  - Night Crashes by 26% to 40%
  - Night Crash Rate by 25% to 40%
  - Night Single Vehicle Crashes by 29% to 53%
  - Night Multiple Vehicle Crashes by 63%
  - Night Crash Severity by 26%
- A Benefit versus Cost analysis found that the crash reduction benefits of street lighting at rural intersections outweigh costs by a wide margin. The average B:C ratio was about 15:1.
- The results of recent case study research suggests that the use of street lighting is more effective at reducing night crashes than either rumble strips or overhead flashers.
- A survey of practice among Minnesota counties found typical lighting installation costs along county facilities in the range of $1,000 to $5,000 per intersection and annual operations maintenance costs in the range of $100 to $600 per light.

Flashing Beacons at Rural Intersections



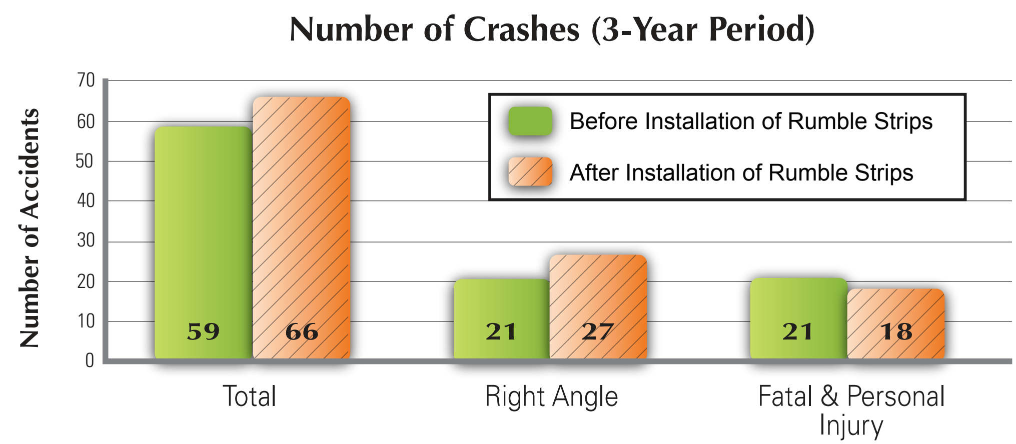
Source: Warning Flashers at Rural Intersection, Minnesota Department of Transportation Final Report No. 1996-01. 1997

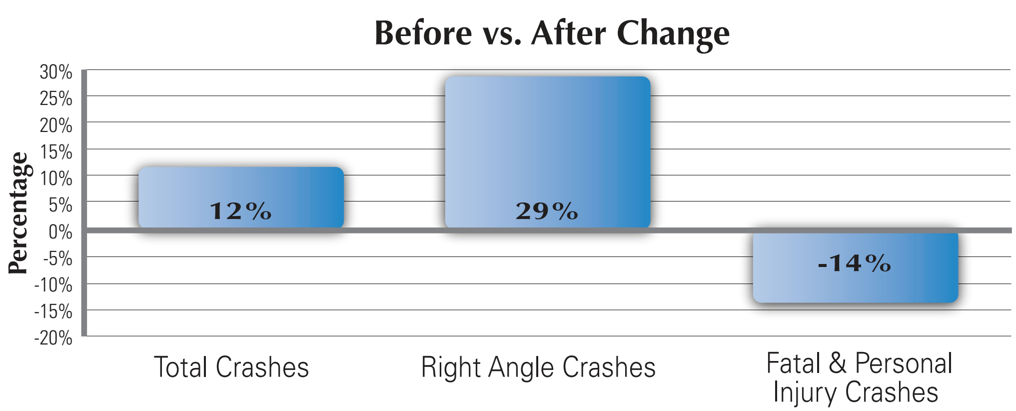


Highlights

- A review of historic crash data indicated that STOP controlled rural intersections with overhead flashers had higher average crash rates than comparable intersections without overhead warning flashers.
- Anecdotal information that surfaced during the investigation of several fatal crashes indicated that some drivers were mistaking Yellow/Red warning flashers for Red/Red flashers that would indicate an All-Way STOP condition.
- In order to address the issue of effectiveness, Mn/DOT commissioned a study by the University of Minnesota's Human Factors Research Lab. The study resulted in the following conclusion:
  - About one-half of drivers surveyed understood the warning intended by the flasher, but most did not adjust their behavior.
  - About 45% of the drivers misunderstood the intended message and thought it indicated an All-Way STOP condition.
  - The change in crash frequency at a sample of intersections was NOT statistically significant.
  - In response to this research, Mn/DOT has begun removing overhead flashers.
- Where there is evidence that additional intersection warning is necessary, options include—use of red flashers on STOP signs or advance warning flashers on STOP AHEAD signs (but there are no studies documenting effectiveness).

