PRACT
Predicting Road ACCidents - a Transferable methodology across Europe: APM/CMF review and Questionnaire

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1. Broad Literature Review
   (over 50 literature sources initially examined)
   • Highway Safety Manual and Related Literature
   • Literature on APM development
   • Web-based CMF databases and Road Safety Toolkits

2. Questionnaire Survey Methodology

3. Questionnaire Survey Results

4. Detailed CMF Review

5. Detailed APM Review

6. Conclusions
• **Predictive method** for estimating the expected average crash frequency of a network, facility or individual site.

• Types of sites include:
  - Freeway Segments
  - 2-way 2-lane Road Segments
  - Intersections
  - Interchange ramps
  - Freeway Speed Change Lanes
  - Crossroad Ramp Terminals

• The estimate relies upon models developed from observed crash data for a number of individual sites.
• **Safety Performance Functions** (SPFs) have been developed for specific facility types and “base conditions”, i.e. geometric design and traffic control features of a "base" site.

• SPF are typically a function of only a few variables, primarily average annual daily traffic (AADT) volumes and segment length.

• Example SPF (for 2-lane rural road): 
  \[ N_{spf} = (AADT) \times (L) \times (365) \times (10^{-6}) \times e^{-0.312} \]
• **Crash Modification Factors (CMFs)**, either as a single number or as a function) account for differences between the base conditions and local conditions of the considered site.

• **Calibration Factor (C)** accounts for differences between the road network for which the models were developed and the one for which the predictive method is applied.
The general form of the predictive models in HSM is:

\[ N_{pred} = N_{spf} \times (CMF_1 \times CMF_2 \times ... \times CMF_y) \times C \]

where:

- \( N_{pred} \) = predicted average crash frequency for a specific year
- \( N_{spf} \) = predicted average crash frequency determined for the base conditions of the SPF
- \( CMF_i \) = crash modification factors accounting for specific site conditions (geometric design, traffic control features, etc)
- \( C \) = calibration factor to adjust the SPF for local conditions related to the network where the model is to be applied
HSM Complementary Literature

• Reports and guides that provide guidance on the implementation of HSM methods and procedures

• Topics:
  - SPF Calibration vs. SPF Development,
  - developing jurisdiction-specific SPFs,
  - guidance on calibration factors,
  - guidance on CMF development,
  - combining multiple CMFs,
  - web-based FHWA CMF Clearinghouse,
  - etc.
Regression *Accident Prediction Models* (APMs) estimate the expected average accident frequency, as a function of traffic volume and road infrastructure characteristics (e.g. number of lanes, type of median, traffic control).

Critical issues: the choice of explanatory variables, the choice of model form and modeling process.
• **RIPCORD-iSEREST Research Project (2005-2008):** APMs for 2-lane 2-way rural roads,
• **RISMET Research Project (2011):** APMs for rural intersections,
• **Turner et al. (2012):** 2-lane 2-way rural roads in New Zealand,
• **Caliendo et al. (2007):** four-lane motorways in Italy,
• **Montella et al. (2008):** motorways in Italy,
• **Cafiso et al. (2010):** 2-lane 2-way rural roads in Italy, etc.
Web-based CMF databases and Road Safety Toolkits

- FHWA CMF Clearinghouse (http://www.cmfclearinghouse.org),
- SPF Clearinghouse (http://spfclearinghouse.org/),
- iRAP Road Safety Toolkit (http://toolkit.irap.org/)
• Brief introductory part,
• Part A regarding the Decision Making Process,
• Part B regarding Data Sources,
• Part C regarding information on CMFs and road safety measures assessment
• Part D, aimed at gathering a summary of experience on road safety measures / CMFs
Geography of Responses

<table>
<thead>
<tr>
<th>Country</th>
<th>Sent questionnaires</th>
<th>Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Belgium</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cyprus</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Denmark</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Finland</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Germany</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Greece</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hungary</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Iceland</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ireland</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Italy</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Norway</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Spain</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>UK</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>USA</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Australia</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Total: 28 sent, 23 received
Aspects Considered During Measures Assessment

- Safety effectiveness
- Implementation cost
- Effective lifespan
- Experience from previous implementation
- Public acceptability

Legend:
- very
- fairly
- not much
- not at all
Use of APMs and CMFs During Measures Assessment

