The purpose of this section is to introduce the expectations of performing safety analysis under Performance-Based Practical Design (PBPD) (FDM 11-1-10) philosophies through implementation of WisDOT’s Safety Certification Process (SCP). The SCP adopts the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) predictive methods and economic appraisal processes.

1.1 Overview
WisDOT is continuously balancing fiscal realities with competing highway needs. As such, all asset improvements (safety, pavement, structures) must be employed with the right fix at the right time and in the right location. This “right fix, right location” philosophy is fundamental to Performance-Based Practical Design (PBPD) practice.

The safety analysis portion of PBPD places emphasis on substantive safety, or long-term safety performance of a roadway, through consistent identification of safety needs while still considering nominal safety by addressing less than lower minimum design criteria roadway elements. Nominal safety is the safety assumed “built in” to the design criteria. What is important to understand is a roadway’s substantive safety does not always correlate to its level of nominal safety. It is not uncommon for a roadway to be nominally safe (i.e., all design elements meet design criteria) but at the same time be substantively unsafe (i.e., has crashes that are higher than expected). Similarly, some roadways that are nominally unsafe (one or more design elements do not meet design criteria) can and do function at a high level of substantive safety. This process will allow for more accurate scoping of the true purpose and need of projects and result in more efficient expenditures throughout the system.

WisDOT’s SCP uses Meta-Manager to complete safety network screening to identify locations that experience more crashes than similar sites and have a higher potential for safety improvement. These “sites of promise” are then subject to a crash vetting process and ultimately predictive crash modeling and economic appraisal (Benefit/Cost) methodologies, to identify and evaluate safety mitigation alternatives for locations on the highway network.

1.2 Acronyms and Definitions
A list of acronyms used throughout this chapter is in Table 1.1; while brief definitions of key SCP terms are presented in Table 1.2.
### Table 1.1 Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>AADT</td>
<td>Average Annual Daily Traffic</td>
</tr>
<tr>
<td>CGA</td>
<td>Contributing Geometric Analysis</td>
</tr>
<tr>
<td>CMF</td>
<td>Crash Modification Factor</td>
</tr>
<tr>
<td>EB</td>
<td>Empirical Bayes</td>
</tr>
<tr>
<td>FDM</td>
<td>Facilities Development Manual</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>HSM</td>
<td>Highway Safety Manual</td>
</tr>
<tr>
<td>IHSDM</td>
<td>Interactive Highway Safety Design Manual</td>
</tr>
<tr>
<td>LOSS</td>
<td>Level of Service of Safety</td>
</tr>
<tr>
<td>PBPD</td>
<td>Performance-Based Practical Design</td>
</tr>
<tr>
<td>RTM</td>
<td>Regression to the Mean</td>
</tr>
<tr>
<td>SCP</td>
<td>Safety Certification Process</td>
</tr>
<tr>
<td>SPF</td>
<td>Safety Performance Function</td>
</tr>
</tbody>
</table>

### Table 1.2 Definitions

<table>
<thead>
<tr>
<th>SCP Element</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration Factor</td>
<td>A factor to adjust crash frequency estimates produced from a safety prediction procedure to approximate local conditions. The factor is computed by comparing existing crash data at the state, regional, or local level to estimates obtained from predictive models.</td>
</tr>
<tr>
<td>Controlling Criteria A</td>
<td>A FHWA-identified geometric design criteria, as adopted from the AASHTO Green Book, that represent the most important design elements used for roadway projects.</td>
</tr>
<tr>
<td>Contributing Geometric Analysis</td>
<td>FDM process that analyzes how geometric features contributed to crash history and prescribes a method for countermeasure selection.</td>
</tr>
<tr>
<td>Crash Cost</td>
<td>Crashes result in economic costs including the costs of vehicle repairs, providing emergency services, traffic delays, medical services, workplace productivity losses, and damage to private property and roadway infrastructure. Crashes involving death or severe injury may also result in intangible costs such as physical pain or emotional suffering. These costs are referred to as quality-adjusted life years (QALY). The comprehensive costs of a crash are the sum of the economic and QALY costs. Detailed information regarding FHWA default crash costs can be found in the FHWA Crash Cost for Highway Safety Analysis.</td>
</tr>
<tr>
<td>Crash Modification Factor (CMF)</td>
<td>A CMF is a factor estimating the potential changes in crash frequency or crash severity due to installing a specific treatment. The CMFs in the HSM have been developed based on rigorous and reliable scientific process. As an example, a 0.70 CMF corresponds to a 30 percent reduction in crashes. A 1.2 CMF corresponds to a 20 percent increase in crashes.</td>
</tr>
<tr>
<td>Discount Rate</td>
<td>Discount rates, used in the economic appraisal, reflect the time value of money. That is, benefits and costs experienced in the near-term are worth more than benefits and costs experienced at the end of the analysis period. For more information, reference FHWA Highway Safety Benefit-Cost Analysis Guide.</td>
</tr>
<tr>
<td>Economic Appraisal</td>
<td>This analysis determines the economic feasibility of a safety improvement and involves comparing life cycle improvement costs with the societal life cycle safety benefit cost of the proposed mitigation.</td>
</tr>
<tr>
<td>SCP Element</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>Empirical Bayes (EB)</td>
<td>EB is a statistical method that weights the predicted crash frequency and the observed crash frequency. Weighting the predicted and observed crashes allows us to use the long-term average crash experience of similar sites and bring that prediction closer to the observed crash history of the site being evaluated.</td>
</tr>
<tr>
<td>Expected Crash Frequency</td>
<td>The number of crashes obtained by weighting the predicted crash frequency and the observed crash frequency using the EB method.</td>
</tr>
<tr>
<td>Facility</td>
<td>This is an HSM term that describes three broad types of roadway facilities for specific application of predictive safety methods. These facilities include Rural Two-Lane, Two-Way Roads, Rural Multilane Highways, and Urban and Suburban Arterials. Within these facility types are several site types that further define project locations. These include diverse types of intersections and segments within the overall facility.</td>
</tr>
<tr>
<td>Interactive Highway Safety Design Model (IHSDM)</td>
<td>IHSDM is a suite of software analysis tools used to evaluate the safety operational and economic effects of design decisions on roadways. This software provides a Crash Prediction Module to implement the HSM Part C methodology. Refer to <a href="https://www.fhwa.dot.gov">FHWA website</a> for more information.</td>
</tr>
<tr>
<td>Meta-Manager</td>
<td>WisDOT’s facilities asset management database.</td>
</tr>
<tr>
<td>Observed Crash Frequency</td>
<td>The number of crashes at a specific, site. Observed crashes are often reported for a 5-year period.</td>
</tr>
<tr>
<td>Performance Based Safety Engineering Analysis (PBSEA)</td>
<td>This analysis involves predictive modeling of crash frequency and severity for a given set of roadway conditions and will be primarily analyzed using IHSDM software. The output of the IHSDM will be used to compare the crash frequency and severity of safety mitigation alternatives to understand the safety benefit(s) of proposed improvement(s).</td>
</tr>
<tr>
<td>Regression to the Mean (RTM)</td>
<td>The natural variation in crash data. If regression to the mean is not accounted for, a site might be selected for study when the crashes are at a randomly high fluctuation or overlooked from study when the site is at a randomly low fluctuation.</td>
</tr>
<tr>
<td>Safety Flag</td>
<td>Meta-Manager indication for a segment that has a crash rate that is one standard deviation above the statewide average for its peer group.</td>
</tr>
<tr>
<td>Safety Performance Function (SPF)</td>
<td>SPFs are equations that predict crash frequency and severity as a function of traffic volume and roadway characteristics (e.g. number of lanes, median type, intersection control, number of approach legs).</td>
</tr>
<tr>
<td>Site of Promise</td>
<td>Segment or intersection within a project’s limits that have a potential for safety improvement.</td>
</tr>
<tr>
<td>System Screen Process</td>
<td>Process involves reviewing Meta-Manager data for safety flags that may indicate a Site of Promise.</td>
</tr>
</tbody>
</table>