Transverse Rumble Strips at Rural Intersections





Source: Mn/DOT's Transportation Synthesis Report, TRS 0701, August 2007

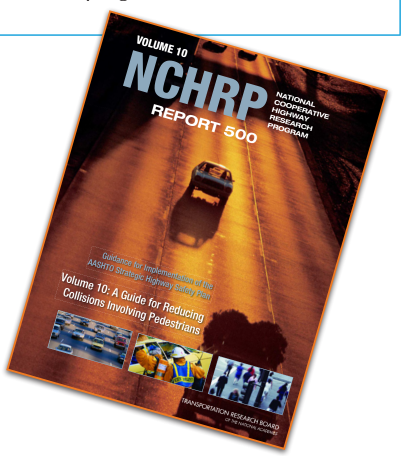
Highlights

- The use of transverse rumble strips to address safety issues at rural intersections has been part of the traffic engineers tool box for many years. However, there are no definitive studies documenting their actual effectiveness.
- Mn/DOT took the opportunity to perform a thorough study of transverse rumble strips as part of preparing their defense in a lawsuit alleging negligence on the state's part for not having rumble strips at a particular intersection. The study resulted in the following conclusions:
  - Based on a search of previous research, no one has ever documented statistically significant crash reductions attributed to the installation of transverse rumble strips on the approach to stop controlled intersections.
  - A Before versus After analysis of 25 rural intersections in Minnesota found that total intersection crashes and right angle crashes actually increased after installing rumble strips. The number of fatal plus injury crashes declined slightly; however, none of the changes was statistically significant.
- Recent work by the University of Minnesota's Human Factors Research Lab found that rumble strips had a minor effect on driver behavior relative to speed reduction and breaking patterns. However, there was no evidence of crash reduction.
- For more information, see Mn/DOT's Transportation Synthesis Report, TRS 0701. www.lrrb.org/trs0701.pdf
- Strategies that been proven effective at improving safety at improving safety at rural Thru/STOP intersections include enhanced signs, markings (C-14) and street lights (C-20).

Pedestrian Safety Strategies

Emphasis Area Objectives and Strategies	
Objectives	**Strategies**
9.1 A Reduce Vehicle Speed	9.1 A1 Implement Road Narrowing Measures 9.1 A2 Install Traffic Calming—Road Sections 9.1 A3 Install Traffic Calming—Intersections 9.1 A4 Provide School Route Improvements
9.1 B Improve Sight Distance and/or Visibility between Motor Vehicles and Pedestrians	9.1 B1 Implement Lighting/Crosswalk Illumination Measures 9.1 B2 Provide Crosswalk Enhancements 9.1 B3 Improve Reflectorization/Conspicuousness of Pedestrians
9.1 C Reduce Pedestrian Exposure to Vehicular Traffic	9.1 C1 Provide Vehicle Restriction/Diversion Measures 9.1 C2 Construct Pedestrian Refuge Islands and Raised Medians 9.1 C3 Install or Upgrade Traffic and Pedestrian Signals 9.1 C4 Provide Sidewalks/Walkways and Curb Ramps 9.1 C5 Install Overpass/Underpass
9.1 D Improve Pedestrian and Motorist Safety Awareness and Behavior	9.1 D1 Provide Education, Outreach, and Training 9.1 D2 Implement Enforcement Campaigns

Source: NCHRP Series 500 (Volume 10)

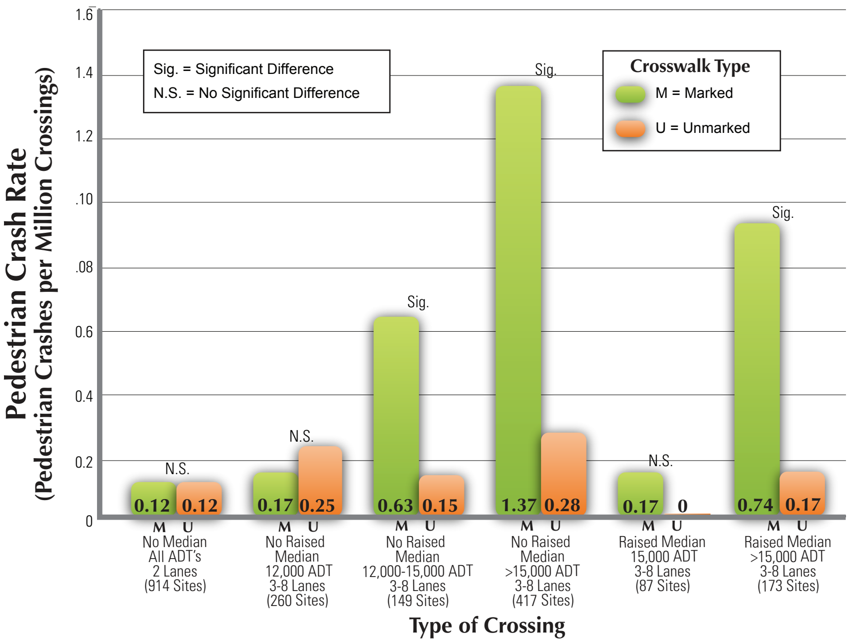


Pedestrian Safety Strategies (1 of 3)

Highlights

- Fatal crashes involving pedestrians are one of AASHTO's Safety Emphasis Areas. In the U.S., there are about 5,000 pedestrians killed each year, which represents about 11% of all traffic fatalities.
- Minnesota averages about 45 pedestrian fatalities annually (about 8% of total traffic fatalities) and our involvement rate (0.4 pedestrian fatalities per 100,000 population) ranks 47th – only Rhode Island, New Hampshire, and Idaho have a lower rate.
- Fatal pedestrian crashes most often occur in urban areas (17%), away from intersections (78%), during good weather (64%). Over two-thirds of the pedestrians killed are male.
- The most common pedestrian activities associated with fatal crashes are walking/working in the road and crossing the roadway.
- The pedestrian was coded for a contributing factor (running into the road – 15%, Failure to yield – 12%, and Alcohol – 10%) in 66% of the crashes vs. 55% for the motorist (Hit & Run – 16% and Failure to yield – 15%).
- The safety strategies in NCHRP Series 500, Vol. 10 are focused on reducing vehicle speeds, improving sight lines, reducing exposure to traffic, plus education and enforcement activities.