- Always: 26%
- Usually: 13%
- Rarely: 44%
- Never: 17%

Final Project Workshop - Manchester, 3rd June 2016
Applicability Criteria of the CMF/Measure Assessment

- Area type (rural, urban etc.)
- Road type
- Road safety deficiency
- Prevailing accident type
- Road user category
- Speed limit
- Traffic volume
- Intersection type
- Intersection traffic control
- Major Road Traffic volume
- Minor Road Traffic volume

- yes
- no
- no data availability
# Summary of Experience on Road Safety Measures / CMFs

**MOTORWAYS & DIVIDED FREEWAYS (without at grade intersections)**

<table>
<thead>
<tr>
<th>Countermeasure - CMF</th>
<th>NEED</th>
<th>AVAILABILITY</th>
<th>TRANSFERABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realignment (of road segments)</td>
<td>18.8%</td>
<td>81.3%</td>
<td>26.7%</td>
</tr>
<tr>
<td>Rectangular rapid flashing beacons</td>
<td>21.4%</td>
<td>78.6%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Dynamic feedback speed signs</td>
<td>33.3%</td>
<td>66.7%</td>
<td>40.0%</td>
</tr>
<tr>
<td>Landscaping and vegetation</td>
<td>35.3%</td>
<td>64.7%</td>
<td>14.3%</td>
</tr>
<tr>
<td>Audible road markings</td>
<td>47.1%</td>
<td>52.9%</td>
<td>35.7%</td>
</tr>
<tr>
<td>Sight distance and sight obstructions</td>
<td>61.1%</td>
<td>38.9%</td>
<td>21.4%</td>
</tr>
<tr>
<td>Animals and wildlife related safety treatments</td>
<td>25.0%</td>
<td>75.0%</td>
<td>15.4%</td>
</tr>
<tr>
<td>Advanced warning devices/signals/beacons</td>
<td>62.5%</td>
<td>37.5%</td>
<td>26.7%</td>
</tr>
<tr>
<td>High friction treatments (including anti-skid/slip)</td>
<td>73.3%</td>
<td>26.7%</td>
<td>42.9%</td>
</tr>
<tr>
<td>Skid resistance (in general)</td>
<td>64.7%</td>
<td>35.3%</td>
<td>40.0%</td>
</tr>
<tr>
<td>Effects of Friction on Motorcycle Crashes</td>
<td>21.4%</td>
<td>78.6%</td>
<td>15.4%</td>
</tr>
<tr>
<td>Variable message signs</td>
<td>58.8%</td>
<td>41.2%</td>
<td>43.8%</td>
</tr>
<tr>
<td>Roadside features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>presence of a barrier</td>
<td>66.7%</td>
<td>33.3%</td>
<td>50.0%</td>
</tr>
<tr>
<td>barrier class</td>
<td>42.9%</td>
<td>57.1%</td>
<td>23.1%</td>
</tr>
<tr>
<td>use of passively safe structures (tested according to EN 12767)</td>
<td>58.8%</td>
<td>41.2%</td>
<td>25.0%</td>
</tr>
<tr>
<td>embankment slope</td>
<td>35.3%</td>
<td>64.7%</td>
<td>14.3%</td>
</tr>
<tr>
<td>replacement of barriers terminals with crashworthy terminals</td>
<td>56.3%</td>
<td>43.8%</td>
<td>28.6%</td>
</tr>
<tr>
<td>crash cushions</td>
<td>61.1%</td>
<td>38.9%</td>
<td>43.8%</td>
</tr>
<tr>
<td>motorcycle protection devices</td>
<td>53.3%</td>
<td>46.7%</td>
<td>21.4%</td>
</tr>
<tr>
<td>clear zone width</td>
<td>75.0%</td>
<td>25.0%</td>
<td>26.7%</td>
</tr>
<tr>
<td>Workzones</td>
<td>86.7%</td>
<td>13.3%</td>
<td>35.7%</td>
</tr>
<tr>
<td>Number of lanes</td>
<td>61.5%</td>
<td>38.5%</td>
<td>61.5%</td>
</tr>
<tr>
<td>Curvature</td>
<td>66.7%</td>
<td>33.3%</td>
<td>42.9%</td>
</tr>
</tbody>
</table>

Complete tables are available at: [http://www.practproject.eu/](http://www.practproject.eu/)
CMF Review – Selection of “high priority” CMFs

