User Guide for Telematics-Based Safety and Cost Mitigation Evaluation

1 Risk Factor Threshold Settings

The system uses telematics-derived driving behavior indicators to identify risk-related events. Users select threshold levels for each risk factor before running the safety and cost mitigation evaluation. These thresholds determine which driving behavior observations are counted as risk-related events.

The current interface includes five risk factors:

Rapid Acceleration

Triggered when longitudinal acceleration exceeds the selected threshold, representing aggressive speeding behavior.

Hard Braking

Triggered when longitudinal deceleration magnitude exceeds the selected threshold, representing abrupt braking behavior.

High Jerk

Triggered when longitudinal jerk exceeds the selected threshold, representing unstable acceleration or deceleration behavior.

Sharp Turning / Lane Change

Triggered when lateral acceleration exceeds the selected threshold, representing sharp turning or rapid lane-changing behavior.

Speed Above Limit

Triggered when the vehicle's speed exceeds the posted speed limit, representing speeding severity.

Low, Medium, and High Threshold Levels

The Low, Medium, and High thresholds represent different event-severity screening levels. Lower thresholds capture more events, including less severe driving behaviors. Higher thresholds capture fewer but more severe events. Users can select thresholds based on the evaluation objective, agency preference, and desired sensitivity level.

2 SMF and CMF Model Description

This section describes how the website estimates predicted crash frequency and predicted crash cost for the selected site or treatment location. The model uses traffic exposure and telematics-derived risk factor frequencies to estimate before-period and after-period outcomes.

2.1 Safety Mitigation Factor

The Safety Mitigation Factor, or SMF, estimates the relative change in predicted crash frequency between the before period and the after period for the selected site or treatment location.

The model predicts crash counts by severity level using traffic exposure and telematics-derived risk factor frequencies. For each site-time observation i, crash severity level s, and risk factor k, the model uses:

- VMT_i: total vehicle miles traveled for observation i
- Z_{ik}: scaled frequency of risk factor k for observation i
- α_s: severity-specific intercept
- β_{sk}: severity-specific coefficient for risk factor k

The predicted crash count for observation i and severity s is:

$$\widehat{Y}_{is} = \text{VMT}_i \times \exp\left(\alpha_s + \sum_k \beta_{sk} Z_{ik}\right) \tag{1}$$

The predicted total crash count for observation i is:

$$\widehat{Y}_{i,\text{total}} = \sum_s \widehat{Y}_{is} \tag{2}$$

The before-period and after-period predicted crash counts are calculated by summing predicted crashes across all observations in each period:

$$\widehat{Y}_{\text{before}} = \sum_{i \in J_{\text{before}}} \widehat{Y}_{i,\text{total}} \tag{3}$$

$$\widehat{Y}_{\text{after}} = \sum_{i \in J_{\text{after}}} \widehat{Y}_{i,\text{total}} \tag{4}$$

The Safety Mitigation Factor is calculated as:

$$\text{SMF} = \frac{\widehat{Y}_{\text{after}}}{\widehat{Y}_{\text{before}}} \tag{5}$$

Interpretation:

- $\text{SMF} < 1$: predicted crash reduction, indicating safety improvement
- $\text{SMF} = 1$: no predicted change in crash frequency
- $\text{SMF} > 1$: predicted crash increase, indicating safety deterioration

2.2 Cost Mitigation Factor

The Cost Mitigation Factor, or CMF, estimates the relative change in predicted crash cost between the before period and the after period. In this website, CMF refers to cost mitigation, not the traditional "Crash Modification Factor." The model first converts predicted crashes into predicted crash cost using severity-specific crash costs.

For observation i:

$$\widehat{\text{Cost}}_i = \sum_s \widehat{Y}_{is} C_s \tag{6}$$

where C_s is the crash cost per event for severity level s.

The before-period and after-period predicted costs are:

$$\widehat{\text{Cost}}_{\text{before}} = \sum_{i \in J_{\text{before}}} \widehat{\text{Cost}}_i \tag{7}$$

$$\widehat{\text{Cost}}_{\text{after}} = \sum_{i \in J_{\text{after}}} \widehat{\text{Cost}}_i \tag{8}$$

The Cost Mitigation Factor is calculated as:

$$\mathrm{CMF} = \frac{\widehat{\mathrm{Cost}}_{\mathrm{after}}}{\widehat{\mathrm{Cost}}_{\mathrm{before}}} \tag{9}$$

Interpretation:

- CMF < 1: predicted crash-cost reduction, indicating cost savings
- CMF $= 1$: no predicted cost change
- CMF > 1: predicted crash-cost increase

3 Comparison-Adjusted SMF and CMF Using an Odds Ratio Method

The raw SMF and CMF compare the after period with the before period for the selected treated site. However, a simple before-after comparison may be affected by background changes that are not caused by the treatment itself. These background changes may include seasonal travel patterns, network-wide crash trends, changes in traffic volume, weather conditions, enforcement intensity, construction activity, or broader changes in driver behavior.

To reduce this bias, the system can use a comparison or control site pool. The control pool includes sites that are similar to the treated site but did not receive the same engineering treatment during the evaluation period. These untreated control sites are used to estimate the background before-after change that would have occurred even without the treatment.

