



## TECHNICAL MEMORANDUM

### Bend Arterial and Collector Safety Project Program Development

Network Screening

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Project #: 11645.0

To: Robin Lewis, PE, City of Bend

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The City of Bend and Kittelson & Associates, Inc. (KAI) are developing and implementing a data-driven transportation safety management program. The framework for the program was documented by KAI in our July 9, 2012 memorandum (draft prepared in June 2012) and is generally illustrated in Figure 1. Network Screening, described in this memorandum, is intended to apply objective methods to evaluate the City's arterial and collector streets to identify sites with high crash frequency or severe crashes where countermeasures could be applied.

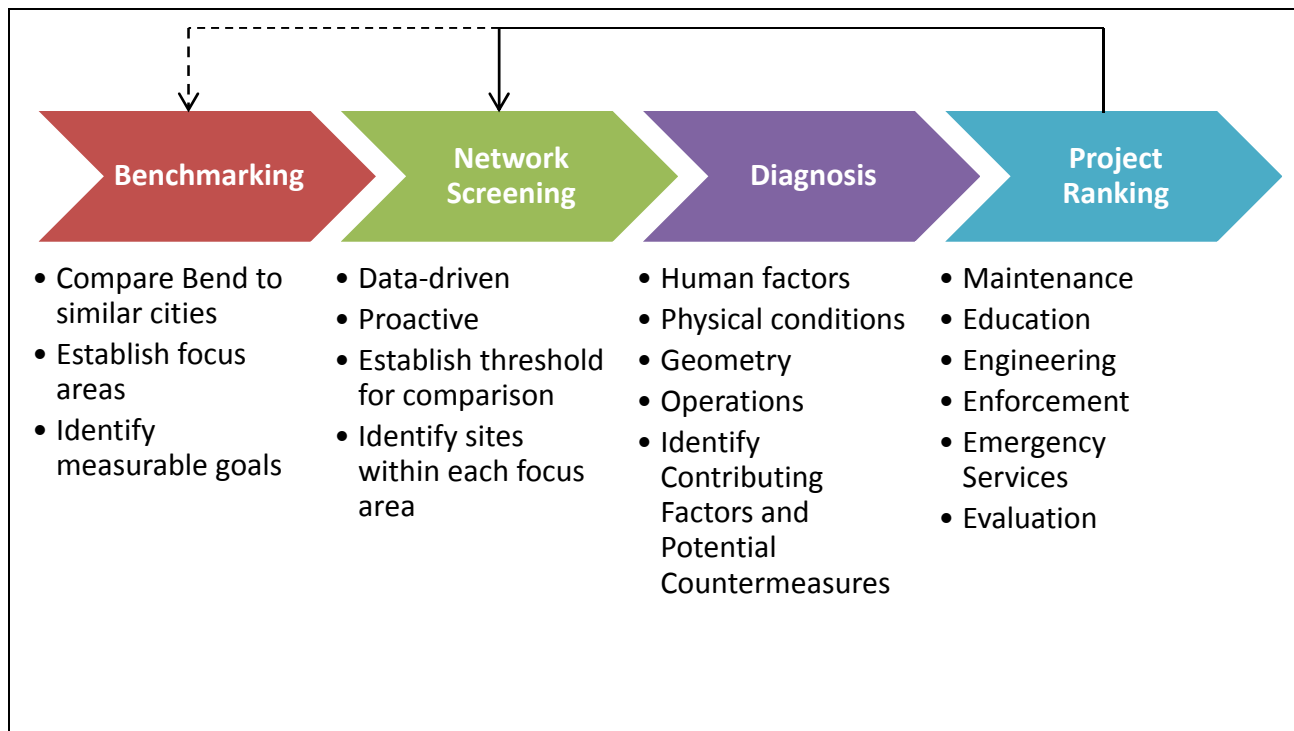


Figure 1 City of Bend Arterial and Collector Safety Program Framework

## OVERVIEW

Network screening methods are described in detail in Chapter 4 of the AASHTO *Highway Safety Manual* (HSM). The methods from the HSM have been adapted to the goals of the City of Bend Safety Program and the scope of this project. Network screening generally includes the following steps:

- 1) Establish focus
- 2) Identify reference populations
- 3) Select performance measures
- 4) Screen and evaluate results

### 1. Establish Focus

Network screening is guided by the focus areas identified through the benchmarking phase, including:

- Fatal crashes
- Roadway Departure crashes
- Alcohol-involved crashes
- Speed-involved crashes
- Pedestrian and bicycle crashes

There were less than 25 fatal crashes reported in Bend over the study period (January 1, 2006 through December 31, 2010) and a manual review of each crash report is feasible. KAI expanded the fatal crash focus area to include injury crashes to apply objective analysis tools and demonstrate network screening.

