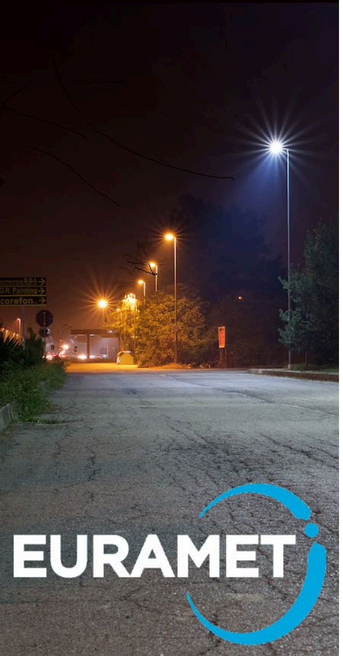
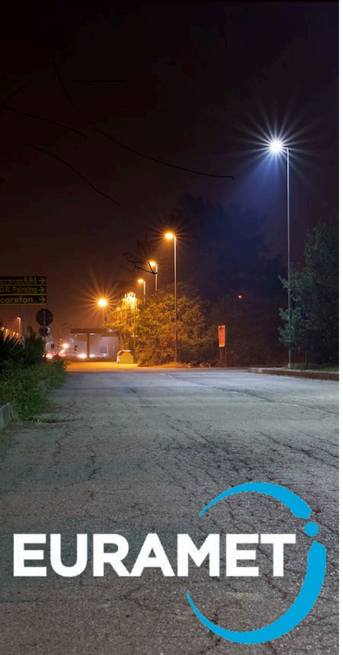


# Spectral behaviour of Road surfaces

Paola Iacomussi

INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

SURFACE 3rd webinar, 17th november 2020



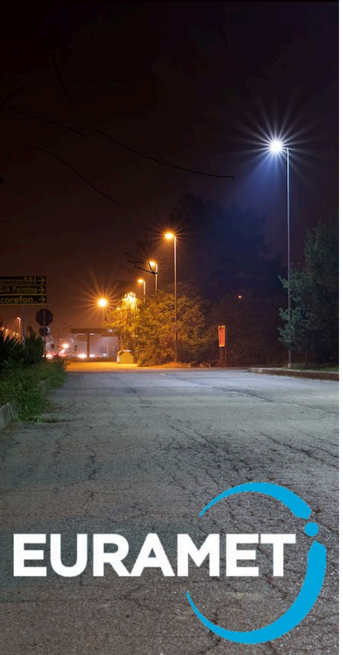
# OUTLINE

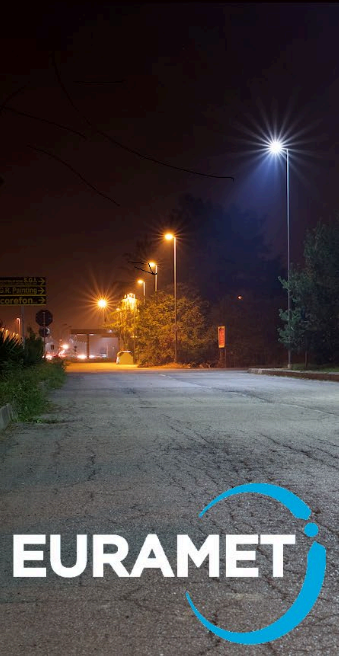
- SURFACE tasks
- Spectral quantities
- Peculiarities and applications of spectral characterisation of road surfaces
- SURFACE investigations
  - Sources
  - Lighting design
  - Uncertainty

# SURFACE Tasks

## SURFACE project aims :

To develop pre-normative guidelines for measurement methods and procedures, for the future evolution of European standards to include aspects such as **mesopic** visual conditions, **spectral properties**.