3.1 Control Site Matching

Control sites should be selected from locations that are reasonably comparable to the treated site. Depending on available data, matching features may include VMT, number of journeys, average speed, roadway type, functional class, traffic volume level, or baseline risk-factor frequency. The goal is not to find identical sites, but to find a reasonable comparison group that reflects similar background trends.

3.2 Comparison-Adjusted SMF

The treated-site SMF is:

$$\mathrm{SMF}_{\mathrm{treated}} = \frac{\widehat{Y}_{\mathrm{after,treated}}}{\widehat{Y}_{\mathrm{before,treated}}} \tag{10}$$

The control-pool SMF is:

$$\mathrm{SMF}_{\mathrm{control}} = \frac{\widehat{Y}_{\mathrm{after,control}}}{\widehat{Y}_{\mathrm{before,control}}} \tag{11}$$

The Comparison-Adjusted SMF is:

$$\mathrm{SMF}_{\mathrm{adjusted}} = \frac{\mathrm{SMF}_{\mathrm{treated}}}{\mathrm{SMF}_{\mathrm{control}}} \tag{12}$$

Equivalently:

$$\mathrm{SMF}_{\mathrm{adjusted}} = \frac{\left(\widehat{Y}_{\mathrm{after,treated}}/\widehat{Y}_{\mathrm{before,treated}}\right)}{\left(\widehat{Y}_{\mathrm{after,control}}/\widehat{Y}_{\mathrm{before,control}}\right)} \tag{13}$$

This adjustment compares the before-after change at the treated site against the before-after change observed at similar untreated control sites. In other words, it asks whether the treated site improved more, improved less, or worsened relative to comparable sites.

Interpretation:

- Comparison-Adjusted SMF < 1: the treated site experienced a larger crash reduction than the control sites, suggesting a positive safety effect after adjustment.

- Comparison-Adjusted SMF = 1: the treated site changed similarly to the control sites, suggesting no clear treatment effect beyond background trends.
- Comparison-Adjusted SMF > 1: the treated site performed worse than the control sites after adjustment.

3.3 Comparison-Adjusted CMF

The same logic applies to predicted crash cost. The treated-site CMF is:

$$\mathrm{CMF}_{\mathrm{treated}} = \frac{\widehat{\mathrm{Cost}}_{\mathrm{after,treated}}}{\widehat{\mathrm{Cost}}_{\mathrm{before,treated}}} \tag{14}$$

The control-pool CMF is:

$$\mathrm{CMF}_{\mathrm{control}} = \frac{\widehat{\mathrm{Cost}}_{\mathrm{after,control}}}{\widehat{\mathrm{Cost}}_{\mathrm{before,control}}} \tag{15}$$

The Comparison-Adjusted CMF is:

$$\mathrm{CMF}_{\mathrm{adjusted}} = \frac{\mathrm{CMF}_{\mathrm{treated}}}{\mathrm{CMF}_{\mathrm{control}}} \tag{16}$$

Equivalently:

$$\mathrm{CMF}_{\mathrm{adjusted}} = \frac{\left(\widehat{\mathrm{Cost}}_{\mathrm{after,treated}} / \widehat{\mathrm{Cost}}_{\mathrm{before,treated}}\right)}{\left(\widehat{\mathrm{Cost}}_{\mathrm{after,control}} / \widehat{\mathrm{Cost}}_{\mathrm{before,control}}\right)} \tag{17}$$

Interpretation:

- Comparison-Adjusted CMF < 1: the treated site achieved greater cost savings than comparable untreated sites.
- Comparison-Adjusted CMF = 1: the cost change is similar to the control-site trend.
- Comparison-Adjusted CMF > 1: the treated site had a worse cost outcome relative to the control-site trend.

3.4 Example

Suppose the treated site has:

$$\mathrm{SMF}_{\mathrm{treated}} = 0.80$$

This means predicted crashes decreased by 20% after implementation. However, suppose similar untreated control sites also improved during the same period:

$$\mathrm{SMF}_{\mathrm{control}} = 0.90$$

Then:

$$\mathrm{SMF}_{\mathrm{adjusted}} = \frac{0.80}{0.90} = 0.89$$

This means the treated site still improved by about 11% relative to the background trend observed in the control sites.

The Comparison-Adjusted SMF and Comparison-Adjusted CMF should be interpreted as normalized treatment-effect indicators. They do not prove causality by themselves, but they provide a more defensible before-after comparison by accounting for changes observed at similar untreated sites.

Table 1: Raw and comparison-adjusted metric meanings.

Metric	Raw Before-After Meaning	Comparison-Adjusted Meaning
SMF	After/before predicted crash frequency at the treated site	Treated-site crash-frequency change divided by control-site crash-frequency change
CMF	After/before predicted crash cost at the treated site	Treated-site crash-cost change divided by control-site crash-cost change

4 Key Takeaways

Key Takeaways

1. SMF measures predicted crash-frequency change between the before and after periods.
2. CMF measures predicted crash-cost change between the before and after periods.
3. For both SMF and CMF, values below 1 indicate improvement, while values above 1 indicate deterioration.
4. Comparison-Adjusted SMF and Comparison-Adjusted CMF compare the treated site against similar untreated control sites.
5. Adjusted metrics are useful when background trends may affect simple before-after results.