The City's safety program is set up as a cyclical process. The City has the flexibility to determine how often the cycle is repeated and whether to include benchmarking each time they repeat the process. Focus areas identified through previous benchmarking efforts can be retained for multiple program cycles, if Benchmarking is not repeated each cycle. Maintaining the same focus areas for subsequent program cycles allows more time for the City to apply resources to address one area before moving onto another.

### 2. Identify Reference Populations

KAI divided the sites within each focus area into several distinct subsets of the City's network (i.e., reference populations). The sites identified for diagnosis include a range of facility types presenting a wide range of opportunities to apply crash countermeasures.

KAI considered a range of potential characteristics to establish reference populations, as outlined in Chapter 4 of the HSM. Due to data limitations, traffic control was the primary characteristic used to establish reference populations. The City provided GIS data identifying traffic control for all

intersections and traffic control reference populations were grouped as signalized, unsignalized (including roundabouts), and other (railroad crossing gates, yield signs, etc.).

### 3. Select Performance Measures

The HSM identifies 13 performance measures that can be used in network screening. Performance measures that reflect crash frequency and severity can be used to evaluate the crash data and determine a quantitative “score” at each site. However, the City does not have a complete database of traffic volume and roadway geometry data that is required for the advanced methods for all arterial and collector streets. Until the City completes their project to develop a traffic volume database and collects data to populate it, the City is limited to applying the first five performance measures shown in Table 1. The performance measures that can be applied do not account for statistical bias. In addition, the Relative Severity Index (RSI) and Equivalent Property Damage Only (EPDO) methods may emphasize sites where a fatal crash has occurred. Therefore, two or more measures can be applied on each reference population and the results can be compared to identify sites with the greatest potential for reducing crash frequency or severity.

Table 1 Summary of Network Screening Performance Measures

Statistical Bias/Data Requirement Continuum*	City of Bend Implementation Category	Network Screening Performance Measure
	Short-term – Data is available	Crash Frequency
		Equivalent Property Damage Only Crash Frequency
		Relative Severity Index
		Crash Type Performance Threshold
		Excess Proportion of Specific Crash Types
	Medium-term – Requires volume data	Critical Rate
		Method of Moments
	Long-term – Requires calibrated safety performance functions and detailed geometric information	Excess Predicted Crashes Using SPFs
		Level of Service of Safety
		Expected Crash Frequency with EB Adjustment
		EPDO Crash Frequency with EB Adjustment
		Excess Expected Crash Frequency with EB Adjustment

\* Performance measures are sorted by implementation category. Implementation categories generally reflect a reduction in statistical bias as additional data is included in analysis.

The three performance measures, shown in **BOLD TEXT** in Table 1, account for severity and crash type, but do not account for changes in traffic volume (i.e., exposure).

Definitions of each measure and step-by-step instructions are provided in Chapter 4 of the HSM. The Relative Severity Index (RSI) measure reflects crash type and traffic control. It applies a monetary value to crashes categorized by crash type and traffic control. The values used in this study are provided in Table 2.

The monetary factors reflect the societal cost (in dollars) of each crash. They were developed by FHWA and are published in the HSM in 2001 dollars. Because the analysis is relative (one site is compared to another), the sheer values do not impact the results, but the differences between categories determine the difference in score. An update of these values is not necessary, but as FHWA publishes an update the City could update their reference values.

Table 2 RSI Crash Cost Estimates by Crash Type (Reference 1)

<b>Crash Type, Traffic Control</b>	<b>Crash Cost</b>
Rear-end, signalized	\$26,700
Rear-end, unsignalized	\$13,200
Side-swipe opposing	\$34,000
Angle, signalized	\$47,300
Angle, unsignalized	\$61,100
Pedestrian/Bicycle	\$158,900
Head-on, signalized	\$24,100
Head-on, unsignalized	\$47,500
Fixed object	\$94,700
Other	\$55,100

The Equivalent Property Damage Only (EPDO) measure reflects crash severity. It applies weighting factors to each crash based on the reported severity, based on values summarized in Table 3.