Pedestrian Crash Rates vs. Crossing Features



Source: Charles V. Zegeer, et al., Safety Effects Of Marked Vs. Unmarked Crosswalks At Uncontrolled Locations: Executive Summary And Recommended Guidelines, 1996-2001, http://www.walkinginfo.org/pdf/r&d/crosswalk_021302.pdf

Pedestrian Safety Strategies (2 of 3)

Highlights

- Three of the more common strategies intended to address pedestrian crashes include reducing vehicle speeds, providing a marked crosswalk, and installing a traffic signal.
- The research is abundantly clear–merely changing the posted speed limit has never reduced vehicle speeds, painting cross-walks at unsignalized intersections is actually associated with higher frequencies of pedestrian crashes, and installing a traffic signal has never been proven effective at reducing pedestrian crashes.
- Reducing vehicle speeds is associated with reducing the severity of a pedestrian crash, but actually reducing speeds requires changing driver behavior and that requires changing the roadway environment. Strategies that have demonstrated an effect on driver behavior include vertical elements (speed bumps and speed tables), narrowing the roadway (converting from a rural to an urban section) and extraordinary levels of enforcement).
- A cross-sectional study of 2,000 intersections in 30 cities across the U.S. found that marked cross-walks at unsignalized intersections are NOT safety devices. The pedestrian crash rate was higher at the marked cross-walks and this effect is greatest for multi-lane arterials with volumes over 15,000 vehicles per day.
- A Before versus After study at over 500 intersections in San Diego and Los Angeles found a 70% reduction in pedestrian crashes following the removal of marked cross-walks at uncontrolled intersections.
- Traffic signals have not proven to be effective at reducing pedestrian crashes – the highest pedestrian crash frequency locations in most urban areas are signalized intersections.
- Observations of pedestrian behavior at traffic signals suggests that there is a low level of understanding of the meaning of the pedestrian indications and a high level of pedestrian violations–very few push the call button and fewer yet wait for the walk indication.

Curb Extensions and Medians

Median Refuge Near Intersection

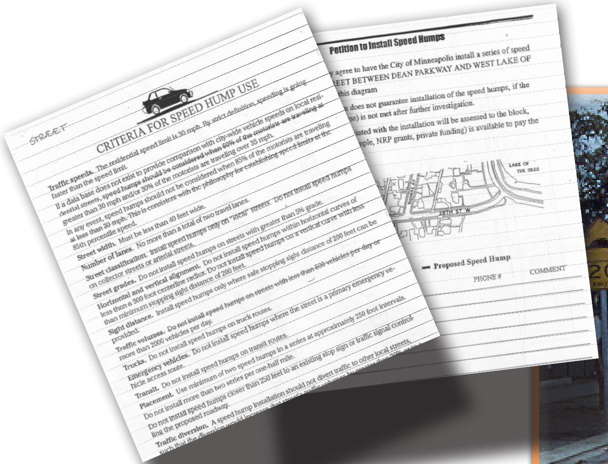
Curb Extensions and Sidewalks

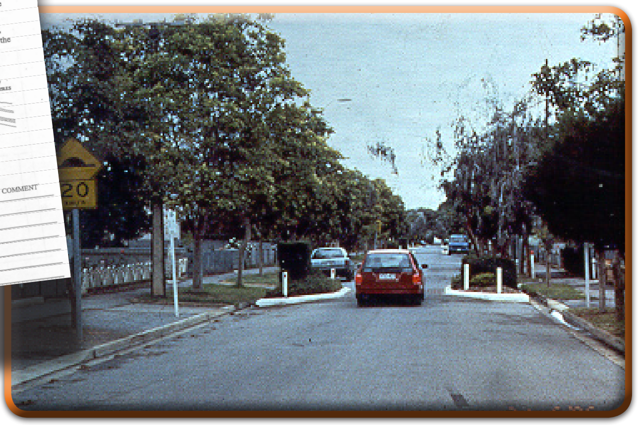
Highlights

- Pedestrian strategies that have proven to be effective include the following:
  - Overpass (in order to be effective, crossing the roadway at-grade must be physically prevented)
  - Street Lighting
  - Refuge/Median Islands – Reduces vehicle speeds at pedestrian crossing locations or intersections.
  - Curb Extensions – Reduces potential vehicle conflicts by reducing pedestrian crossing distance and time. Also, improves lines of sight.
  - Sidewalks

Pedestrian Safety Strategies (3 of 3)

Neighborhood Traffic Control Measures





Source: ITE Traffic Calming Seminar

Highlights

- Neighborhood traffic control (traffic calming) usually involves applying design techniques and devices on local streets in order to modify driver behavior and traffic characteristics.
- The application of these devices are usually limited to residential streets, have been infrequently used on residential collectors and should not be considered on arterials due to the presence of transit vehicles, trucks and emergency responders.
- Typical techniques involve the use of signs, markings, road narrowing or diverters, vertical elements and the use of technology to increase the enforcement presence.
- A few studies of the effectiveness of these devices have been conducted – the general conclusions are:
  - Speed humps/bumps are moderately effective at lowering speeds in the range of 3 to 7 mph (in the immediate vicinity of the device).
  - Adding STOP signs lowers speeds by about 2 mph, in the vicinity of the STOP sign, but also reduces compliance – a greater number of drivers completely disregard the sign than come to a complete stop. In addition, speeds in the segments between STOP signs have been observed to increas drivers attempting to make up for lost time.
  - Changing speed limit signs has never changed driver behavior.
  - Enforcement does change driver behavior – only when present.