**FDM 11-38-3 Policy**  
August 15, 2019

WisDOT’s implementation of Performance-Based Practical Design (PBPD) uses the SCP for determining and approving safety-driven roadway improvements to the system. The SCP incorporates AASHTO’s HSM predictive safety methods into WisDOT’s project development process.

Refer to [FDM 11-1-5](#) for WisDOT’s Asset Management by a Practical Design System Preservation Approach that incorporates the SCP.

The end product of the SCP is the Safety Certification Document (SCD). See [FDM 11-1 Attachment 10.1](#) for a table showing when a SCD is required.

**FDM 11-38-5 Overview of Safety Quantification in the Project Development Process**  
May 15, 2019

Quantifying safety early in the project development process is key to determining safety improvement impacts to projects. Proposed safety improvements in a project must be balanced with other competing fiscal needs of the project such as operational, environmental, and pavement concerns. Historically, safety benefits have been assumed inherent, or “built in”, to design policies and practices.

There are methods and tools available to quantify safety benefits in the development and analysis of safety mitigation alternatives in projects. These methods and tools allow WisDOT to quantify the crash frequency and
severity of safety mitigation alternatives which allows safety to be explicitly considered in the evaluation of alternatives on projects.

To facilitate the safety comparison of alternatives, WisDOT employs Performance Based Safety Engineering Analysis (PBSEA) which involves predictive crash modeling, and Economic Appraisal (EA) to compare the cost of crashes to the cost of roadway improvements. Predictive crash modeling can be used to estimate crash frequencies and severities for safety mitigation alternatives on a project. Economic appraisal techniques can then assign average costs to the crash frequency and severities of the safety mitigation alternatives to monetize safety benefits. In this way, safety can then be considered in conjunction with other monetary costs (construction, real estate) in evaluating alternatives.

10.1 General
The Safety Certification Process (SCP) is a step-by-step process of determining whether safety improvements should be included on a project, and if so, quantifying safety mitigation alternatives, monetizing the resulting safety benefits, completing benefit-cost comparisons of the mitigation alternatives, and documenting decisions and judgements throughout the process.

This process requires the analyst to supplement the process with sound engineering judgement and experience based on specific project conditions, context, and modal priorities. Engineering judgement should be used and documented to address items not covered in this process.

The SCP will be used to support all safety improvements on a WisDOT project and generally includes the following steps (Refer to Attachment 10.1 for a process flowchart):

1. **Sites of Promise by System Screening**: Safety screening to identify highway segments and intersections with potential for crash reduction
2. **Crash Vetting for the Sites of Promise**: Investigation of the Sites of Promise to understand crash trends and patterns, identify the contributing factors to crashes at those sites, and vet crashes where there is no engineering solution
3. **Contributing Geometric Analysis (CGA)**: Analyze how geometric features contributed to the crash history and identify possible countermeasures
4. **Safety Mitigation Certification**: This two-part process includes Performance Based Safety Engineering Analysis and Economic Appraisal. This involves predictive crash modeling and application of economic appraisals to determine benefit-cost. Overall these two processes allow direct monetary comparison of mitigation alternatives.
5. **Safety Certification Document (SCD)**: End-product that describes the process, engineering judgment, and support for safety improvements for a project

10.2 Sites of Promise by System Screening
10.2.1 General
All WisDOT projects required to complete a SCD start with a safety screening. The goal of this first step is to identify the project’s Sites of Promise, which are roadway segments or intersections along the project corridor that have a high potential to reduce crashes with targeted, cost-effective improvements. Only segments or intersections that are identified as a Site of Promise move forward in the SCP.

10.2.2 Sites of Promise by System Screening Process
The following process shall be used to establish Sites of Promise along a specific project corridor:

For segments:
1. Obtain the Meta-Manager spreadsheet for the Region in which the project is located.
2. In the Safety tab, locate the PDP segments that make up the project corridor.
3. Identify flagged segments. These are Sites of Promise and shall continue to be evaluated in the SCP.
   - Segments are flagged when the Total Crash Rate (RATEFLAG) or KAB Crash Rate (MMGR_KAB_CRSH_RT_FL) is at least one standard deviation above the peer group average. A value of 1.0 or greater indicates the segment is flagged. Refer to the Meta-Manager User Guide for further description of these flags.
   - Refer to Figure 10.1 for a sample screenshot of the Meta-Manager safety worksheet and
presentation of crash flags.