Table 3 Societal Crash Costs by Severity (Reference 1)

<b>Severity</b>	<b>Cost</b>	<b>Weight</b>
Fatal	\$4,008,900	542
Injury	\$82,600	11
PDO	\$7,400	1

## 4. Screen and Evaluate Results

The HSM describes multiple methods for applying network screening tools. Implementation of those methods required developing a custom spreadsheet and GIS-based tools to reflect the City's safety program goals. The tools will be provided to the City for future program cycles.

KAI applied the network screening tools on three focus areas to demonstrate their use. The application informed the City on how to vary the method based on differing goals of each focus area. KAI's customized screening method includes the following general steps for conducting the screening:

1. Obtain crash data for all reported crashes in Bend city limits for a period of 3 to 5 years
2. Map crashes in GIS and filter out crashes not on the City arterial and collector street network
3. Use GIS to summarize those crashes occurring within 150 feet of an intersection on the collector and arterial network.
4. Use GIS to query crash database and export subsets of crashes by focus area
5. Use PivotTables in Excel to summarize crashes by reference populations
6. Apply performance measures in Excel to rank sites within each reference population

KAI conducted network screening for three of the five focus areas: fatal and injury crashes, speed-involved crashes, and pedestrian and bicycle crashes. The City conducted network screening of the additional focus areas: alcohol-involved crashes and roadway departure crashes.

Sites within ODOT's jurisdiction or where improvements are planned and funded through the General Obligation (GO) Bond Program were ranked by KAI, but not selected for diagnosis. These sites include intersections and segments on US 20, US 97, Reed Market Road (East of 3<sup>rd</sup> Street to West of 27<sup>th</sup> Street), Brookwood Avenue/Powers Road, and 18<sup>th</sup> Street/Empire Avenue.

### *Fatal and Injury Crashes*

The ten highest-ranked signalized and unsignalized intersections (ranked based on RSI and EPDO performance measures) are summarized in Table 4 and Table 5, respectively.

Sites selected for diagnosis are highlighted with bold text and are color-coded to illustrate each site's ranking across performance measures. Grey text indicates sites that are within ODOT's jurisdiction or included in the GO Bond.

Table 4 Fatal and Injury Crash Network Screening Results at Signalized Intersections

Site Rank	High Ranking Intersections by Performance Measure		
	RSI	EPDO	Frequency
1	HIGHWAY 20/ NE 8TH ST	HIGHWAY 97/ POWERS RD	HIGHWAY 97/ POWERS RD
2	HIGHWAY 20/ NE GREENWOOD AVE	HIGHWAY 20/ SE 27TH ST	HIGHWAY 20/ NE 8TH ST
3	HIGHWAY 97/ POWERS RD	<b>POWERS RD/ SE 3RD ST</b>	HIGHWAY 20/ NE GREENWOOD AVE
4	<b>REED MARKET RD/ SE 3RD ST</b>	REED MARKET RD/ SE 27TH ST	HIGHWAY 97/ ROBAL LN
5	BROSTERHOUS RD/ SE 3RD ST	HIGHWAY 20/ NE 8TH ST	<b>REED MARKET RD/ SE 3RD ST</b>
6	<b>NE NEFF RD/ NE PURCELL BLVD</b>	HIGHWAY 20/ NE GREENWOOD AVE	<b>NE NEFF RD/ NE PURCELL BLVD</b>
7	<b>POWERS RD/ SE 3RD ST</b>	HIGHWAY 97/ ROBAL LN	<b>NE 3RD ST/ NE FRANKLIN AVE</b>
8	<b>NE 3RD ST/ NE FRANKLIN AVE</b>	<b>REED MARKET RD/ SE 3RD ST</b>	HIGHWAY 20/ NE PURCELL BLVD
9	NW OLNEY AVE/ NW WALL ST	<b>NE 3RD ST/ NE FRANKLIN AVE</b>	NE 3RD ST/ NE OLNEY AVE
10	NW FRANKLIN AVE/ NW WALL ST	<b>NE NEFF RD/ NE PURCELL BLVD</b>	COOLEY RD/ HIGHWAY 97
		HIGHWAY 20/ NE PURCELL BLVD	

As shown in Table 4, four signalized intersection sites ranked in the top ten under RSI and EPDO performance measures. Those sites will be advanced for further diagnosis.