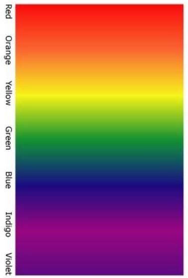


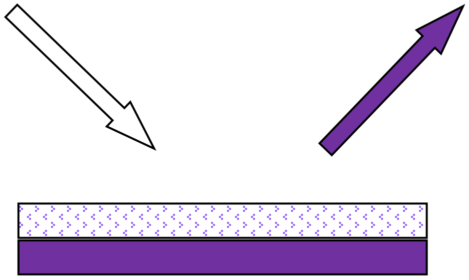
# SPECTRAL Quantities

- **Spectral Reflection Factor** i.e. reflectance

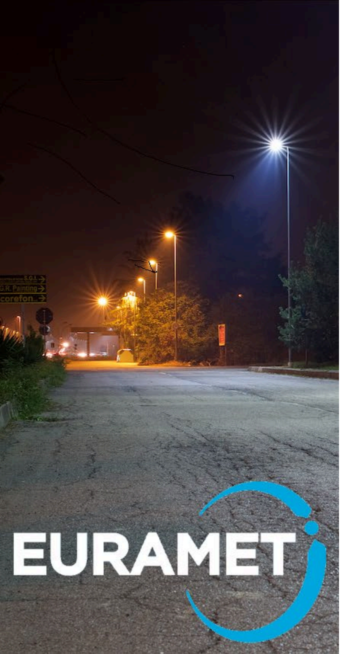
  Is the ratio of reflected spectral flux [$(\Phi_r(\lambda)$] to the incident spectral flux [$(\Phi_i(\lambda)$]

$$\rho(\lambda) = \frac{d\Phi_r(\lambda)}{d\Phi_i(\lambda)}$$



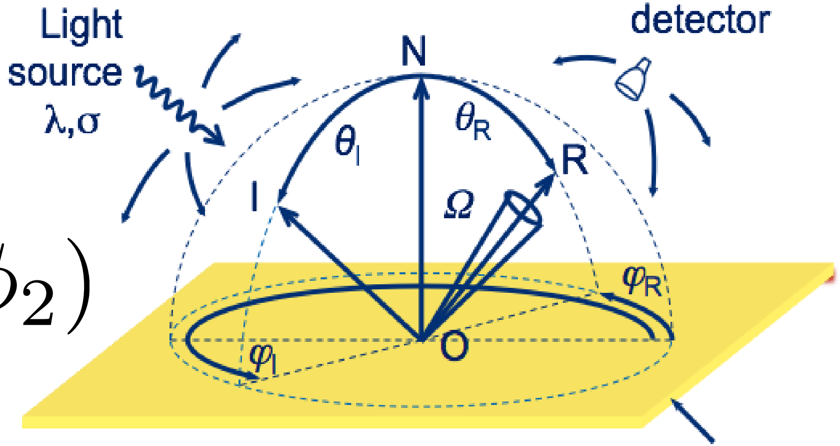

# SPECTRAL Quantities



- Luminance coefficient

$$q = \frac{L}{E} \quad [sr^{-1}]$$

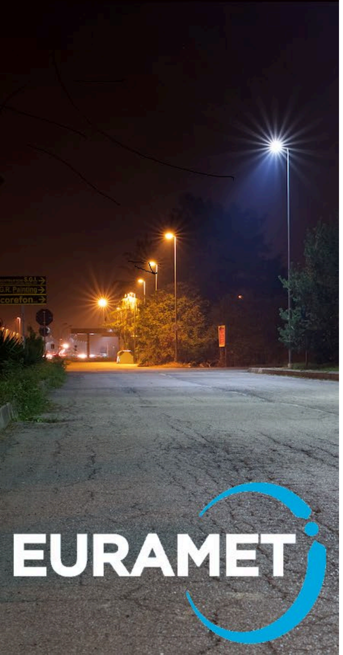
$$q = (\epsilon_1; \epsilon_2; \phi_1; \phi_2)$$