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<th>ACSI_INTS_NM</th>
<th>HWY&amp;DIR</th>
<th>RATEFLAG</th>
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</tr>
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</table>

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<tr>
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<th>INTERSECTION_CRASH RATE FLAG</th>
<th>INTERSECTION_KAB CRASH RATE FLAG</th>
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</tr>
</tbody>
</table>

**Figure 10.1 Safety Worksheet Sorted Data Screenshot**

4. **Review and validate input data.** This includes checking the roadway type (peer group) and annual average daily traffic (AADT) volume. Examples of potential issues include:

   - The majority of a project corridor is identified as a 55-mph expressway (peer group 220). However, three consecutive roadway segments in the middle of the project corridor with segment crash rate flags are identified as a 65-mph expressway (peer group 210). This may indicate a coding error in the Meta-Manager data and should be reviewed.

   - A section of a project corridor is identified with an AADT of 12,000 vehicles per day. However, an intersection in the project corridor is flagged for intersection crash rate and intersection KAB crash rate with a spot AADT of 5,600 vehicles per day. This may indicate a coding error in the Meta-Manager data and should be reviewed.

Refer to **Figure 10.3** and **Figure 10.4** for example screenshots of Meta-Manager data and how to validate the data. If inputs are not accurate, revise the data and recalculate the associated flags. Refer to the Meta-Manager User Guide for the necessary calculations.
5. Corridor segments that were validated and Meta-Manager flags remain, are identified as Sites of Promise and shall continue the SCP process.


For intersections:

1. Obtain the Intersection Network Screening spreadsheet here:
2. Identify the INT_IDs for the project intersections using the maps linked in the Intersection Maps tab.
3. Locate the project intersections in the Network Screening tab using the INT_IDs.
4. Review and validate input data. This includes checking the control type and AADT for each intersection. If inputs are incorrect, revise the data and confirm the calculations were updated.
5. Identify flagged intersections. These are Sites of Promise and shall continue to be evaluated in the SCP.
   - Intersections are flagged when the Level of Service of Safety (LOSS) is a category 4 for either Total Crashes or KABC Crashes. Refer to the Intersection Network Screening User’s Guide for
more information about LOSS and the Intersection Network Screening spreadsheet.

6. Document all intersections within the project corridor in the Safety Certification Worksheet. Provide additional documentation for flagged intersections in the System Screening – Sites of Promise section of the Safety Certification Worksheet (Attachment 10.2).

Project corridors that do not have any flagged segments or intersections require no further safety evaluation and shall be documented as such in the SCD. Refer to FDM 11-38-10.6 for information on the SCD.

Attachment 10.3 visually depicts the process of discerning Sites of Promise by System Screening, as described above.

10.3 Crash Vetting for the Sites of Promise

10.3.1 General

After determining the project corridor includes at least one Site of Promise, a comprehensive crash data verification process, “crash vetting”, ensues. Historical crash data are reviewed to verify the crashes used in further safety analysis are relevant to the project and require further safety analysis. It is not uncommon to find crashes that are not applicable to the safety engineering process (i.e. cannot be corrected through engineering improvements). This step allows the analyst to confirm only applicable crashes move forward in the process.

10.3.2 Crash Vetting for the Sites of Promise Process

1. Obtain crash reports (MV4000 or DT4000) for all the flagged segments or intersections (from the Sites of Promise step)

2. Crash vetting: Identify crashes to exclude in data analytics and the SCP.
   - Vet out crashes involving deer and other animals unless the origins of the crash are unrelated to the animal. For example, if a driver ran off the road and hit an animal but the animal was not the root cause of the crash.
   - Vet out crashes outside the flagged segment limits (document points of judgment)
   - Vet out crashes relating to roadway conditions not affiliated with the highway or geometric conditions (debris in road, etc.).
   - Evaluate crashes relating to driver/pedestrian conditions to determine if human error was the primary contributing factor to the crash. Examples of this include:
     - Use of drugs/alcohol, distracted driving, driver fell asleep, pedestrian entered roadway without proper right of way, etc.
     - Crash that resulted from an obvious case of “road rage”
     - Crash resulted from driver following too close to the vehicle in the lead for the roadway conditions (tailgating, inattentiveness, etc.)
     - Crash resulted from driver entering the highway from a shoulder or other area that would not be anticipated for conflict.
     - Secondary crashes that resulted from a motorist’s inattentive driving while moving through an incident zone, such as a crash in the opposite lanes. Often secondary crashes occur as a result of motorists looking at the first crash.
     - Crash resulting from a motorist excessively speeding
     - Crashes resulting from improper lane changes or violating the rules of the road such as making a U-turn on a two-lane roadway
   
   Crashes like that that may be flagged as human error should also be compared to identify any crash trends for potential roadway condition impacts. For example, a crash where an impaired driver drove off the road along a curved segment should not be removed if there are frequent occurrences of run off the road crashes without the influence of drugs or alcohol. This evaluation will help to determine if these crashes are impacted by roadway characteristics.

   Significant judgment should be applied in this step to determine if “engineering solutions” are applicable to a crash. Applications of this judgment should be documented as described later in this section.
   - Evaluate vehicle factors (e.g., blown tire, defective equipment, engine fires) to determine if they were the primary contributing factor to the crash. Determine if roadway geometric conditions also contributed to the crash. If yes, keep the crash for further data analysis. If not, eliminate the crash record for the safety evaluation. Document decision.

3. Analyze the remaining crash data for patterns and trends to assist with identification of mitigations.
The following sorting method for the remaining crash records in flagged segments or intersections is recommended:

- Location
- Type
- Daylight condition (day, night)
- Road condition (dry, wet, snow, ice)
- Severity
- Time of day/year
- Contributing factors (geometric conditions, pavement quality conditions, etc.)