• “High Priority” CMF types for review:
  - CMFs included in AASHTO's HSM,
  - CMFs that more than 50% of NRAs considered as highly desirable according to the questionnaire survey

• 92 “high priority” CMF types were selected:
  - 54 from the HSM,
  - 49 from the questionnaire survey,
  - 1 added by the project team (CMF type 26: Horizontal Curve Delineation on Freeway Segments),
  - 12 types originated from both HSM and survey).
CMFs were grouped into the following six roadways element categories for the subsequent review:

1. Freeway segments
2. Speed change lanes
3. Ramp segments
4. Crossroad ramp terminals
5. Rural road segments (2-way 2-lane)
6. Rural road intersections
<table>
<thead>
<tr>
<th>CMF type no</th>
<th>CMF title</th>
<th>Originated from</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMF type 1</td>
<td>Freeway segment - Horizontal curve</td>
<td>HSM &amp; Questionnaire</td>
</tr>
<tr>
<td>CMF type 2</td>
<td>Freeway segment - Lane width</td>
<td>HSM</td>
</tr>
<tr>
<td>CMF type 3</td>
<td>Freeway segment - Inside shoulder width</td>
<td>HSM</td>
</tr>
<tr>
<td>CMF type 4</td>
<td>Freeway segment - Median width</td>
<td>HSM</td>
</tr>
<tr>
<td>CMF type 5</td>
<td>Freeway segment - Median barrier</td>
<td>HSM &amp; Questionnaire</td>
</tr>
<tr>
<td>CMF type 6</td>
<td>Freeway segment - High volume</td>
<td>HSM</td>
</tr>
<tr>
<td>CMF type 7</td>
<td>Freeway segment - Lane change</td>
<td>HSM</td>
</tr>
<tr>
<td>CMF type 8</td>
<td>Freeway segment - Outside shoulder width</td>
<td>HSM</td>
</tr>
<tr>
<td>CMF type 9</td>
<td>Freeway segment - Shoulder rumble strip</td>
<td>HSM</td>
</tr>
<tr>
<td>CMF type 10</td>
<td>Freeway segment - Outside clearance</td>
<td>HSM</td>
</tr>
<tr>
<td>CMF type 11</td>
<td>Freeway segment - Outside barrier</td>
<td>HSM &amp; Questionnaire</td>
</tr>
<tr>
<td>CMF type 12</td>
<td>Freeway segment - Workzones</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 13</td>
<td>Freeway segment - Roadside features - clear zone width</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 14</td>
<td>Freeway segment - High friction treatments (including anti-skid/slip)</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 15</td>
<td>Freeway segment - Number of lanes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 16</td>
<td>Freeway segment - Effect of traffic (volume/capacity - % trucks &amp; buses)</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 17</td>
<td>Freeway segment - Sight distance and sight obstructions</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 18</td>
<td>Freeway segment - Roadside features - crash cushions</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 19</td>
<td>Freeway segment - Skid resistance (in general)</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 20</td>
<td>Freeway segment - Roadside features - use of passively safe structures (tested according to EN 12767)</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 21</td>
<td>Freeway segment - Automated speed enforcement (section or average)</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 22</td>
<td>Freeway segment - Advanced warning devices/signals/beacons</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 23</td>
<td>Freeway segment - Roadside features - replacement of barriers terminals with crashworthy terminals</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 24</td>
<td>Freeway segment - Effect of ramp entrance/exit (distance to the analysed section)</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 25</td>
<td>Freeway segment - Variable message signs</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>CMF type 26</td>
<td>Freeway segment - Horizontal curve delineation</td>
<td>Consortium</td>
</tr>
</tbody>
</table>
For each of the 92 CMF types a **one-page summary** was developed, presenting the most important information of the review.

<table>
<thead>
<tr>
<th>CMF name &amp; description:</th>
<th>Number of studies: 4 (48 estimates)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CMF type 21: Freeway segment</strong> - Automated speed enforcement (section or average)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of studies by methodology:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empirical Bayes Before-After (3), Not specified (Handbook of road safety measures) (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of studies by country:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy (2), US (1), Norway (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range of estimates:</th>
<th>Mean value of estimates:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.42 – 1.21</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Earliest year of accident data used in studies:</th>
<th>Latest year of accident data used in studies:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2009</td>
</tr>
</tbody>
</table>

**Comment on the state of the literature:**

The range of available CMFs covers different accident severity levels, different crash types and indicates changes in accident occurrence due to installation of automated speed enforcement. Thereby a differentiation was also made by different timeframes after the installation of the speed cameras.