Table 5 Fatal and Injury Crash Network Screening Results at Unsignalized Intersections

Site Rank	High Ranking Intersections by Performance Measure		
	RSI	EPDO	Frequency
1	<b>BEAR CREEK RD/ PETTIGREW RD</b>	EMPIRE AVE/ O B RILEY RD	<b>BEAR CREEK RD/ PETTIGREW RD</b>
2	EMPIRE AVE/ NE 18TH ST	SE 2ND ST/ SE DAVIS AVE	EMPIRE AVE/ NE 18TH ST
3	BROOKSWOOD BLVD/ POWERS RD	FIREROCK RD/ O B RILEY RD	BROOKSWOOD BLVD/ POWERS RD
4	AMERICAN LN/ REED MARKET RD	<b>BEAR CREEK RD/ PETTIGREW RD</b>	AMERICAN LN/ REED MARKET RD
5	<b>NW GREENWOOD AVE/ NW HILL ST</b>	EMPIRE AVE/ NE 18TH ST	<b>NW GREENWOOD AVE/ NW HILL ST</b>
6	<b>SW REED MARKET RD/ SW BOND ST</b>	BROOKSWOOD BLVD/ POWERS RD	HIGHWAY 97/ NW HAWTHORNE AVE
7	NE 1ST ST/ NE FRANKLIN AVE	AMERICAN LN/ REED MARKET RD	DIVISION ST/ SW REED MARKET RD
8	NW AWBREY RD/ NW PORTLAND AVE	<b>NW GREENWOOD AVE/ NW HILL ST</b>	<b>NE 1ST ST/ NE GREENWOOD AVE</b>
9	<b>SE 2ND ST/ SE WILSON AVE</b>	<b>NE 1ST ST/ NE GREENWOOD AVE</b>	<b>SE 2ND ST/ SE WILSON AVE</b>
10	COUNTRY CLUB DR/ MURPHY RD	<b>SE 2ND ST/ SE WILSON AVE</b>	NW NEWPORT AVE/ NW 14TH ST
		HIGHWAY 97/ NW HAWTHORNE AVE	<b>SW REED MARKET RD/ SW BOND ST</b>
		DIVISION ST/ SW REED MARKET RD	
		NW NEWPORT AVE/ NW 14TH ST	
		<b>SW REED MARKET RD/ SW BOND ST</b>	

As shown in Table 5, the Bear Creek/ Pettigrew intersection was the highest-ranked unsignalized intersection under RSI. This reflects one or more severe crashes. That intersection and four others highlighted in bold text will be included in the diagnosis.

*Speed-involved Crashes*

Signalized and unsignalized intersections were ranked based on RSI and EPDO performance measures to identify those intersections with high crash frequency or severe crashes. The 10 highest-rank sites are summarized in Table 6 and Table 7, respectively. Sites selected for diagnosis are highlighted with bold text and are color-coded to illustrate each site’s ranking across by performance measures. Grey text indicates sites that are within ODOT’s jurisdiction or included in the GO Bond.

Table 6 Speed-involved Crash Network Screening Results at Signalized Intersections