4. At this stage of the process the analyst is using judgment to vet out crashes based on contributing factors that cannot be linked to a pattern or element that is subject to engineering solutions. The analyst should use their judgment to vet out crashes they believe are not subject to mitigations with an engineering solution. Document these comments in the Vetted Comments column in the WisTransPortal crash data spreadsheet. Refer to Figure 10.5 for a screenshot illustrating an example of how an analyst may save their “vetted” comments within the WisTransPortal crash data worksheet.

<table>
<thead>
<tr>
<th>ACCNMBR</th>
<th>ONHWY</th>
<th>ATSTR</th>
<th>ACCDATE</th>
<th>NTFYHOUR</th>
<th>MNRCOLL</th>
<th>ROADCOND</th>
<th>ACCDSVR</th>
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<td>140909843</td>
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<td></td>
<td>9/13/2014</td>
<td>16</td>
<td>REAR</td>
<td></td>
<td>INJ</td>
<td>Inattentive driving, following too close</td>
</tr>
<tr>
<td>141111075</td>
<td>8</td>
<td></td>
<td>11/24/2014</td>
<td>11</td>
<td>NO</td>
<td>SNOW</td>
<td>INJ</td>
<td>Snowy road, too fast for conditions</td>
</tr>
<tr>
<td>150702884</td>
<td>8</td>
<td>SWANSON RD</td>
<td>7/4/2015</td>
<td>17</td>
<td>REAR</td>
<td></td>
<td>PD</td>
<td>Too fast for conditions</td>
</tr>
<tr>
<td>151112019</td>
<td>8</td>
<td>SWANSON RD</td>
<td>11/19/2015</td>
<td>14</td>
<td>HEAD</td>
<td>ICE</td>
<td>INJ</td>
<td>Icy road, too fast for conditions</td>
</tr>
<tr>
<td>160106278</td>
<td>8</td>
<td>WOODLAND D</td>
<td>1/21/2016</td>
<td>7</td>
<td>REAR</td>
<td>ICE</td>
<td>PD</td>
<td>Snowy road, too fast for conditions</td>
</tr>
<tr>
<td>160201385 L</td>
<td>2/6/2016</td>
<td>9 SSS</td>
<td>PD</td>
<td>Misjudged maneuvering distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>160302658</td>
<td>8</td>
<td>RAPEL RD</td>
<td>3/11/2016</td>
<td>8</td>
<td>NO</td>
<td></td>
<td>PD</td>
<td>Driver asleep at the wheel</td>
</tr>
<tr>
<td>160303803</td>
<td>8</td>
<td>WOODLAND D</td>
<td>3/12/2016</td>
<td>16</td>
<td>REAR</td>
<td></td>
<td>INJ</td>
<td>Inattentive driving</td>
</tr>
<tr>
<td>160506464</td>
<td>8</td>
<td></td>
<td>5/24/2016</td>
<td>7</td>
<td>ANGL</td>
<td>WET</td>
<td>INJ</td>
<td>Miscoded, not on project corridor</td>
</tr>
<tr>
<td>160509184</td>
<td>8</td>
<td>ROBERTS RD</td>
<td>5/27/2016</td>
<td>16</td>
<td>NO</td>
<td></td>
<td>PD</td>
<td>Wheel came off</td>
</tr>
<tr>
<td>160601320</td>
<td>8</td>
<td></td>
<td>6/8/2016</td>
<td>14</td>
<td>NO</td>
<td></td>
<td>PD</td>
<td>Inattentive driving</td>
</tr>
<tr>
<td>160606302</td>
<td>8</td>
<td></td>
<td>6/15/2016</td>
<td>0</td>
<td>NO</td>
<td>WET</td>
<td>INJ</td>
<td>Inattentive driving</td>
</tr>
<tr>
<td>160903434</td>
<td>8</td>
<td></td>
<td>9/14/2016</td>
<td>19</td>
<td>ANGL</td>
<td></td>
<td>INJ</td>
<td>Inattentive driving</td>
</tr>
<tr>
<td>160911439</td>
<td>8</td>
<td></td>
<td>9/23/2016</td>
<td>17</td>
<td>NO</td>
<td></td>
<td>PD</td>
<td>Unsecured load</td>
</tr>
<tr>
<td>161002529</td>
<td>Y</td>
<td></td>
<td>10/6/2016</td>
<td>12</td>
<td>REAR</td>
<td></td>
<td>PD</td>
<td>Inattentive driving</td>
</tr>
<tr>
<td>161004103</td>
<td>8</td>
<td></td>
<td>10/7/2016</td>
<td>14</td>
<td>NO</td>
<td></td>
<td>INJ</td>
<td>Served to avoid animal in road</td>
</tr>
<tr>
<td>161100775</td>
<td>8</td>
<td></td>
<td>11/3/2016</td>
<td>11</td>
<td>NO</td>
<td></td>
<td>INJ</td>
<td>Not on project</td>
</tr>
</tbody>
</table>

Figure 10.5 WisTransPortal Crash Data Spreadsheet with Vetting Comments

5. After vetting, are there remaining segmental or intersection crashes that can be mitigated with engineering solutions?
   - No. Further safety evaluation is not required. Include the WisTransPortal crash data worksheet with the vetted comments in the Safety Certification Document.
   - Yes. Proceed to step 6.

6. Document the remaining and vetted crashes in the Crash Vetting - Sites of Promise section of the Safety Certification Worksheet. The remaining crashes shall be further evaluated in the Contributing Geometric Analysis (CGA) process.
10.4 Contributing Geometric Analysis (CGA)

10.4.1 General
If there are crashes that can be mitigated with engineering countermeasures, they are evaluated further to
determine if existing geometric features contributed to the type and severity of those crashes. If existing
geometric features did not contribute to the type and severity of the crashes, other possible countermeasures
should be identified to target the contributing factors identified in the crashes. This is done through the
Contributing Geometric Analysis (CGA) process.

10.4.2 Contributing Geometric Analysis (CGA) Process
1. Determine if geometric features contribute to the type or severity of the crashes. See Attachment 10.4
   for a list of geometric features and some common crash trends associated with those features.