Table 8.3. General Warrants. (Sarasota, FL)

Warrant	Major Collectors	Minor Collectors	Local Residential Streets
1. Minimum traffic volume	>8,000 vpd or 800 vph	>4,000 vpd or 400 vph	>1,000 vpd or 100 vph
2. Anticipated cut-through traffic	50%	40%	25%
3. 85th percentile speed	10 mph > speed limit	10 mph > speed limit	> speed limit
4. Pedestrian crossing volume	>100 per hour	>50 per hour	>25 per hour
5. Accidents per year	6	6	3

vpd = vehicles per day; vph = vehicles per hour
Source: Engineering Department, City of Sarasota, FL.

Table 8.4. Speed Hump Warrants. (Montgomery County, MD)

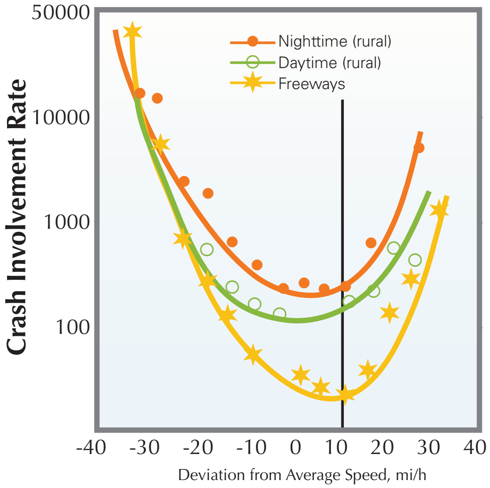
Criterion	Original	Interim	Present
Minimum volume	60 vph	100 vph	100 vph
Minimum 85th percentile speed Secondary street Primary street	 31 mph 34 mph	 31 mph 31 or 36 mph (depending on speed limit)	 32 mph 34 or 39 mph (depending on speed limit)
Minimum length of segment	None	1,000 feet	1,000 feet
Resident concurrence	67%	80% on treated street	80% on treated street 50% on side streets

vph = vehicles per hour; mph = miles per hour
Source: Department of Public Works and Transportation, Montgomery County, MD.

Source: ITE, Traffic Calming - State of the Practice

https://www.ite.org/traffic/tcstate.htm

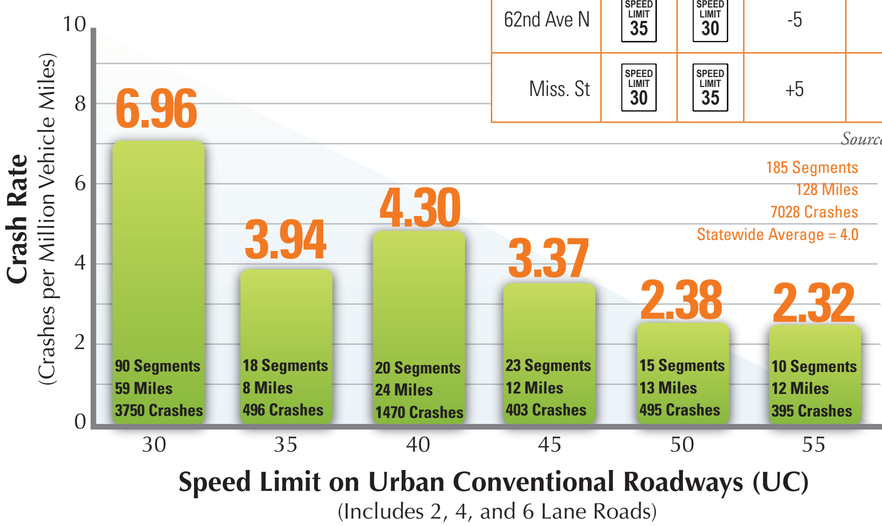
Speed Zoning



Source: Solomon, 1964, and Cirillo, 1968

Speed Zoning Studies					
Study Location	Before	After	Sign Change +/- MPH	85% Before After	Change MPH
T.H. 65	SPEED LIMIT 40	SPEED LIMIT 30	-10	34 34	0
T.H. 65	SPEED LIMIT 50	SPEED LIMIT 40	-10	44 45	+1
Anoka CSAH 1	SPEED LIMIT 45	SPEED LIMIT 40	-5	48 50	+2
Anoka CSAH 24	SPEED LIMIT 30	SPEED LIMIT 45	+15	49 50	+1
Anoka CSAH 51	SPEED LIMIT 40	SPEED LIMIT 45	+5	45 46	+1
Hennepin CSAH 4	SPEED LIMIT 50	SPEED LIMIT 40	-10	52 51	-1
Noble Ave	SPEED LIMIT 30	SPEED LIMIT 35	+5	37 40	+3
62nd Ave N	SPEED LIMIT 35	SPEED LIMIT 30	-5	37 37	0
Miss. St	SPEED LIMIT 30	SPEED LIMIT 35	+5	39 40	+1

Source: Mn/DOT UnPublished



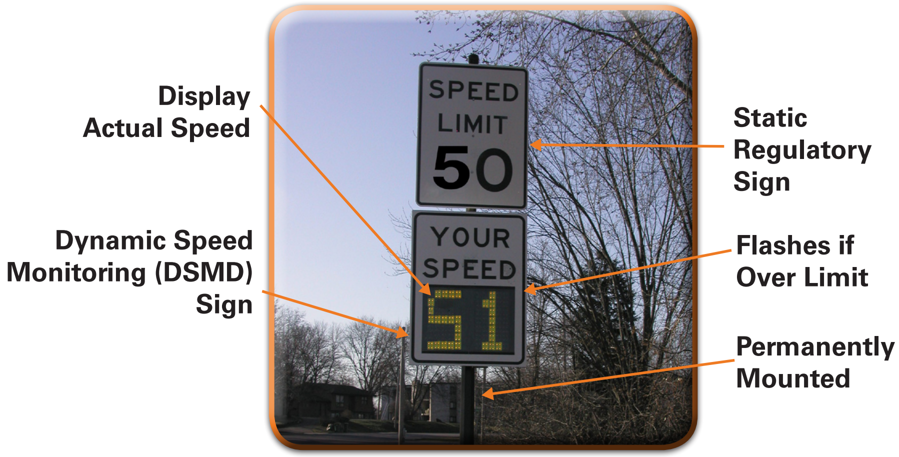
Source: "Statistical relationship between vehicular crashes and highway access" Report: MN/ RC–1998–27

