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

Anastasios Dragomanovits, Research Associate

Alexandra Laiou, Research Associate

George Yannis, Professor

National Technical University of Athens (NTUA)

Presentation Structure

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

Highway Safety Manual (1/4)

- **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.

Highway Safety Manual (2/4)

- **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.
- SPFs 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):
  $N_{spf} = (AADT) \times (L) \times (365) \times (10^{-6}) \times e^{(-0.312)}$

Highway Safety Manual (3/4)

- **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.

Highway Safety Manual (4/4)

The **general form of the predictive models in HSM** is:

$$N_{pred.} = N_{spf} \times (CMF_1 \times CMF_2 \times \ldots \times CMF_y) \times C$$

where:

$N_{pred.}$ = predicted average crash frequency for a specific year

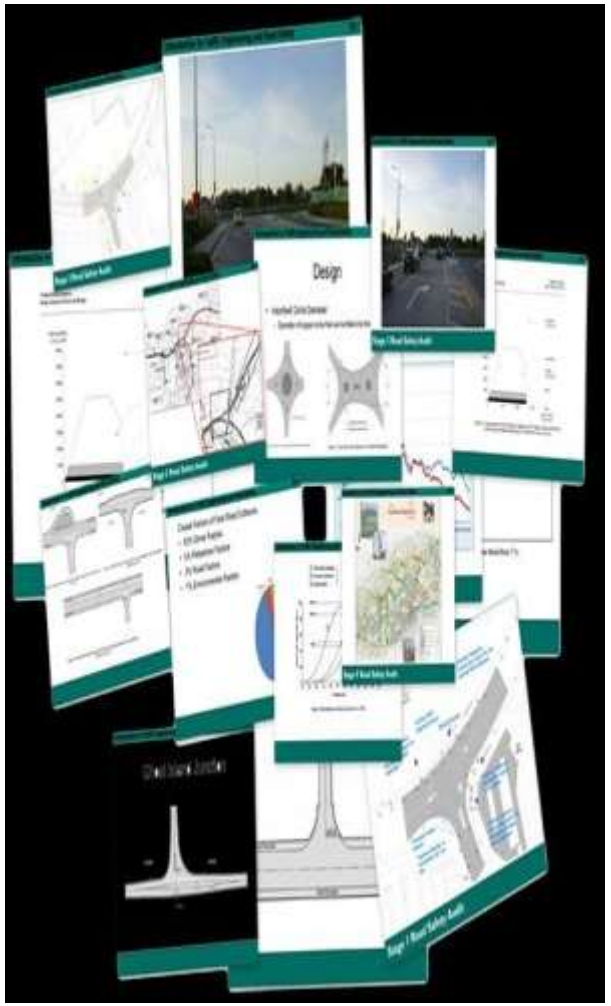
N_{spf} = predicted average crash frequency determined for the base conditions of the SPF

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.



Literature on APM Development (1/2)

- 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)

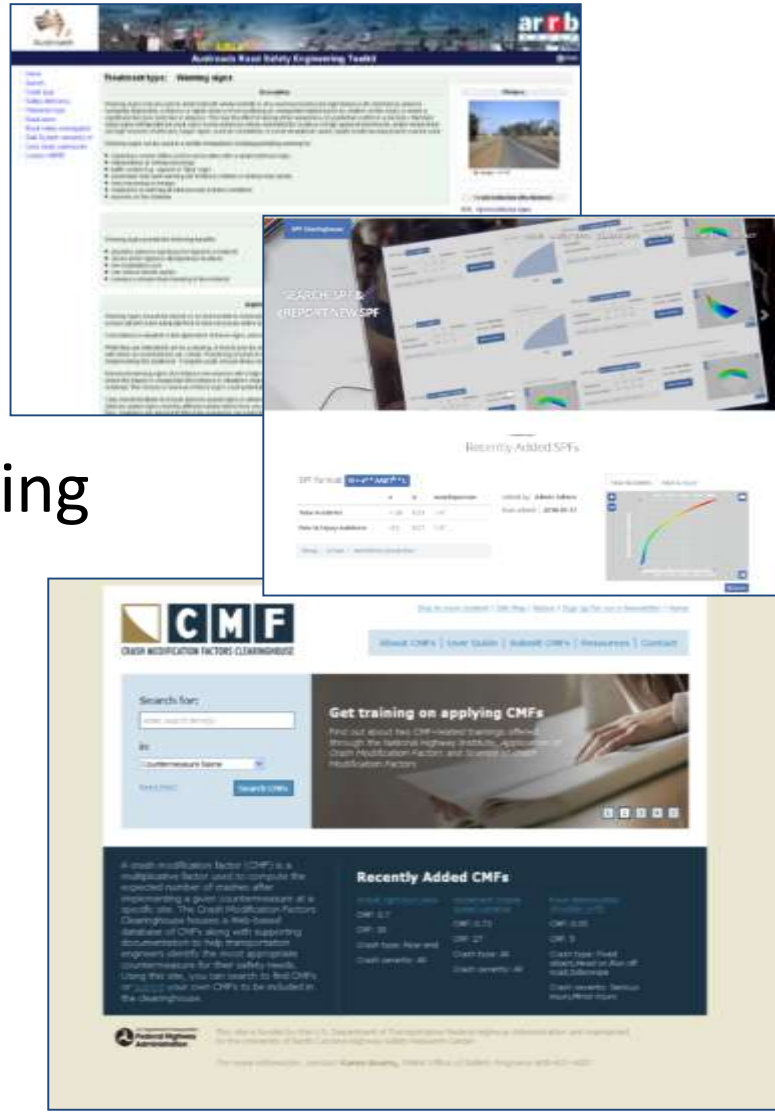
- Critical issues: the choice of explanatory variables, the choice of model form and modeling process

Literature on APM Development (2/2)

- *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/),
- AustRoads Road Safety Engineering Toolkit (http://www.engtoolkit.com.au/),
- iRAP Road Safety Toolkit (http://toolkit.irap.org/)