2. Document the geometric features that contributed to the crashes and the countermeasures identified
to target those factors in the Contributing Geometric Analysis columns of the Safety Certification
   Worksheet (Attachment 10.2).

3. If existing geometric features did not contribute to the type and severity of the crashes, identify
   possible countermeasures to target the contributing factors identified in the vetted WisTransPortal
   crash data spreadsheet and summarized for each flagged segment in the Crash Vetting – Sites of
   Promise section of the Safety Certification Worksheet (Attachment 10.2). See Attachment 10.5
   for a Safety Improvement Prompt List that target specific crash types and contributing factors. If no practical
   countermeasures exist, document in the SCD.

10.5 Safety Mitigation Certification

10.5.1 General
The Safety Mitigation Certification Process (SMCP) is initiated if safety improvements were identified in the
CGA. Each safety improvement identified shall be evaluated to determine the cost-effectiveness of mitigating
crashes and improving the safety performance at the flagged location(s). The SMCP includes two components:

   1. Performance Based Safety Engineering Analysis
   2. Economic Appraisal

10.5.2 Performance Based Safety Engineering Analysis

10.5.2.1 General
The Performance Based Safety Engineering Analysis (PBSEA) process uses predictive modeling when possible
to evaluate the future safety performance of each safety mitigation alternative. This modeling should be
completed using the Interactive Highway Safety Design Model (IHSDM) software which evaluates the impact  
of potential safety improvements on crashes. Predictive modeling has the following advantages:

   - It allows safety to be quantified so investments in infrastructure improvements have the highest
     potential to improve long term safety performance.

   - It allows for the effect of various design alternatives on crash frequency and severity to be calculated.

10.5.2.2 Performance Based Safety Engineering Analysis Process
This process evaluates the safety impacts of the safety mitigation alternatives that are selected to target the
contributing factors of the crashes identified through the CGA process.

For existing conditions (i.e. base conditions), future no-build conditions, and each safety improvement
alternative, identify the evaluation method to quantify the safety impacts of each alternative. Method 1, 2 (A/B),
or 3 (A/B) should be used for all alternatives on a project. The evaluation methods are described below, with
Method 1 being the least reliable method and Method 3 (A/B) being the most reliable method. Methods 2 and 3
have a variation where a Part D or other CMF is needed to modify the SPF prediction to more closely represent
the site conditions. Method 3 (A/B) applies the EB Method to obtain the expected crash frequency. When an
external CMF is needed to modify the SPF prediction, refer to WisDOT's CMF policy found in Chapter 12 of the

   - Method 1: Observed Crash Frequency modified by a CMF
     - Use when the site configuration or traffic volumes are outside of the applicable ranges of the
       SPFs. This method does not account for changes in traffic volumes or regression-to-the-mean
       (RTM) bias. RTM is when periods of relatively high crash frequencies are followed by periods
       with relatively low crash frequencies simply due to the variability of crashes. RTM can
       overestimate or underestimate the effect of safety improvements. Figure 10.6 illustrates RTM
- Applying a CMF to the Observed Crash Frequency results in an Estimated Crash Frequency

**Figure 10.6 Variation in Short Term Observed Crash Frequency**

- Method 2A: Predicted Crash Frequency
  - Use when the site configuration can be evaluated using HSM SPFs and the EB Method is not applicable. See Attachment 10.6 for a chart illustrating which design elements are covered by the HSM SPFs. See Method 3B for more information on the EB Method.
  - An example of where this method could be used is to evaluate the safety impacts of converting an urban four-lane divided roadway to a five-lane with a two-way left-turn lane (TWLTL).

- Method 2B: Predicted Crash Frequency with CMF Adjustments
  - Use when the site configuration has design elements that are not covered by the HSM SPFs but a CMF exists to more accurately model the site conditions and the EB Method is also not applicable. See Method 3B for more information on the EB Method.
  - An example of where this method could be used is to evaluate the safety impacts of converting an existing urban signalized intersection to a roundabout.

- Method 3A: Expected Crash Frequency
  - Use when the site configuration can be evaluated using HSM SPFs with corresponding CMFs and the EB Method is applicable.
  - The EB Method is applied to incorporate a location’s observed crash history with the predicted (long-term) crash frequency. By weighting the observed crash frequency from the specific location and the predicted crash frequency from many similar sites, the analyst can obtain the expected crash frequency. The Expected Crash Frequency is the most reliable estimate of crashes.
  - Note: All segment or intersection crashes are included when applying the EB method, not only the remaining crashes identified in the CGA process.
  - An example of where this method could be used is to evaluate the safety impacts of increasing the lane width from 11’ to 12’ on a two-lane rural highway segment. Lane width is a design element that is directly covered by the HSM SPFs.

- Method 3B: Expected Crash Frequency with CMF Adjustments
  - Use when the site configuration has design elements that are not covered by the HSM SPFs but a CMF exists to more accurately model the site conditions and the EB Method is also applicable.
  - CMF is required to modify SPF to more accurately model conditions.
  - The EB Method is applied to incorporate a location’s observed crash history with the predicted
(long-term) crash frequency. By weighting the observed crash frequency from the specific location and the predicted crash frequency from many similar sites, the analyst can obtain the expected crash frequency. The expected crash frequency is the most reliable estimate of crashes.

- Note: All segment or intersection crashes are included when applying the EB method, not only the remaining crashes identified in the CGA process.

- An example of where this method could be used is to evaluate the safety impacts of adding shoulder rumble strips on a two-lane rural highway segment.

The steps to determine the most reliable and appropriate analysis method are described in steps 1 through 5 and also illustrated in Attachment 10.7 (Flowchart for Choosing a Safety Mitigation Method).

1. Does an applicable SPF exist for the facility type? An SPF may exist for a facility type, but the analyst needs to confirm that the applicable elements and ranges of the SPF are met and that the site conditions (e.g. number of lanes, AADT, urban vs rural, etc.).
   - Yes. Predictive modeling is applicable. Proceed to next step.
   - No. Predictive modeling is not applicable. Use Method 1 and Proceed to Step 9.