Highlights

- There are two basic types of speed zones in Minnesota:
  1. Statutory speed limits established by the legislature – 30 mph on City Streets, 55 mph on Rural Roads, 65 mph on Rural Expressways, and 70 mph on Rural Interstates.
  2. Speed zones established based on the results of an engineering study of a particular roadway. The legislature has assigned the responsibility for setting the speed limits in the zones to the Commissioner of Transportation.
- The premise underlying the establishment of speed limits is that most drivers will select a safe and reasonable speed based on their perception of the roadway's condition and environment. This has lead to the practice of conducting a statistical analysis of a sample of actual vehicle speeds as part of a comprehensive engineering investigation.
- The two primary performance measures are:
  1. 85th percentile speed – The speed below which 85% of the vehicles are traveling.
  2. 10 mph Pace – the 10 mph range that contains the greatest number of vehicles.
  - Experience has shown that the most effective speed limits are those that are close to the 85th percentile speed and in the upper part of the 10 mph pace.
- There are three important safety–related messages related to vehicle speeds and speed limits:
  1. Research demonstrates that roads with speed limits near the 85th percentile speed have the lowest crash rates.
  2. On urban roadways, crash rates have an inverse relationship with speed limits (crash rates go <u>down</u> as speed limits increase). Crash rates have a direct relationship with the number of access points along a road.
  3. Artificially established speed limits have <u>NEVER</u> been successful at changing behavior or reducing crashes.

Technology Applications

The Technology

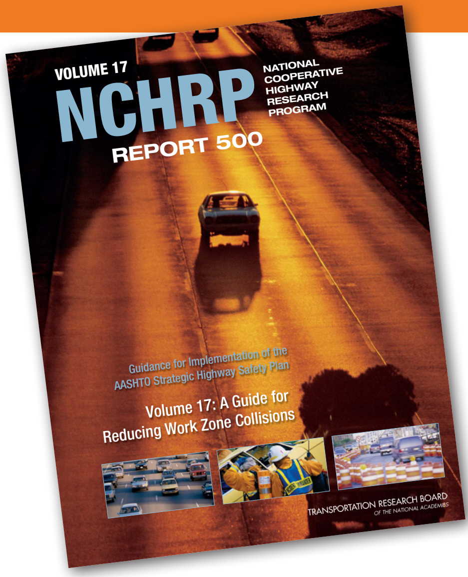


Dynamic Mainline Warning Sign

Highlights

- The Federal Highway Administration and Mn/DOT have invested in a considerable amount of research regarding the use of new technology to address traffic operations and safety deficiencies.
- Advanced technologies have been successfully deployed to address freeway traffic management, and a new generation of traffic signal controllers and optical detectors are improving traffic flow on urban arterials.
- Research is currently underway at several universities, including the University of Minnesota, to better understand factors contributing to intersection crashes in order to develop new devices for assisting drivers in selecting safe gaps at uncontrolled intersections, making safer turns at controlled intersections, and providing additional warning when drivers violate the intersection control.
- The following examples of new devices have already been deployed:
  - Missouri and North Carolina Department of Transportation's use of Dynamic Mainline warning signs—Instead of a static intersection warning sign, loop detectors on the stop controlled approaches activate flashers on the mainline only when vehicles are present. An initial safety review of two or more expressway intersections found a 30 to 50% reduction in angle crashes following installation.
  - Dakota, Ramsey, and Washington Counties have deployed Dynamic Speed Monitoring Display Signs in five speed transition zones in the Minneapolis – St. Paul Metropolitan Area. Before vs. After studies have documented statistically significant speed reductions in the range of 5 to 10 mph following installation.

Work Zones



Emphasis Area Objectives and Strategies

Objectives	Strategies
19.1 D Improve driver compliance with work zone traffic controls	19.1 D1 Enhance enforcement of traffic laws in work zones (T) 19.1 D2 Improve credibility of signs (E) 19.1 D3 Improve application of increased driver penalties in work zones (T)
19.1 E Increase knowledge and awareness of work zones	19.1 E1 Disseminate work zone safety information to road users (T) 19.1 E2 Provide work zone training programs and manuals for designers and field staff (T)
19.1 F Develop procedures to effectively manage work zones	19.1 F1 Develop or enhance agency-level work zone crash data system (T) 19.1 F2 Improve coordination, planning, and scheduling of work activities (T) 19.1 F3 Use incentive to create and operate safer work zones (T) 19.1 F4 Implement work zone quality assurance procedures (i.e., safety inspections or audits (T)
(P) = Proven; (T) = Tried; (E) = Experimental. A detailed explanation of (P), (T), and (E) appears in Section V. Several have substrategies with different ratings.	