PRACT Questionnaire

- 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


CEDR Transnational Road Research Programme
Call 2013: Safety

funded by Germany, Ireland, UK and Netherlands

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

PRACT
Predicting Road ACcidents - a Transferable methodology across Europe

Questionnaire

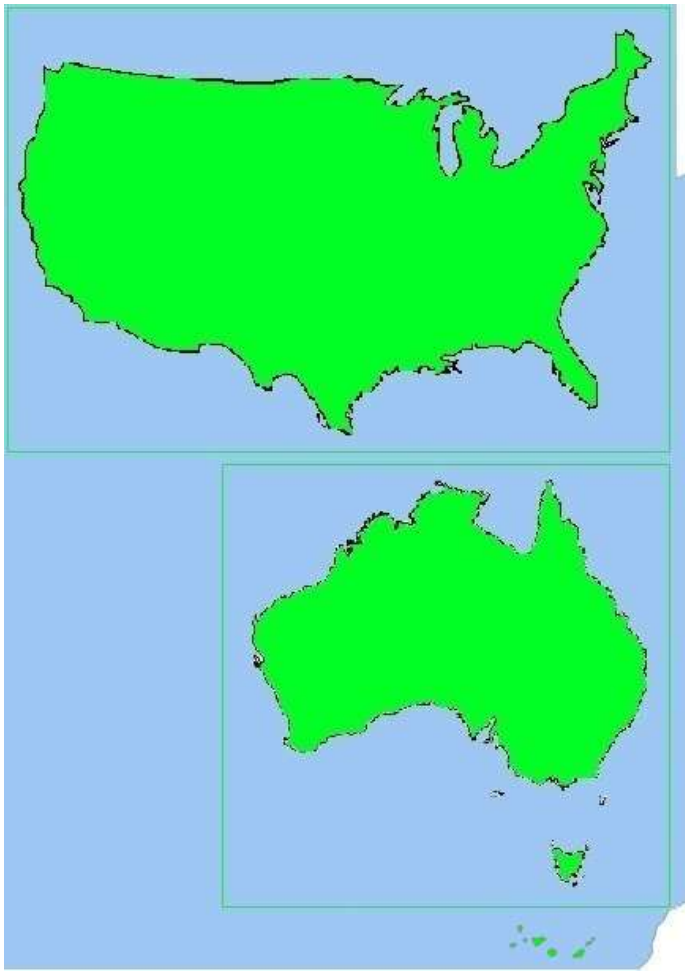
Imperial College London

With the support of:

autostrade per l'Italia
IRF
ERF
TRB
ANB25 Committee

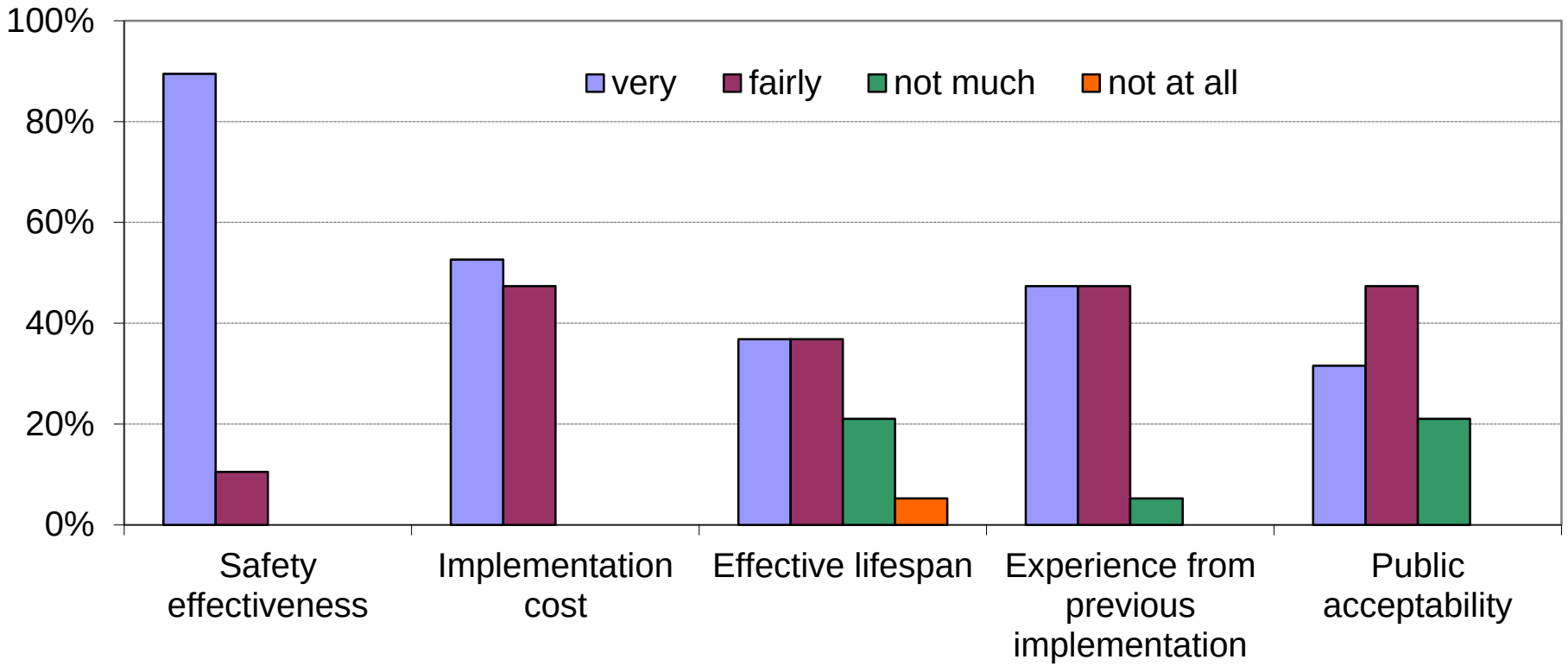
pract
www.practproject.eu

Geography of Responses

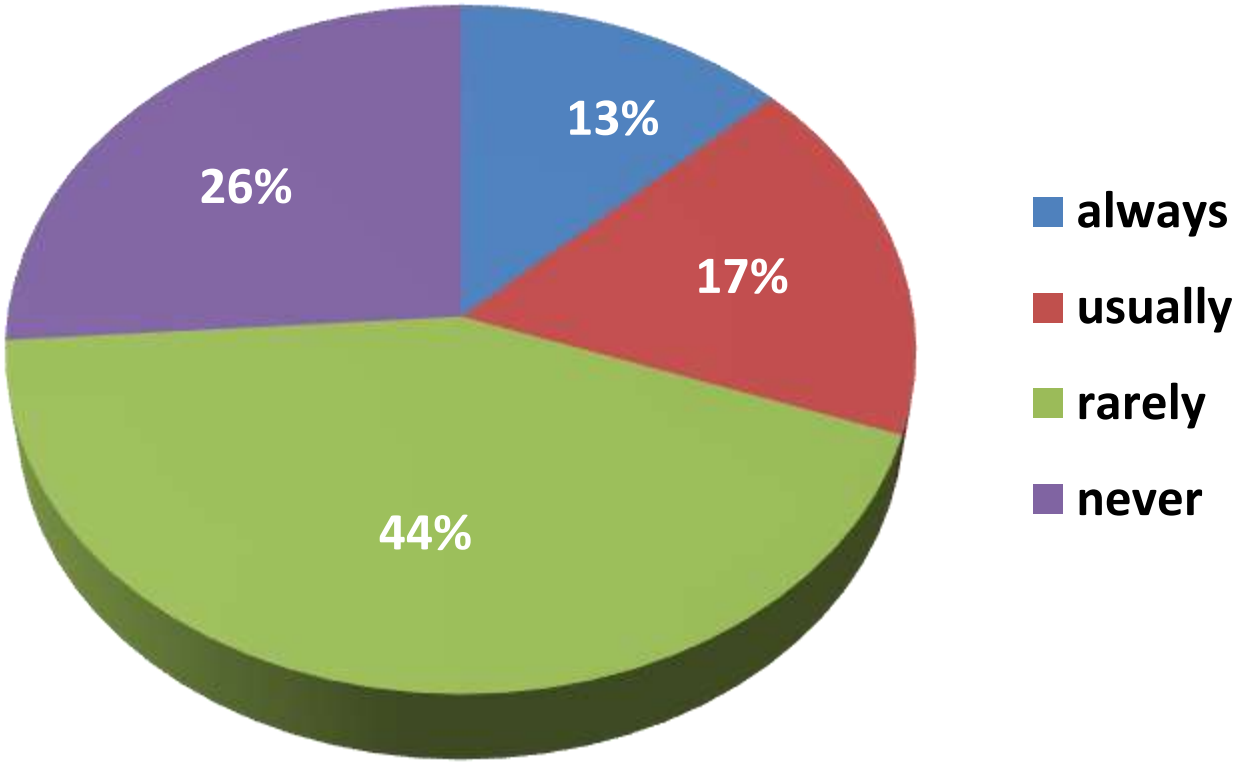


Country	Sent questionnaires	Received
Austria	1	1
Belgium	2	1
Cyprus	1	1
Denmark	1	1
Finland	1	1
Germany	1	1
Greece	1	1
Hungary	1	1
Iceland	1	1
Ireland	1	1
Italy	3	2
Luxembourg	1	1
Netherlands	1	1
Norway	1	1
Slovenia	1	1
Spain	1	1
Switzerland	1	1
UK	5	3
USA	2	1
Australia	1	1
Total	28	23

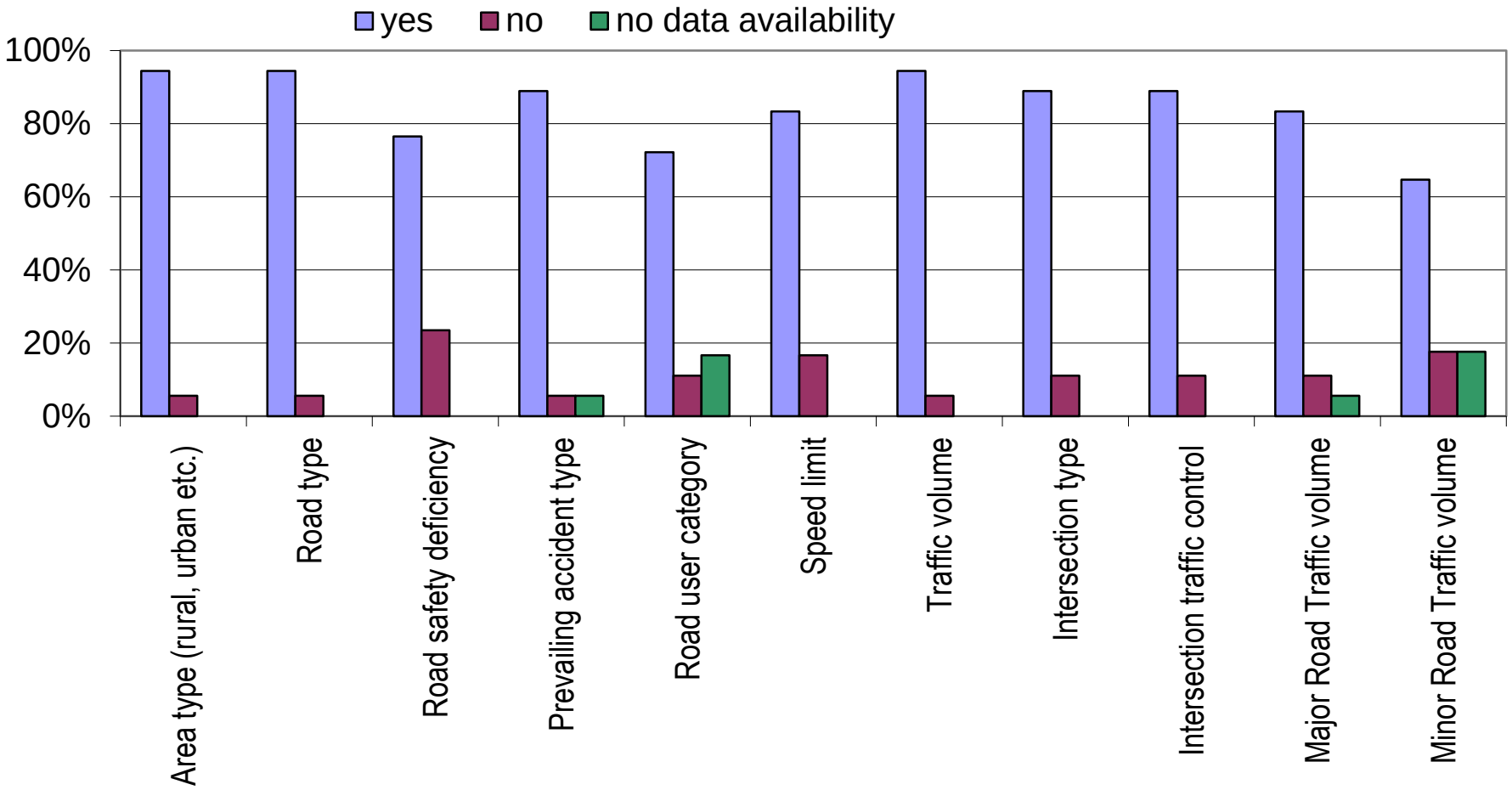
Aspects Considered During Measures Assessment