2. Are SPF elements available to accurately model existing conditions or mitigation alternatives (elements are the CMF adjustments factors that make up the applicable SPF)
   - Yes. Method 2A can be used to accurately model conditions. Proceed to Step 4 to determine if EB method should be applied.
   - No. Proceed to Step 3.

3. CMF external to one within an SPF is required. Use WisDOT CMF tables. Method 2B or 3B (Empirical Bayes) is applicable. Proceed to Step 4.

4. Are observed crash data available (minimum of two years)? Crash data may not be available if the site does not exist yet or recently constructed and there are not enough years of crash data available.
   - Yes. Proceed to next step to determine if the EB Method should be applied.
   - No. The EB Method is not applicable. Use either Method 2A or 2B, as previously determined. Proceed to Step 7.

5. Are the mitigation alternatives significantly different than existing conditions?
   - “Significantly different” explanation is referenced in HSM Volume 2, Appendix A.2.1
   - Yes. The EB Method is not applicable. Use either Method 2A or 2B, as previously determined. Proceed to Step 7.
   - No. The EB Method is applicable. If Method 2A was previously determined to be the most reliable, use Method 3A for the analysis to implement EB. If Method 2B was previously determined to be the most reliable, use Method 3B for the analysis to implement the EB Method. Proceed to next step.

Develop Required Input Data

6. If Method 3A or 3B was selected as the most reliable method, determine years of existing crash data to use for the EB method:
   - Use up to five of the most recent years of crash data.
   - Confirm no geometric or traffic control changes have occurred over the duration of the crash data. If changes have occurred, utilize only the years of crash data after the change (shall have at least two years of data).

7. Determine AADT for all years of crash data that will be used:
   - If AADT data are only available for one year, it is typically assumed that the AADT is the same for all years of the before period.
   - If AADT data are available for more than one year, interpolate to generate AADT for other years.
   - If crash data are available for years prior to the first year of AADT data, assume missing year(s) AADT equal to the first available AADT.

8. Evaluation period is ten years for all safety analyses. Compile AADT for all years of evaluation period.
   - AADT data will likely not be available for all years of the evaluation period. If AADT data are available for more than one year but not all years, interpolate to generate AADT for all ten years.
Perform Safety Analysis

9. Use Method 1 to estimate the safety impacts of a mitigation alternative(s)
   - This method is typically applied, using the Highway Safety Benefit-Cost Analysis Tool.
   - Apply the applicable CMFs to the observed crash frequency to estimate the crash frequency for
     the mitigation alternative(s).
   - The difference in estimated crash frequencies is then used in the economic appraisal process of
     this tool.

10. Use Method 2 (A/B) or 3 (A/B) to predict the safety impacts of mitigation alternatives
    - The Interactive Highway Safety Design Model (IHSDM) should be used to predict crashes for
      both the existing/base conditions and mitigation alternatives. The IHSDM applies the SPFs and
      SPF elements contained in the part C of the HSM for (Methods 2A and 3A) and CMFs in Part D
      or other source for alternatives where HSM Part D CMFs are required (Methods 2B and 3B) the
      IHSDM shall be used to apply the SPFs and then the Highway Safety Benefit Cost Analysis tool
      is used to apply CMFs in Part D or other source to the predicted crashes.
    - Once any step in the Safety Mitigation process is completed externally to the IHSDM tool, then
      all subsequent steps in the SMCP will need to be completed externally as well.
    - For Methods 3A and 3B, the EB Method is applied to increase the statistical reliability of the
      prediction. All segment or intersection crashes should be included in the EB analysis, not just
      the remaining crashes identified after the CGA step. If the EB Method is NOT applicable
      (Methods 2A and 2B), then existing crash data is not used in the safety analysis.
    - If the safety analyses were completed utilizing the Station Based method in the IHSDM, the
      Economic Appraisal can be completed within the IHSDM using the economic analysis tool.
    - If safety analyses were completed outside the IHSDM (applying a CMF outside the IHSDM for
      example), the difference between the predicted crashes for future conditions with no mitigation
      and predicted crashes for future conditions with mitigations needs to be quantified. These
      quantified differences in crashes are then carried forward and used in the Economic Appraisal
      process (FDM 11-38-10.5.3).

11. Document all findings, including the following:
- Number of crashes for the base condition and each mitigation alternative, categorized by crash severity on the KABCO scale.

Note:

Administrative Tool: The IHSDM software has an Administrative Tool that houses the SPFs and CMF adjustment factors that make up the applicable SPF, crash distribution and cost data sets, and calibration factors that allow the analyst with Departmental approval to edit, add or use alternative inputs when employing the IHSDM software to the Performance Based Safety Engineering Analysis Process. Refer to Figure 10.7 for an example screenshot of the Administration Tool interface.

10.5.3 Economic Appraisal

10.5.3.1 General

The purpose of the economic appraisal process is to compare the estimated benefits of a proposed safety improvement with the estimated total life-cycle costs of that improvement. The economic appraisal process can be used to justify the cost-effectiveness of proposed safety improvements, identify and prioritize improvements with the highest return on investment, and help document the decision-making process. Key outputs of this process include an estimated benefit-cost ratio and the net-present value of each safety improvement alternative. Each of these outputs should be considered when selecting the most appropriate improvement option. Refer to Table 1.2 for definitions of terms used in the Economic Appraisal process.