Source: NCHRP Series 500 Reports, Vol. 17 A Guide for Reducing Work Zone Collisions

Highlights

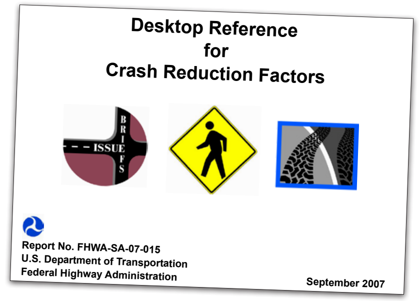
- Addressing crashes in work zones is one of AASHTO's Safety Emphasis Areas based on the fact that these crashes result in 1,000 fatalities and 40,000 injuries each year.
- Minnesota averages around 1,600 crashes in work zones annually, with approximately 10 fatalities and over 700 injuries.
- These statistics support the conclusion that crashes in work zones are over represented and that driving conditions in work zones differ from normal driving conditions.
- Work zones can be a challenge for drivers because of a variety of unexpected conditions – distractions, congestion, a greater demand for more precise navigation, etc.
- A review of Minnesota's work zone crashes found that the most frequent type is a Rear End, the most severe type is a road departure (often involving an edge drop or uneven pavement) and that hours of darkness are most at risk.
- The strategies suggested in the NCHRP Series 500 Report, Volume 17 represent a comprehensive approach – a coordinated effort by engineers, law enforcement and educators.
- From a highway agency perspective the key strategies involve design of work zones (have a plan consistent with the MNMUTCD and Field Manual), regular inspection and maintenance of the devices (to make sure the are placed correctly and still relevant) and worker safety (adequately trained and wearing high visibility garments).
- Concerns about traffic operations and safety has resulted in a new Federal rule on work zone safety and mobility, which Mn/DOT has also adopted as policy for all projects on the State system and for State Aid projects that include Federal Funds. Basically, this new policy requires the preparation of a Work Zone Mobility Impact Assessment (http://www.dot.state.mn.us/tecsup/tmemo/active/tm07/16t05.pdf) and the work zone management strategies (including traffic control, travel demand management and public information) to mitigate impacts.

Crash Reduction Factors

Countermeasure(s)	Crash Type	Crash Severity	Area Type	Road Type	Daily Traffic Volume (veh/day)	Ref.	Effectiveness: Crash Reduction Factor/Function	Effectiveness: Std. Error	Effectiveness: Range Low	Effectiveness: Range High	Study Type
SIGNS											
Implement sign corrections to MUTCD standards	All	Injury	Urban	Local		5	15	10			Meta Analysis
	All	PDO	Urban	Local		5	7	6			Meta Analysis
Install chevron signs on horizontal curves	All	Fatal/ Injury	Rural	2-lane		38	20				
	All	All				15	35				
	All	All	Urban	Arterial (Urban)		5	64	49			Simple Before-After
	All	All				15	20				
	All	All				15	35				
	All	All				15	50				
Install curve advance warning signs	All	Fatal/ Injury	Rural	2-lane		38	10				
	All	Injury				5	30	71			Meta Analysis
	All	PDO				5	8	16			Meta Analysis
	All	All				15	30				
	All	Fatal				15	55				
	All	All				15	30				
	All	All				15	23				
	All	Injury				15	20				
	Head-on	All				15	29				
	ROR	All				15	30				
	ROR	All	All	All		1	30				
Install curve advance warning signs (advisory speed)	All	Injury				5	13	9			Meta Analysis
	All	PDO				5	29	23			Meta Analysis
	All	All				15	29				
	All	All				15	20				

Source: FHWA-SA-07-015, September 2007

Highlights



- The Federal Highway Administration has published the most comprehensive set of crash reduction factors – "Desktop Reference for Crash Reduction Factors."
- This document provides estimates of the crash reduction that might be expected if a specific countermeasure is implemented, based on the results contained in published research.
- Crash reduction factors (CRFs) are provided for intersection treatments, roadway departure strategies, and pedestrian amenities.
- In many cases, the Desktop Reference includes multiple CRFs for the same countermeasure in order to suggest a range of potential effectiveness. For example, installing chevron signs on horizontal curves is expected to reduce all crashes by 20 to 64 percent.
- These CRFs are a useful guide, but it remains necessary to apply engineering judgment and to consider site–specific environmental, traffic volume, traffic mix, geometric conditions, and operational conditions that will affect the actual safety impact of any countermeasure.
- In Minnesota, these CRFs are considered a supplement to estimates of safety effectiveness derived from analyses of our own crash records.
- www.transportation.org/sites/safetymanagement/docs/desktop%20reference%20complete.pdf

Average Crash Costs

$6,800,000	Per FATAL Crash
$390,000	Per SEVERITY A Crash – Incapacitating Injury
$121,000	Per SEVERITY B Crash – Nonincapacitating Injury
$75,000	Per SEVERITY C Crash – Possible Injury
$12,000	Per PROPERTY DAMAGE ONLY Crash

Source: Developed by Mn/DOT Office of Traffic, Safety and Technology

Highlights

- Mn/DOT uses the following comprehensive crash costs when computing the expected benefits associated with roadway and traffic control improvements.
- The costs shown were developed in 2008 by Mn/DOT on a per crash basis for use in calculating benefit/cost comparisons only. The costs include economic cost factors and a measure of the value of lost quality of life that society is willing to pay to prevent deaths and injuries associated with motor vehicle crashes. Costs originally published by the FHWA on a per injury (and fatality) basis, were utilized in the development.
- Due to the very high cost for fatal crashes and the effect this can have on the outcome of benefit/cost analyses, it is the practice in Minnesota to value fatal crashes as 2x"Severity A Crash" ($780,000 per crash) unless there is a high frequency of fatal crashes of a type susceptible to correction by the proposed action.