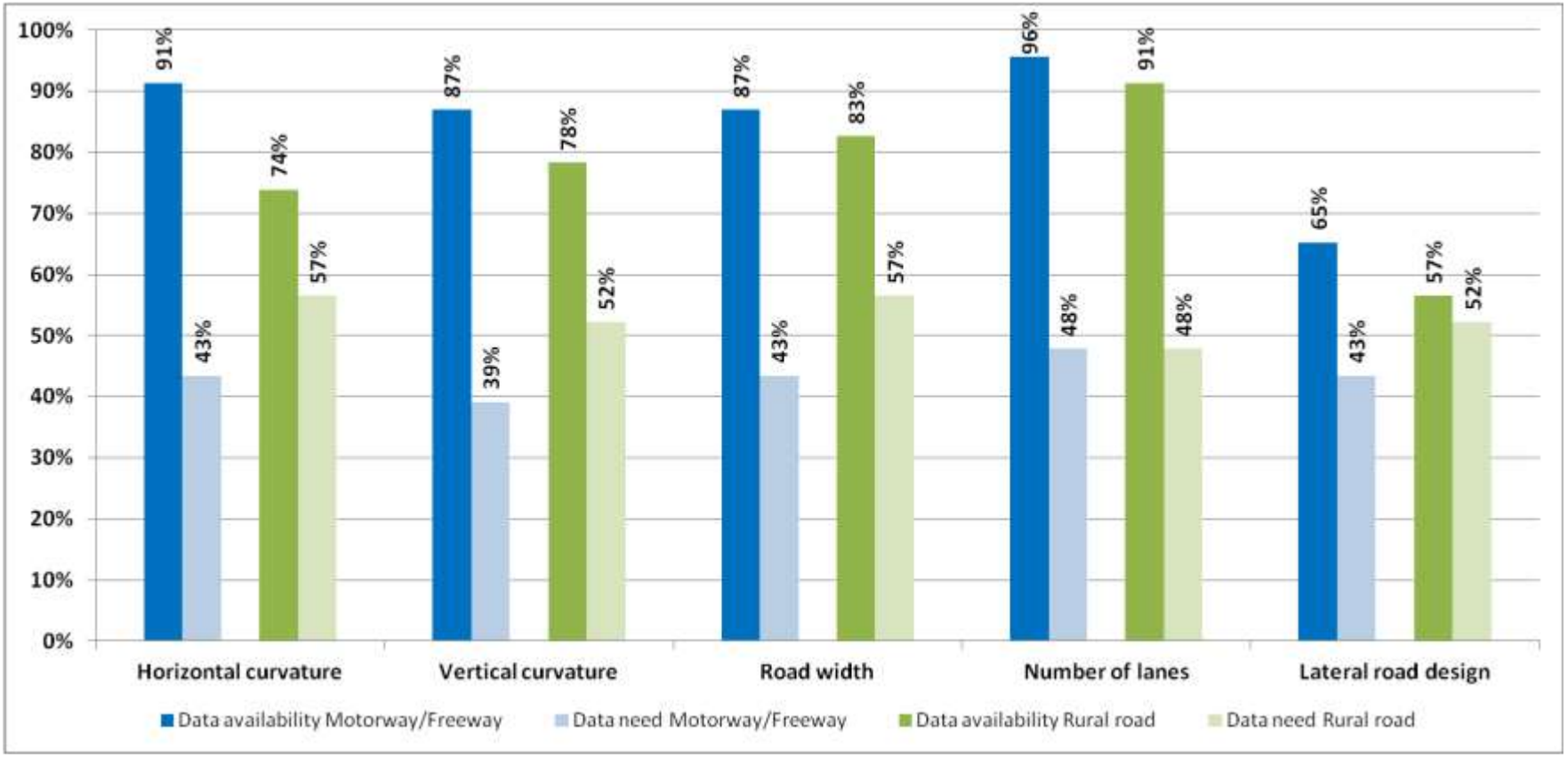
Use of APMs and CMFs During Measures Assessment