Table 10.2 lists the potential benefits of a safety improvements that can be monetized for benefit-cost analysis:
### Table 10.2 Benefits of Safety Improvements

<table>
<thead>
<tr>
<th>Element of Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash Benefits</td>
<td>Calculates the monetary benefit for annual crash reductions resulting from a reduction in crash frequency and severity.</td>
</tr>
<tr>
<td>Travel Time Benefits</td>
<td>Currently not applicable</td>
</tr>
<tr>
<td>Reliability Benefits</td>
<td>Currently not applicable</td>
</tr>
<tr>
<td>Vehicle Operating Cost Benefits</td>
<td>Currently not applicable</td>
</tr>
<tr>
<td>Emission Benefits</td>
<td>Currently not applicable</td>
</tr>
</tbody>
</table>

Table 10.3 lists the descriptions of the safety improvement costs:

### Table 10.3 Costs of Safety Improvements

<table>
<thead>
<tr>
<th>Element of Cost</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Support</td>
<td>Currently not applicable</td>
</tr>
<tr>
<td>Construction</td>
<td>Costs of materials and construction to build the improvement.</td>
</tr>
<tr>
<td>Real Estate</td>
<td>Costs to acquire property necessary to build the improvement.</td>
</tr>
<tr>
<td>Maintenance and Operation</td>
<td>Currently not applicable</td>
</tr>
<tr>
<td>Rehabilitation</td>
<td>Currently not applicable</td>
</tr>
<tr>
<td>Mitigation</td>
<td>Currently not applicable</td>
</tr>
</tbody>
</table>

#### 10.5.3.2 Economic Appraisal Tools

Multiple software tools are approved for conducting the Economic Appraisal process within WisDOT’s SCP:
- The IHSDM
- Highway Safety Benefit-Cost Analysis (BCA) Tool

Regardless of which tool is used to conduct the Economic Appraisal, several variables must be defined regarding time periods of analysis and life-cycle and benefit valuation. WisDOT maintains a listing of these variables that shall be used consistently across all projects. Contact BTO for the appropriate economic appraisal values prior to conducting the appraisal. The analysis period (i.e. return on investment period) is assumed to be ten (10) years.

#### 10.5.3.3 Crash Costs

Crash costs are estimated monetary values that a state agency adopts to quantify the impact of a change in safety performance as part of a benefit-cost analysis. These values are updated to account for inflation or where new research indicates the need for an update.

The SCP focuses on evaluating safety impacts and therefore, does not cover any other benefits or costs to a project such as vehicle delay due to travel times, vehicle operating costs or vehicle emissions.

Table 10.4 summarizes the approved crash costs for use in the economic appraisal process.
Wisconsin-specific crash costs were developed using the methods described in FHWA’s Crash Costs for Highway Safety Analysis guide. These crash costs were developed along with the Highway Safety Benefit-Cost Analysis tool described in FDM 11-38-10.5.3.2.

**Note:** Current WisDOT Crash Costs are in 2016 dollars. Crash costs are periodically updated to reflect changes in economic measures.

### 10.5.3.4 IHSDM Costs
IHSDM has “built-in” economic appraisal functions that allow the user to complete an economic appraisal of one or more mitigation alternatives if the alternatives were fully analyzed within the IHSDM during the Performance Based Safety Engineering Analysis (PBSEA). This functionality includes estimating the cost of crashes and conducting simple benefit-cost analysis. Additional information and detailed tutorials can be found at www.ihsdm.org.

1. Select New EA Project from Economic Analyses Operations. Input values for EA Project Title, Comment (optional), and Description (optional). Click Next and Finish.

2. Choose Crash Cost Configuration option. By default, the EA Tool uses the FHWA national average crash unit costs adjusted to the year of analysis. The crash costs included in Table 10.4 should be input through the Economic Analysis Model Data sets section of the Crash Prediction window in the IHSDM Administration Tool.

3. Click Add from the EA Project Editor window to add the Base Case CPM Evaluation and one or more Alternative Case CPM Evaluations. Select the “Is Base Case” option for the Base Case. Leave this option unchecked for the Alternative Cases.

4. Assign CPM Evaluations to Base and Alternative Cases. In the EA Project Editor window, select a case, click the Edit button to open the Edit the Case window. Click the Add button to select previously completed CPM evaluations. Repeat for all cases. Users should ensure that the analysis period for the Base Case and Alternative Case CPM Evaluations is consistent across all cases.

5. Click Calculate Crash Cost button. This calculates the present value of crash costs based on criteria established in the Crash Cost Configuration step. Alternatively, the present value of crash costs may be input directly if calculation of these costs is needed outside of the IHSDM Tool.

6. Input the present value of “Other Cost” in the “Edit the Case” window. This includes construction and annual maintenance costs. These costs should be calculated outside of the IHSDM tool using the discount rate and analysis period established in the IHSDM Tool.

7. Select “New EA Analysis” from the “EA Project Operations” window. Follow prompts for analysis title, comments, and description, and selection analysis type. The analysis types include Benefit/Cost, Net Present Value, Annual Net Benefits. In the initial version of the EA Tool, only the Benefit/Cost option is available.

### 10.5.3.5 Highway Safety Benefit-Cost Analysis Tool
In some cases, the IHSDM will not be an option for conducting the economic appraisal. Examples include cases where no SPF is available for the roadway or intersection type being analyzed or if the safety mitigation alternative requires a SPF element (i.e., CMF adjustment factor) not included in the IHSDM Tool.
Economic Appraisals conducted outside of the IHSDM should follow the FHWA’s approach outlined in the *Highway Safety Benefit-Cost Analysis Guide*. A summary of these steps and notes regarding how they should be adapted to the IHSDM process are summarized below. These calculations are completed in the same manner as those implemented in the IHSDM.

1. Calculate the number of annual crashes for each year of the evaluation period by crash severity for the base condition (i.e. no mitigation) and all mitigation alternatives.

2. Calculate the crash costs associated with the base condition (i.e. no mitigation) and mitigation alternatives for each year of the evaluation period by multiplying the crash unit costs by the predicted number of crashes by the crash type and summing the results. This process is outlined below.

   i. The crash cost per crash is calculated for each year for all severity levels (i.e. K, A, B, C, O)

   \[ CUC_{i,y} = CUC_{i,y_0} \times (1 + CCI) \] ^{(y_j - y_0)}

   Where:

   \( CUC_{i,y} \) = crash unit cost; severity level \( i \), in evaluation year \( y_j \)

   \( CCI \) = crash cost index

   \( i \) = severity levels K, A, B, C, O

   ii. The number of crashes for all severity levels is multiplied by the corresponding crash unit costs.

   \[ CC_{i,y} = N_{i,y_j} \times CUC_{i,y_j} \]

   Where:

   \( CC_{i,y} \) = cost of crashes of severity level \( i \), in evaluation year \( y_j \)