Crash Reduction "Benefit/ Cost" (B/C) Ratio Worksheet

B/C worksheet

Control Section	T.H. / Roadway	Location	Beginning Ref. Pt.	Ending Ref. Pt.	State, County, City or Township	Study Period Begins	Study Period Ends
	I-494	Portland Ave to Nicollet Ave	3+00.848	4+00.357	Hennepin Co.	1/1/2004	12/31/2006
Description of Proposed Work	Construct Westbound auxiliary lane between Portland and Nicollet						

Accident Diagram Codes		1 Rear End	2 Sideswipe Same Direction	3 Left Turn Main Line	5 Right Angle	4,7 Ran off Road	8, 9 Head On/ Sideswipe -Opposite Direction	Pedestrian	6, 90, 99 Other	Total
Study Period: Number of Crashes — Fatal	F									
Personal Injury (PI)	A									
	B									
	C	3								3
Property Damage	PD	7	3							10
% Change in Crashes (*Recommend using MnDOT's *% Change in Crashes*)	F									
PI	A									
	B									
	C	-25%								
	PD	-25%	-25%							
Change in Crashes = No. of crashes x % change in crashes	F									
PI	A									
	B									
	C	-0.75								-0.75
	PD	-1.75	-0.75							-2.50

Year (Safety Improvement Construction)	2013
Project Cost (exclude Right of Way)	$ 600,000
Right of Way Costs (optional)	
Traffic Growth Factor	3%
Capital Recovery	
1. Discount Rate	4.5%
2. Project Service Life (n)	30

Type of Crash	Study Period: Change in Crashes	Annual Change in Crashes	Cost per Crash	Annual Benefit
F			$ 6,800,000	
A			$ 390,000	
B			$ 121,000	
C	-0.75	-0.25	$ 75,000	$ 7,750
PD	-2.50	-0.83	$ 12,000	$ 3,833
Total				$ 11,583

B/C= 0.47

Using present worth values,

B= $ 283,990

C= $ 600,000

See "Calculations" sheet for amortization.

Office of Traffic, Safety and Operations November 2007

Note: The Excel™ Spreadsheet File may be Downloaded from Mn/DOT's Website

Highlights

- Comparing the expected crash reduction benefits of a particular safety countermeasure to the estimated cost of implementation is an accepted analytical tool used in evaluating alternatives at one location or to aid in the prioritization of projects across a system.
- The basic concept is to give preference to the project(s) that produced the greatest benefit for the least amount of investment.
- The worksheet calculates benefits as the expected reduction in crash costs on an annual basis and compares this value to the annualized value of the estimated construction cost.
- The methodology only accounts for benefits associated with crash reduction. However, the process could be revised to also account for other benefits such as improved traffic operations (reduced delay and travel times).
- It should be noted that benefit/cost analysis does not attempt to account for all potential benefits associated with any particular project since some economic and social benefits are very difficult to quantify.

Typical "Benefit/Cost" Ratios for Various Improvements

Rank	Construction Classification	B/C Ratio
1	Illumination	21.0
2	Relocated Breakaway Utility Poles	17.2
3	Traffic Signs	16.3
4	Upgrade Median Barrier	13.7
5	New Traffic Signals	8.3
6	New Median Barrier	8.3
7	Remove Obstacles	8.3
8	Impact Attenuators	7.8
9	Upgrade Guardrail	7.6
10	Upgraded Traffic Signals	7.4
11	Upgraded Bridge Rail	7.1
12	Sight Distance Improvements	7.0
13	Groove Pavement for Skid Resistance	5.6
14	Replace or Improve Minor Structure	5.2
15	Turning Lanes and Traffic Separation	4.4
16	New Rail Road Crossing Gates	3.9
17	Construct Median for Traffic Separation	3.3
18	New Rail Road Crossing Flashing Lights	3.2
19	New Rail Road Flashing Lights and Gates	3.0
20	Upgrade Rail Road Flashing Lights	2.9
21	Pavement Marking and Delineations	2.6
22	Flatten Side Slopes	2.5
23	New Bridge	2.2
24	Widen or Improve Shoulder	2.1
25	Widen or Modify Bridge	2.0
26	Realign Roadway	2.0
27	Overlay for Skid Treatment	1.9

Source: FHWA, Highway Safety Evaluation System (April 14, 1999)

Highlights

- The Federal Highway Administration has documented the benefit/cost ratios for a variety of typical safety–related roadway improvements.
- Typical benefits/costs ranged from 1.9 for skid overlays to 21.0 for illumination.
- These benefits/costs should only be used as a guide and not as the definitive expected value at any particular location in Minnesota.
- Benefits/costs in the range of 2 to 21 would likely only be achieved at locations with crash frequencies significantly higher than the expected values.
- Mn/DOT funded safety research has documented benefits/costs for a variety of safety projects, including:
  - Street lighting at rural intersections (21:1)
  - Cable median barrier along freeways (10:1)
  - Access management (in the range of 3:1 to 1:1)