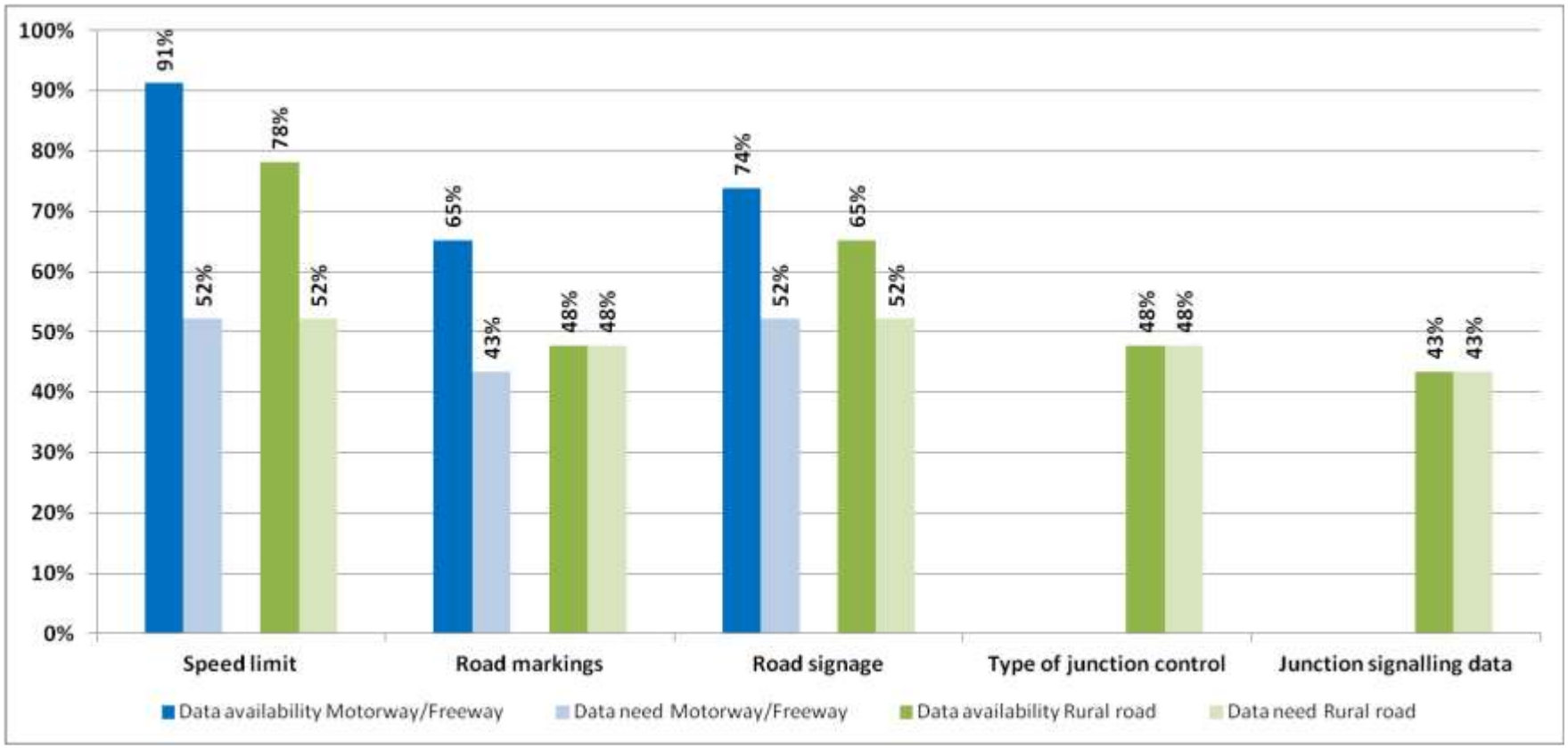
Applicability Criteria of the CMF/Measure Assessment