   \( N_{i,y_j} \) = number of predicted crashes; severity level \( i \), in evaluation year \( y_j \)

   iii. The crash costs for all severities is summed together to determine the total crash costs for the base condition and mitigation alternative(s).

   \[ CC_{y_j} = \sum_{i=K,A,B,C,O} CUC_{i,y_j} \]

   Where:

   \( CC_{y_j} \) = sum of societal crash costs for evaluation, in year \( y_j \) (i.e. in the year the unit crash costs are based on)

   iv. The discount rate is applied to the crash costs to discount future crash costs back to present value.

   \[ CC_{PV,y_j} = CC_{y_j} \frac{1}{(1 + r)^{(y_j - y_0)}} \]

   Where:

   \( r \) = discount rate

   v. The total present value of crash costs for the base condition and mitigation alternative(s) is determined.
Where:

\[ CC_{PV} = \sum_j CC_{PV,y_j} \]

\( CC_{PV} = \text{total crash costs for evaluation period in present dollars} \)

\( CC_{PV,y_j} = \text{present value of crash costs for the evaluation year } y_j \)

3. Determine the benefit-cost ratio for all mitigation alternatives.

\[ B_{PV,k} = CC_{PV,Alt_k} - CC_{PV,Base} \]

\[ C_{PV,k} = C_{Alt_k} - C_{Base} \]

\[ B/C_k = \frac{B_{PV,k}}{C_{PV,k}} \]

Where:

\( B_{PV,k} = \text{benefit of mitigation alternative } k \)

\( CC_{PV,Alt_k} = \text{present value of crash costs for mitigation alternative } k \)

\( CC_{PV,Base} = \text{present value of crash costs for base condition} \)

\( C_{PV,k} = \text{additional cost of mitigation alternative compared to base condition} \)

\( CC_{PV,Alt_k} = \text{present value of construction costs for mitigation alternative } k \)

\( CC_{PV,Base} = \text{present value of construction costs for base condition} \)

\( B/C_k = \text{benefit – cost ratio of mitigation alternative } k \)

10.6 Safety Certification Document

10.6.1 General

This section explains the requirements for the Safety Certification Document (SCD), the end-product of the Safety Certification Process (SCP). The purpose of the SCD is to:

1. Summarize the process
2. Provide backup data used in the process steps for reviewers
3. Provide consistency across projects
4. Provide assumptions and details of engineering judgment
5. Document the safety performance and economic appraisal of safety mitigation alternatives, and
6. Provide a formal approval document with signature line for the Regional Planning Chief

While the SCD summarizes safety mitigation alternatives that may be implemented, the SCD should not state a definitive recommendation for a safety mitigation alternative. The SCP provides the opportunity to explore a wide range of potential safety mitigation alternatives to implement; however, safety is one aspect of the project design scope. It is possible that the recommended alternative may not have the highest benefit-cost ratio, depending on the outcome of the completed environmental process. Furthermore, the environmental process may dictate that additional safety mitigation alternatives not initially considered be re-analyzed through the SCP process.

10.6.2 Content

The first piece of the SCD is a summary narrative that is consistent across projects. A template for the SCD is in Attachment 10.8.

Important process outputs shall be attached to the narrative to complete the details of the document. Those important elements associated with each of the process steps as outlined in FDM 11 38-10 are shown in Table 10.5. This table presents the data that the analyst should save from each step of the SCP. The analyst should use judgment to document and save additional data as project-specific issues arise that are beyond the needs described in the table.
Table 10.5 Documentation Needs and Format

<table>
<thead>
<tr>
<th>Step in SCP</th>
<th>Data to Include in SCD Attachments</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sites of Promise by System Screening</td>
<td>Tabular data illustrating safety flags</td>
<td>PDF</td>
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<tr>
<td></td>
<td>Raw Meta-Manager file from project</td>
<td>XLS/Spreadsheet</td>
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<td>(kept in electronic file)</td>
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<tr>
<td>Crash Vetting for Sites of Promise</td>
<td>WisTransPortal crash data spreadsheet with crash vetting comments</td>
<td>PDF</td>
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<td>Safety Certification Worksheet</td>
<td>PDF</td>
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<tr>
<td>Contributing Geometric Analysis (CGA) Process</td>
<td>Safety Certification Worksheet</td>
<td>PDF</td>
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<tr>
<td>Safety Mitigation Certification Process</td>
<td>IHSDM output report</td>
<td>PDF</td>
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<td></td>
<td>IHSDM final working file</td>
<td>Native file format</td>
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<td></td>
<td>Highway Safety Benefit/Cost Analysis Tool results</td>
<td>PDF</td>
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</table>

10.6.3 Approval Process

Concurrence by the Bureau of Traffic Operations (BTO), Traffic Engineering and Safety Section, is required for all projects that complete the Safety Mitigation Certification Process (SMCP). This review and concurrence process shall occur prior to approval by the Regional Planning Chief. The intent of BTO’s review is to ensure the policy, methods, and tools described in FDM 11-38 are applied consistently statewide. Review of detailed inputs and outputs shall be completed by the Region.

Send the SCD and all supporting documents to DOTBTOSafetyEngineering@dot.wi.gov. BTO will review the SCD and provide comments or concurrence to the Region within 15 business days.

Regional Planning Chiefs shall approve all project Safety Certification Documents.

LIST OF ATTACHMENTS

Attachment 10.1 Safety Certification Process Flowchart
Attachment 10.2 Safety Certification Worksheet
Attachment 10.3 Sites of Promise by System Screening Process Flowchart
Attachment 10.4 Geometric Features
Attachment 10.5 Safety Improvement Prompt List
Attachment 10.6 Design Elements Covered in HSM Predictive Methods
Attachment 10.7 Flowchart for Using a Safety Mitigation Method
Attachment 10.8 Safety Certification Document

FDM 11-38-15 Examples for Safety Certification Process

15.1 General

Examples for the Safety Certification Process can be found on the Traffic Operations Manuals web page:


The examples include all five Performance Based Safety Engineering Analysis methods and associated Economic Appraisals. These examples are limited in nature and are for demonstrative purposes in exemplifying the Safety Certification Process.