Lessons Learned —Contents

Lessons Learned: Crash Characteristics

- At the National level the number of traffic related fatalities during the past 10 years is relatively flat - averaging between 42,000 and 43,000 deaths per year.
- Over this same 10 year period, the trend in Minnesota is decidedly better – the number of traffic related fatalities has declined at a rate approaching 3% per year and the interim safety goal of getting under 500 traffic fatalities was achieved in 2006 (when 494 Minnesotans died in traffic crashes).
- In 2006 the National fatality rate was 1.4 fatalities per 100 million vehicle miles traveled and the range was from 0.8 to 2.3. Minnesota's fatal crash rate was 0.9, which was the second lowest in the country and the lowest of any state not in the northeast.
- Fatal crashes in Minnesota are not distributed evenly across the State – 70% of fatal crashes are in rural areas and the fatality rate on rural roads is more than 2.5 times the rate in urban areas.
- AASHTO's Strategic Highway Safety Plan suggested and the Federal Highway Administration has adopted a new national safety performance measure – the number of traffic fatalities.
- Crashes are typically caused by a variety of factors, but the primary factor is driver behavior followed by roadway features and vehicle equipment failures.
- The adoption of the new safety performance measure – a focus on traffic fatalities – has resulted in a better understanding of the fact that fatal crashes are different than other less severe crashes. The most common type of crash is a rear end (28% of all crashes), however, the most common types of fatal crashes include; Run-off-road (34%), Angle crashes (23%) and Head-on crashes (17%).
- Fatal crashes are not evenly distributed across the population of drivers – young drivers (under 20) represent about 7% of all drivers but are involved in almost 14% of fatal crashes.
- Most crashes occur on dry roads in good weather and during daylight conditions – it's a function of exposure. However, nighttime hours present a greater risk for severe crashes – 11% of all crashes occur during dark conditions but 26% of fatal crashes occur during hours of darkness.
- Contrary to popular opinion, signalized intersections are only rarely safety devices. The average crash rate, severity rate and crash density is higher at signalized intersections compared to the statistics for STOP controlled locations.
- The most common types of intersection related crashes are Rear End and Right Angle. The installation of a traffic signal changes the crash type distribution – increasing Rear End crashes and reducing (but not eliminating) Right Angle crashes.
- Crash rates on roadway segments are a function of location (rural vs. urban), design (conventional vs. expressway vs. freeway) and the degree to which access is managed. Rural freeways and 2-lane roads have the lowest crash rates, urban minor arterials have the highest crash rates and rural county highways and township roads have the highest fatal crash rates.
- Urban crashes are predominantly two vehicle (Rear End and Right Angle) and rural crashes are predominantly single vehicle (Run-Off-Road and Deer Hits).
- Within design categories of roads (rural 2-lane, urban 4-lane, expressway, etc.) the density of access can be used to predict crash rates – segments with higher access densities have higher crash rates in both rural and urban areas.

Lessons Learned: Safety Improvement Process

- Mn/DOT's current Strategic Highway Safety Plan (SHSP) was approved in September, 2007. The Plan was data driven, comprehensive (addressed the four Safety E's), systematic (considered all roads), identified a new safety performance measure (fatal and severe injury crashes) and established a new interim safety goal (400 or fewer fatalities by 2010).
- The SHSP identified seven Safety Emphasis Areas for Minnesota in two categories – Driver Behavior (safety belts, alcohol, speeding and young drivers) and Infrastructure (intersection, run-off-road and head-on crashes).
- In urban areas the primary factors associated with fatal crashes are intersections and speeding and rural areas the primary factors are safety belts, alcohol and road departures.
- A comprehensive safety improvement process includes both a "Black Spot" analysis focused on reactive implementation of safety strategies and a system wide analysis focused on proactively implementing generally low cost safety strategies broadly across an agencies system of roads.
- Three alternative methods are suggested for identifying "Black Spots" – the annual number of crashes at a given location, the crash rate or the critical crash rate. Each method has advantages and disadvantages. Documenting the number of crashes annually is the easiest from a data gathering perspective; however, it has no ability to account for differences in expected crash values based on type of intersection control or roadway design. The critical crash rate method is the most challenging to use because of the need for comprehensive crash statistics for both individual locations and the entire system; however, it effectively accounts for random nature of crashes and is the most statistically reliable.
- The recommended analytical method for conducting a detailed study of an individual location involves comparing the Actual crash characteristics to the Expected characteristics and then evaluating the differences. It is important to note that the expected crash frequency of any given location is never zero.
- Of the three traditional methods for identifying hazardous locations (number of crashes, crash rate and critical crash rate), the Critical Crash Rate is the most statistically reliable, but this is also the most data intensive method. However, the use of any method is better than not conducting a periodic safety inventory.
- The single most important practice to support improving safety at the local level is for agencies to dedicate a portion of their annual capital improvement program to implementing low-cost safety strategies on their system.

Lessons Learned: Traffic Safety Tool Box

- Current traffic safety tool boxes are better stocked and include a more comprehensive set of safety strategies as a result of recent efforts by NCHRP (the Series 500 Reports-Implementation of AASHTO's Strategic Highway Safety Plan) and FHWA (Report No. FHWA-SA-07-015 Desktop Reference for Crash Reduction Factors).
- The NCHRP Reports include 22 volumes documenting over 600 safety strategies dealing with all four safety E's – Education, Enforcement, Engineering and Emergency Services. The NCHRP Reports categorize strategies as Proven (effective at reducing crashes), Tried or Experimental. Examples of Proven strategies include:
  - Street Lights
  - Access Management
  - Roadside Safety Initiatives
  - Roundabouts
  - Cable Median Barrier
  - Left turn Lanes (on urban arterials)
  - Traffic Signal Optimization
- A variety of traditional strategies that were once thought to be effective are considered to be Tried, because there are no statistically reliable studies documenting effectiveness. These Tried strategies include; Installing Traffic Signals, Overhead Flashers (at rural intersections) and the installation of Transverse Rumble Strips (on the approach to STOP controlled intersections).
- Match the magnitude of the solution to the magnitude of the problem.
- Consider interim measures when implementation of the ultimate solution would take years to implement.
- The most effective safety strategies usually include elements from each of the four safety E's—Education, Enforcement, Engineering and Emergency Services.

MINNESOTA DEPARTMENT OF TRANSPORTATION