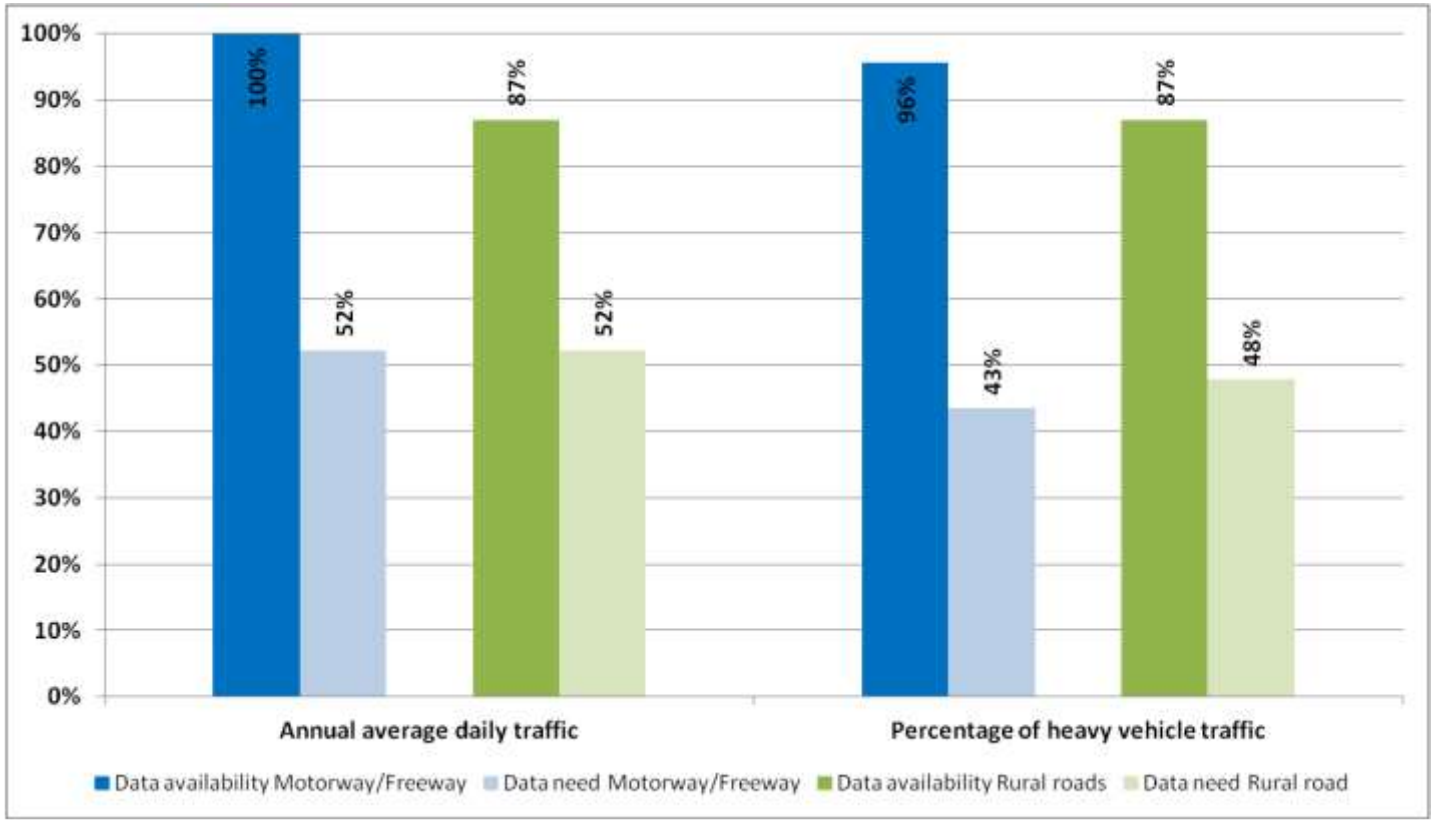
Road Design Data Availability and Need



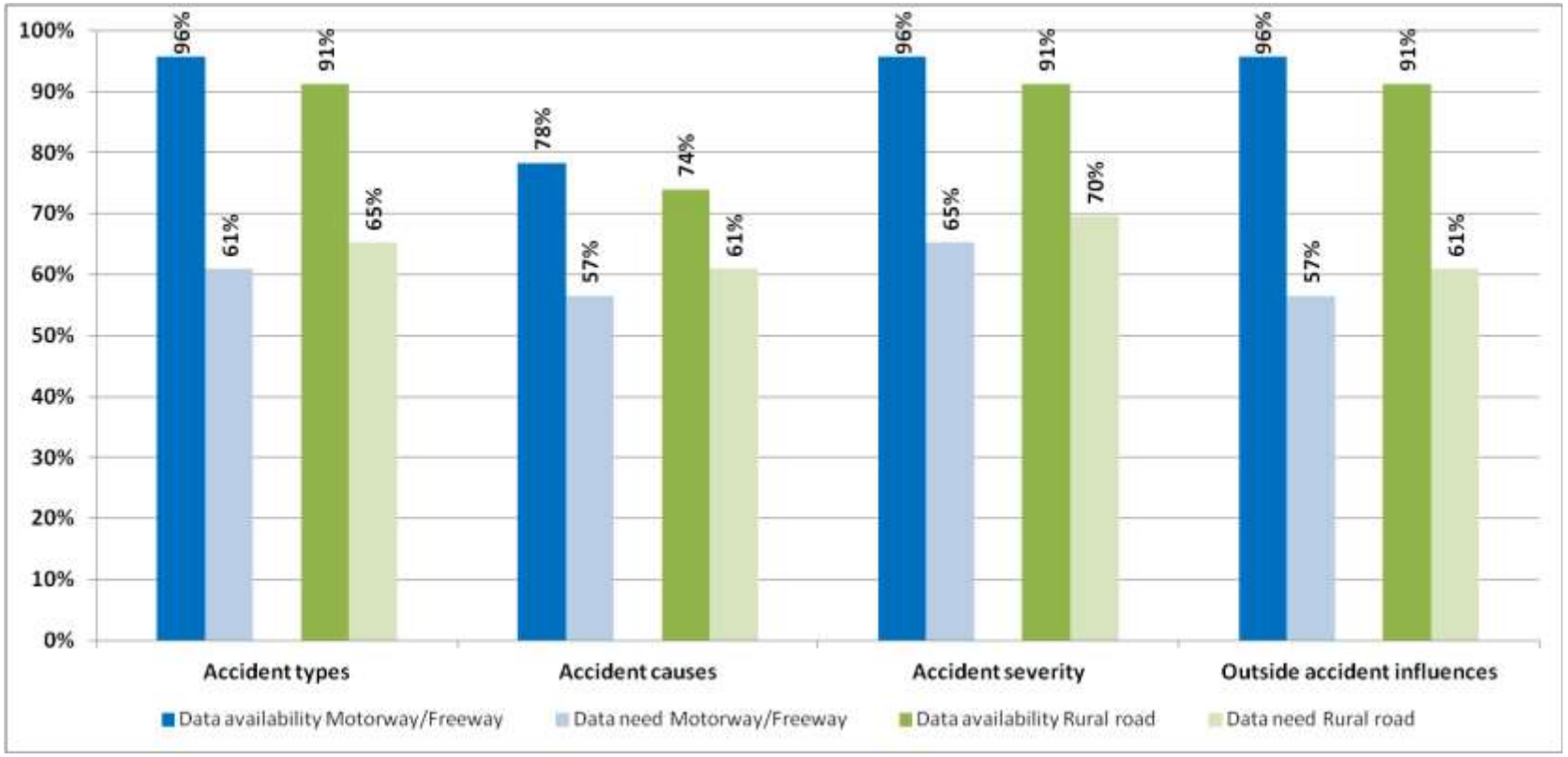
Road Operation Data Availability and Need



Traffic Data Availability & Need



Accident Data Availability & Need



Summary of Experience on Road Safety Measures / CMFs

MOTORWAYS & DIVIDED FREEWAYS (without at grade intersections)	NEED		AVAILABILITY		TRANSFERABILITY	
Countermeasure - CMF	**HIGH**	**LOW**	**HIGH**	**LOW**	**HIGH**	**LOW**
Realignment (of road segments)	18,8%	81,3%	26,7%	73,3%	54,5%	45,5%
Rectangular rapid flashing beacons	21,4%	78,6%	7,1%	92,9%	45,5%	54,5%
Dynamic feedback speed signs	33,3%	66,7%	40,0%	60,0%	63,6%	36,4%
Landscaping and vegetation	35,3%	64,7%	14,3%	85,7%	63,6%	36,4%
Audible road markings	47,1%	52,9%	35,7%	64,3%	81,8%	18,2%
Sight distance and sight obstructions	61,1%	38,9%	21,4%	78,6%	63,6%	36,4%
Animals and wildlife related safety treatments	25,0%	75,0%	15,4%	84,6%	30,0%	70,0%
Advanced warning devices/signals/beacons	62,5%	37,5%	26,7%	73,3%	72,7%	27,3%
High friction treatments (including anti-skid/slip)	73,3%	26,7%	42,9%	57,1%	63,6%	36,4%
Skid resistance (in general)	64,7%	35,3%	40,0%	60,0%	63,6%	36,4%
Effects of Friction on Motorcycle Crashes	21,4%	78,6%	15,4%	84,6%	36,4%	63,6%
Variable message signs	58,8%	41,2%	43,8%	56,3%	63,6%	36,4%
Roadside features						
presence of a barrier	66,7%	33,3%	50,0%	50,0%	75,0%	25,0%
barrier class	42,9%	57,1%	23,1%	76,9%	72,7%	27,3%
use of passively safe structures (tested according to EN 12767)	58,8%	41,2%	25,0%	75,0%	58,3%	41,7%
embankment slope	35,3%	64,7%	14,3%	85,7%	45,5%	54,5%
replacement of barriers terminals with crashworthy terminals	56,3%	43,8%	28,6%	71,4%	66,7%	33,3%
crash cushions	61,1%	38,9%	43,8%	56,3%	76,9%	23,1%
motorcycle protection devices	53,3%	46,7%	21,4%	78,6%	54,5%	45,5%
clear zone width	75,0%	25,0%	26,7%	73,3%	50,0%	50,0%
Workzones	86,7%	13,3%	35,7%	64,3%	50,0%	50,0%
Number of lanes	61,5%	38,5%	61,5%	38,5%	60,0%	40,0%
Curvature	66,7%	33,3%	42,9%	57,1%	63,6%	36,4%