Site Rank	High Ranking Intersections by Performance Measure		
	RSI	EPDO	Frequency
1	<b>NE NEFF RD/ NE PURCELL BLVD</b>	<b>NE NEFF RD/ NE PURCELL BLVD</b>	<b>NE NEFF RD/ NE PURCELL BLVD</b>
2	HIGHWAY 20/ SE 27TH ST	<b>REED MARKET RD/ SE 3RD ST</b>	<b>REED MARKET RD/ SE 3RD ST</b>
3	<b>BUTLER MKT RD/ NE 27TH ST</b>	COOLEY RD/ HIGHWAY 97	COOLEY RD/ HIGHWAY 97
4	<b>REED MARKET RD/ SE 27TH ST</b>	<b>NW BOND ST/ NW COLORADO AVE</b>	<b>NW BOND ST/ NW COLORADO AVE</b>
5	SE 3RD ST/ SE WILSON AVE	<b>REED MARKET RD/ SE 27TH ST</b>	HIGHWAY 20/ ROBAL LN
6	HIGHWAY 97/ POWERS RD	HIGHWAY 97/ POWERS RD	SE 3RD ST/ SE WILSON AVE
7	NW OLNEY AVE/ NW WALL ST	HIGHWAY 20/ SE 27TH ST	HIGHWAY 20/ SE 27TH ST
8	SW COLORADO AVE/ SW INDUSTRIAL WAY	NE 3RD ST/ NE FRANKLIN AVE	NE 3RD ST/ NE FRANKLIN AVE
9	<b>NW BOND ST/ NW COLORADO AVE</b>	NE 3RD ST/ NE GREENWOOD AVE	NE 3RD ST / NE GREENWOOD AVE
10	HIGHWAY 97/ SE 3RD ST	REED MARKET RD/ SE 15TH ST HIGHWAY 97/ SE 3RD ST	WILSON AVE/ SE 15TH ST HIGHWAY 97/ SE 3RD ST

As shown in Table 6, the Neff Road/ Purcell Boulevard intersection represents a location where speed-related crashes have resulted in frequent or severe crashes. Diagnosis will be conducted on that intersection and four others identified in the table in bold text.



Table 7 Speed-involved Crash Network Screening Results at Unsignalized Intersections

Site Rank	High Ranking Intersections by Performance Measure		
	RSI	EPDO	Frequency
1	BROOKSWOOD BLVD/ POWERS RD	<b>FIREROCK RD/ O B RILEY RD</b>	<b>BROOKSWOOD BLVD/ PINEBROOK BLVD</b>
2	<b>BROOKSWOOD BLVD/ PINEBROOK BLVD</b>	<b>COUNTRY CLUB DR/ MURPHY RD</b>	BROOKSWOOD BLVD/ POWERS RD
3	<b>COUNTRY CLUB DR/ MURPHY RD</b>	<b>BEAR CREEK RD/ PETTIGREW RD</b>	<b>COUNTRY CLUB DR/ MURPHY RD</b>
4	15TH ST/ SHERWOOD FOREST DR	SW REED MARKET RD/ SW CENTURY DR	SW COLORADO AVE/ SW COLUMBIA ST
5	<b>BEAR CREEK RD/ PETTIGREW RD</b>	SE 15TH ST/ SE WILSON AVE	15TH ST/ SHERWOOD FOREST DR
6	NW RIVERSIDE BLVD/ NW TUMALO AVE	EMPIRE AVE/ NE 18TH ST	<b>BEAR CREEK RD/ PETTIGREW RD</b>
7	NW KANSAS AVE/ NW WALL ST	NE 27TH ST/ NE CONNERS AVE	SW REED MARKET RD/ SW CENTURY DR
8	SE 2ND ST/ SE SCOTT ST	NW NEWPORT AVE/ NW 14TH ST	NW RIVERSIDE BLVD/ NW TUMALO AVE
9	MT WASHINGTON DR/ SKYLINERS RD	SW REED MARKET RD/ ALDERWOOD CIR	SE 2ND ST/ SE SCOTT ST
10	BROSTERHOUS RD/ CLAY PIGEON CT	<b>BROOKSWOOD BLVD/ PINEBROOK BLVD</b>	BROSTERHOUS RD/ CLAY PIGEON CT

As shown in Table 7, four unsignalized intersections with speed-related crashes have resulted in frequent or severe crashes. Diagnosis will be conducted on all four intersections identified in the table.

*Pedestrian and Bicycle Crashes*

Signalized and unsignalized intersections were ranked based on the RSI performance measures to identify those intersections with high crash frequency or severe crashes. Given the frequency of crashes per site, the five highest-rank sites are summarized in Table 8 and Table 9. The EPDO method cannot be applied because all crashes involve pedestrians and are weighted with the same value.