**List of studies estimating CMF:**

- FHWA Clearinghouse CMFs, Federal Highway Administration (FHWA), URL: http://www.cmfclearinghouse.org/


The review resulted in a comprehensive **CMF Inventory** that includes a total of **1,526 CMFs** (Factors and Functions). For each CMF detailed data have been compiled, such as:

- Basic information.
- CMF development information.
- Information about the study from which the CMF was retrieved.
- Information on the considered road elements.
- Basic accident information
- Information about the relevant safety deficiency and the corresponding countermeasures.
• All identified APMs were included, not only “high priority” ones.

• APMs were also grouped into the six roadway element categories:
  1. Freeway segments
  2. Speed change lanes
  3. Ramp segments
  4. Crossroad ramp terminals
  5. Rural road segments (2-way 2-lane)
  6. Rural road intersections
A second level grouping considered the **form** of the model:

1. **Regression Equation APMs** are stand-alone models that are able to predict accidents based on a series of road and traffic related data (independent variables).

2. **SPF and CMF APMs** (such as the HSM models), use a SPF to calculate an initial accident frequency for specific “base” conditions. At a second stage, CMFs are used to account for geometric design or traffic control features differences between base conditions and local conditions of the site under consideration.
A total of **146 different APMs** were examined; 85 Regression Equation models and 61 SPF & CMF models.

For each of the 6 roadway element categories a **one-page summary** was developed, presenting the most important information of the review.

### APM Category: Non-urban Motorways and Freeways

<table>
<thead>
<tr>
<th>Number of studies</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of studies by APM type:</td>
<td>APM (4), SPF &amp; CMF Models (10), APM &amp; SPF (3)</td>
</tr>
<tr>
<td>Number of studies by APM methodology:</td>
<td>Poisson Negative Multinomial regression model (1), Negative Binomial regression (3), Additive conventional linear regression model (1), Multiplicative conventional linear regression model (1), Exponential Poisson regression model (1), Generalized Linear Model (1), General Estimating Equation (2)</td>
</tr>
<tr>
<td>Number of studies by country:</td>
<td>Italy (4), New Zealand (1), Taiwan (1), Korea (1), US Illinois (1), US Virginia (1), US Missouri (1), US Florida (2), Canada (4), US (1)</td>
</tr>
<tr>
<td>Earliest year of accident data used in studies:</td>
<td>1995</td>
</tr>
<tr>
<td>Latest year of accident data used in studies:</td>
<td>2014</td>
</tr>
<tr>
<td>Comment on the state of the literature:</td>
<td>The range of available APMs &amp; SPFs covers different accident severity levels, different crash types, different weather and daytime conditions and different number of vehicles. The APMs &amp; SPFs indicates the changes in accident occurrence due to changes AADT, segment length and a set of other explaining variables (road design characteristics).</td>
</tr>
</tbody>
</table>

### List of studies estimating APMs:

The review resulted in a comprehensive **APM Inventory** that includes a total of **146 models**, compiled as **273 inventory entries**.

Data compiled for each APM:
- Basic information.
- APM development information.
- Information about the study from the APM was retrieved.
- Information on the considered road elements.
- Basic accident information
Conclusions (1/3)

- The review of international literature indicates **significant advances in the field of accident prediction modeling.**

- Generally, **high levels of data availability** were reported, particularly for motorways.
Conclusions (2/3)

- There are still several CMF types with no or limited availability in the literature:
  - For rural motorways: roadside clear zone width; number of lanes; traffic composition; sight distance and sight obstructions; use of passively safe structures on the roadside; replacement of barrier terminals with crashworthy terminals etc.
  - For 2-way 2-lane rural roads: presence of a barrier on the roadside; sight distance and sight obstructions; use of passively safe structures on the roadside; presence of workzones; replacement of barrier terminals with crashworthy terminals; audible road markings; roadside barrier class; advanced warning devices, signals or beacons; raised islands and pedestrian refuge islands; automated speed enforcement; segment lighting etc.
• CMF estimates and APMs tend to be based **primarily on US data**, and the limited existing European estimates mostly refer to a small set of countries, namely: Portugal, Spain, Germany, Norway, UK and Italy.

• However, most National Road Administrations (NRAs) still **do not systematically use such methods** during decision making.
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