Complete tables are available at: http://www.practproject.eu/

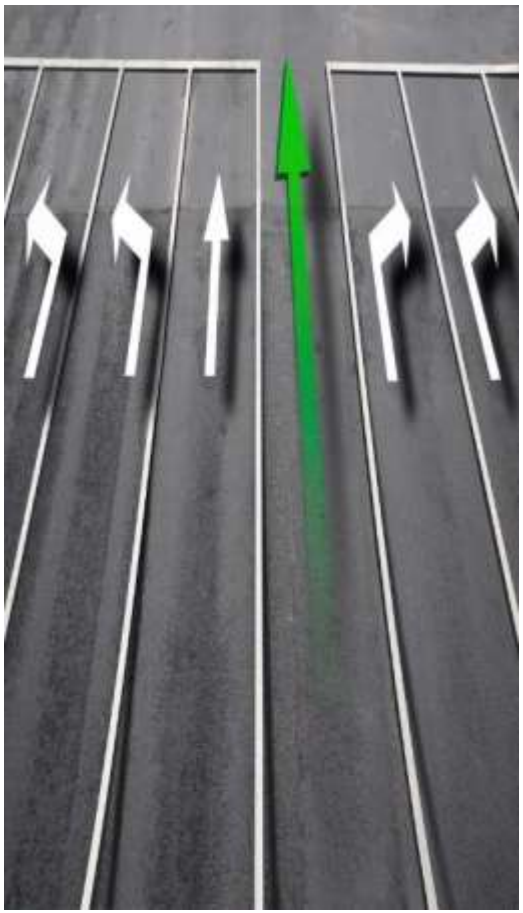
CMF Review – Selection of "high priority" CMFs

- **"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).

Roadway element categories of CMFs

CMFs were grouped into the following six **roadway 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



.

Freeway Segments CMF types

CMF type no	CMF title	Originated from
CMF type 1	Freeway segment - Horizontal curve	HSM & Questionnaire
CMF type 2	Freeway segment - Lane width	HSM
CMF type 3	Freeway segment - Inside shoulder width	HSM
CMF type 4	Freeway segment - Median width	HSM
CMF type 5	Freeway segment - Median barrier	HSM & Questionnaire
CMF type 6	Freeway segment - High volume	HSM
CMF type 7	Freeway segment - Lane change	HSM
CMF type 8	Freeway segment - Outside shoulder width	HSM
CMF type 9	Freeway segment - Shoulder rumble strip	HSM
CMF type 10	Freeway segment - Outside clearance	HSM
CMF type 11	Freeway segment - Outside barrier	HSM & Questionnaire
CMF type 12	Freeway segment - Workzones	Questionnaire
CMF type 13	Freeway segment - Roadside features - clear zone width	Questionnaire
CMF type 14	Freeway segment - High friction treatments (including anti-skid/slip)	Questionnaire
CMF type 15	Freeway segment - Number of lanes	Questionnaire
CMF type 16	Freeway segment - Effect of traffic (volume/capacity - % trucks & buses)	Questionnaire
CMF type 17	Freeway segment - Sight distance and sight obstructions	Questionnaire
CMF type 18	Freeway segment - Roadside features - crash cushions	Questionnaire
CMF type 19	Freeway segment - Skid resistance (in general)	Questionnaire
CMF type 20	Freeway segment - Roadside features - use of passively safe structures (tested according to EN 12767)	Questionnaire
CMF type 21	Freeway segment - Automated speed enforcement (section or average)	Questionnaire
CMF type 22	Freeway segment - Advanced warning devices/signals/beacons	Questionnaire
CMF type 23	Freeway segment - Roadside features - replacement of barriers terminals with crashworthy terminals	Questionnaire
CMF type 24	Freeway segment - Effect of ramp entrance/exit (distance to the analysed section)	Questionnaire
CMF type 25	Freeway segment - Variable message signs	Questionnaire
CMF type 26	Freeway segment - Horizontal curve delineation	Consortium

CMF Review Results (1/2)

For each of the 92 CMF types a **one-page summary** was developed, presenting the most important information of the review

CMF name & description: *CMF type 21: Freeway segment - Automated speed enforcement (section or average)*	
Number of studies: *4 (48 estimates)*	
Number of studies by methodology: *Empirical Bayes Before-After (3), Not specified (Handbook of road safety measures) (1)*	
Number of studies by country: *Italy (2), US (1), Norway (1)*	
Range of estimates: *0.42 – 1.21*	Mean value of estimates: *-*
Earliest year of accident data used in studies: *2001*	Latest year of accident data used in studies: *2009*
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/* *Montella, A., Persuad, B., D'Apuzzo, M., Imbriani, L., "Safety Evaluation of an Automated Section Speed Enforcement System." Presented at the 91st Annual Meeting of the Transportation Research Board, Paper No. 12-0226, Washington, D.C., (2012)* *Elvik R., Hoye A., Vaa T., Sorensen M., The Handbook of Road Safety Measures, 2nd Edition, Emerald Group Publishing Ltd., 2009* *La Torre F., Fanfani F., Rossi M., Valutazione dell'effetto dell'introduzione del sistema Safety Tutor sulla sicurezza stradale. Bachelor Thesis presented in March 2015.*	