Table 8 Pedestrian and Bicycle Crash Network Screening Results at Signalized Intersections

Site Rank	High Ranking Intersections by Performance Measure	
	RSI	Frequency
1	<b>POWERS RD/ SE 3RD ST</b>	<b>NE 3RD ST/ NE GREENWOOD AVE</b>
2	<b>NE 3RD ST/ NE GREENWOOD AVE</b>	HIGHWAY 20/ NE 8TH ST
3	HIGHWAY 20/ NE 8TH ST	<b>BROSTERHOUS RD/ SE 3RD ST</b>
4	<b>BROSTERHOUS RD/ SE 3RD ST</b>	<b>POWERS RD/ SE 3RD ST</b>
5	<b>NW FRANKLIN AVE/ NW WALL ST</b>	<b>NW FRANKLIN AVE/ NW WALL ST</b>
	NW GREENWOOD AVE/ NW WALL ST	NW GREENWOOD AVE/ NW WALL ST
	REED MARKET RD/ SE 3RD ST	REED MARKET RD/ SE 3RD ST
	NE 3RD ST/ NE FRANKLIN AVE	NE 3RD ST/ NE FRANKLIN AVE

Table 9 Pedestrian and Bicycle Crash Network Screening Results at Unsignalized Intersections

Site Rank	High Ranking Intersections by RSI	
	RSI	Frequency
1	SE 2ND ST/ SE DAVIS AVE	<b>NW AWBREY RD/ NW PORTLAND AVE</b>
2	<b>NW AWBREY RD/ NW PORTLAND AVE</b>	<b>NW GREENWOOD AVE/ NW HILL ST</b>
	<b>NW GREENWOOD AVE/ NW HILL ST</b>	<b>NE 1ST ST/ NE FRANKLIN AVE</b>
	<b>NE 1ST ST/ NE FRANKLIN AVE</b>	SW REED MARKET RD/ SW BOND ST
	SW REED MARKET RD/ SW BOND ST	

As shown in Table 8 and Table 9, four signalized and three unsignalized intersections were identified for diagnosis, based on the RSI performance measure. There was strong correlation between Frequency and RSI performance measures reflecting the low frequency of crashes per site.

*Alcohol-involved Crashes*

*Roadway Departure Crashes*

What types of crashes were included? How did we rank and choose top few sites for diagnosis?

**NETWORK SCREENING FINDINGS**

The RSI and EPDO performance measures applied to screen the network for fatal and injury crashes, speed-involved crashes, and bicycle and pedestrian crashes resulted in identifying three to five sites for diagnosis per reference population. Table 10 and 0 summarize intersection selected for diagnosis at signalized and unsignalized intersections, respectively.



Table 10 Summary of Signalized Intersections Selected for Network Screening

Intersection	Focus Areas
REED MARKET RD/ SE 3RD ST	Fatal and injury, speed-involved
NE NEFF RD/ NE PURCELL BLVD	Fatal and injury, speed-involved
POWERS RD/ SE 3RD ST	Fatal and injury, bicycle and pedestrian
NE 3RD ST/ NE FRANKLIN AVE	Fatal and injury
BUTLER MKT RD/ NE 27TH ST	Speed-involved
REED MARKET RD/ SE 27TH ST	Speed-involved
NW BOND ST/ NW COLORADO AVE	Speed-involved
NE 3RD ST/ NE GREENWOOD AVE	Bicycle and pedestrian
BROSTERHOUS RD/ SE 3RD ST	Bicycle and pedestrian
NW FRANKLIN AVE/ NW WALL ST	Bicycle and pedestrian
	Alcohol-involved
	Roadway departure

Table 11 Summary of Unsignalized Intersections Selected for Network Screening

Intersection	Focus Areas
SE 2ND ST/ SE WILSON AVE	Fatal and Injury
BEAR CREEK RD/ PETTIGREW RD	Fatal and Injury, Speed-involved
NW GREENWOOD AVE/ NW HILL ST	Fatal and Injury, Bicycle and Pedestrian
NE 1ST ST/ NE GREENWOOD AVE	Fatal and Injury
SW REED MARKET RD/ SW BOND ST	Fatal and Injury
BROOKSWOOD BLVD/ PINEBROOK BLVD	Speed-involved
COUNTRY CLUB DR/ MURPHY RD	Speed-involved
FIREROCK RD/ O B RILEY RD	Speed-involved
NW AWBREY RD/ NW PORTLAND AVE	Bicycle and Pedestrian
NE 1ST ST/ NE FRANKLIN AVE	Bicycle and Pedestrian

## NEXT STEPS

The sites identified through network screening will be subjected to diagnosis to determine factors contributing to crash frequency or severity.