CMF Review Results (2/2)

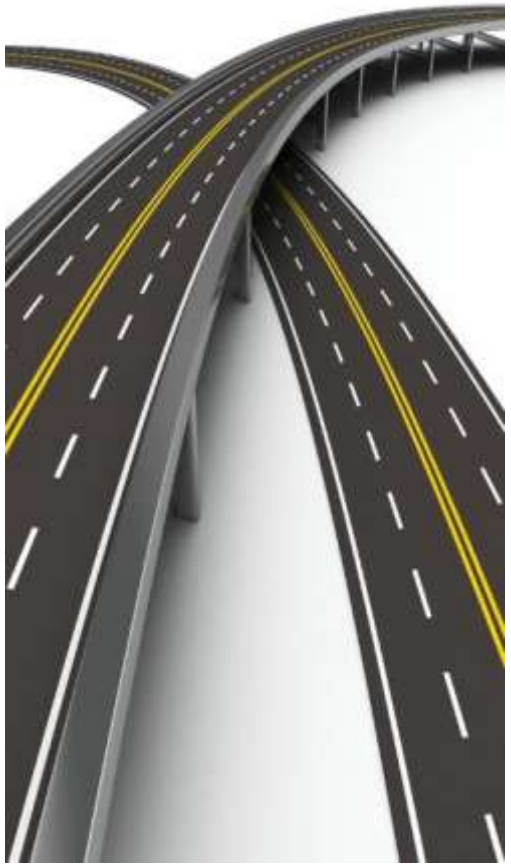
The review resulted in a comprehensive **CMF Inventory** that includes a total of **1,526 CMFs** (Factors and Functions). For each CMF detailed data have been compiled, such as:

- 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.

APM Review Principles (1/2)

- **All identified APMs were included**, not only “high priority” ones.

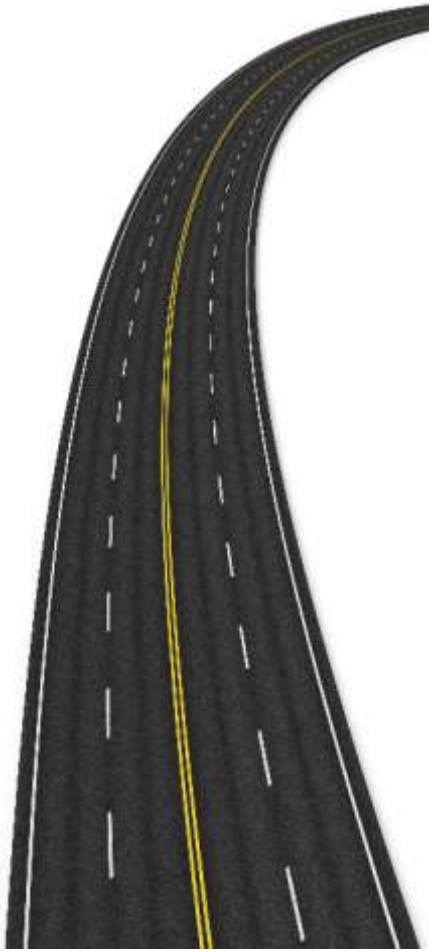
- APMs were also grouped into the **six roadway element categories**:
  1. Freeway segments
  2. Speed change lanes
  3. Ramp segments
  4. Crossroad ramp terminals
  5. Rural road segments (2-way 2-lane)
  6. Rural road intersections



APM Review Principles (2/2)

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.



APM Review Results (1/2)

- 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*	
Number of studies: *17*	
Number of studies by APM type: *APM (4), SPF & CMF Models (10), APM & SPF (3)*	
Number of studies by APM methodology: *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), Multiplicative Poisson regression model (1), Generalized Linear Model (1), General Estimating Equation (2)* *Some analysed studies used different methodologies. That why the sum is different from the above mentioned number of APMs.*	
Number of studies by country: *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)*	
Earliest year of accident data used in studies: *1995*	Latest year of accident data used in studies: *2014*
Comment on the state of the literature: *The range of available APMs & SPFs covers different accident severity levels, different crash types, different weather and daytime conditions and different number of vehicles. The APMs & SPFs indicates the changes in accident occurrence due to changes AADT, segment length and a set of other explaining variables (road design characteristics).*	
List of studies estimating APMs: 1. *Hadi M. A., Aruldhas J., Chow L.F., Wattleworth J.A. (1995). Estimating safety effects of cross-section design for various highway types using negative binomial regression. Transportation research record 1500* 2. *Chen J.-S., Wang S.-C. (1999). Statistically modelling relationship between accident types and highway features. Civil Engineering and Enviromental System, 16:1, 51-65, DOI 10,1080/02630259908970251, Taiwan* 3. *Lord D., Manar A., Vizioli A. (2004). Modeling crash-flow-density and crash-flow-V/C ratio relationships for rural and urban freeway segments. Accident Analysis and Prevention vol. 37, pg 185-199* 4. *Caliendo C., Guida M., Parisi A. (2006). A crash-prediction model for multilane roads. Accident Analysis and Prevention vol. 39, pg 657-670, Salerno, Italy* 5. *Sayed T., de Leur P. (2008). Collision prediction models for British Columbia. Prepared for: Engineering Branch BC Ministry of Transportation & Infrastructure* 6. *Begum, S.M. Morjina Ara (2008). Investigation of model calibration issues in the safety performance assessment of Ontario highways. Theses and dissertations. Paper 168. Toronto, Ontario, Canada* 7. *Dumont J., Hadayeghi A., El Haddad E., Dagenais C., Levesque H., Lemaire I. (2010).*	

APM Review Results (2/2)

The review resulted in a comprehensive **APM Inventory** that includes a total of **146 models**, compiled as **273 inventory entries** (several models were compiled as more than one entry, in order to properly handle complex parameters, e.g. parameters included in a tabular form in the model).

For each APM detailed data have been compiled:

- 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.

Conclusions (3/3)

- 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.

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

Anastasios Dragomanovits, Research Associate

Alexandra Laiou, Research Associate

George Yannis, Professor

National Technical University of Athens (NTUA)