- Radiance coefficient

$$q_e = \frac{L_e}{E_e} \quad [sr^{-1}]$$

$$q_e = (\epsilon_1; \epsilon_2; \phi_1; \phi_2; \lambda)$$



# SPECTRAL Quantities

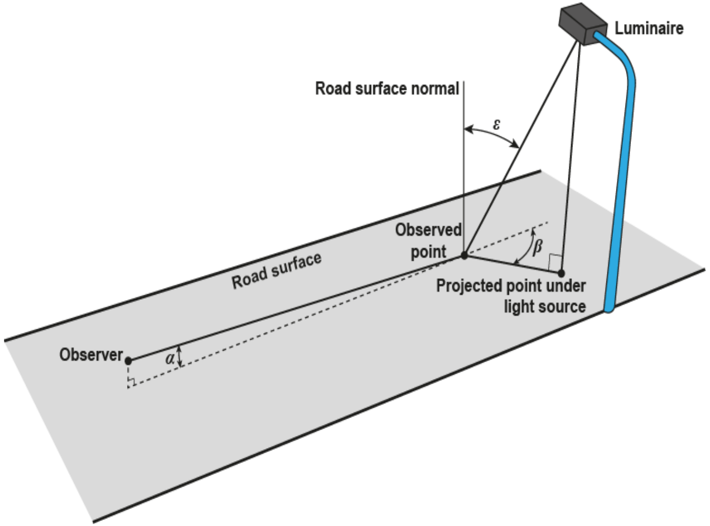
- Luminance coefficient

$$q = \frac{L}{E} \qquad [sr^{-1}]$$

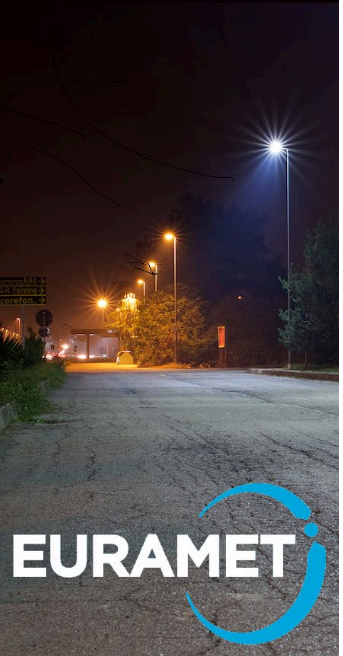
$$q = (\alpha; \epsilon; \beta)$$

- Radiance coefficient

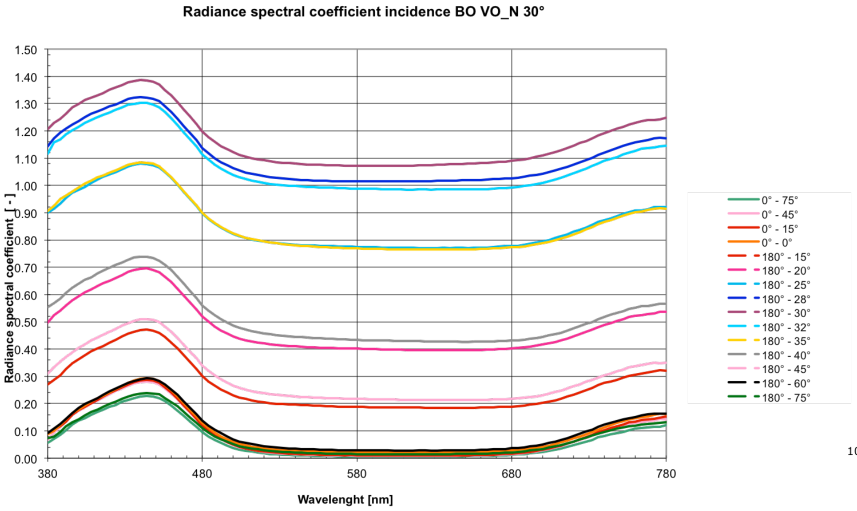
$$q_e = \frac{L_e}{E_e} \qquad [sr^{-1}]$$

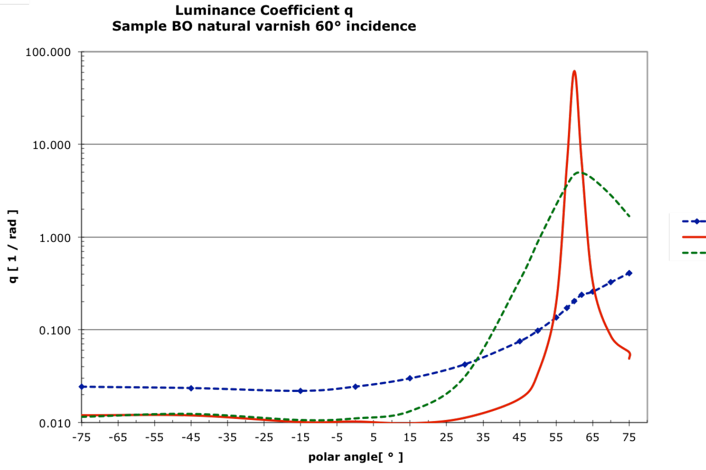



$$q_e = (\alpha; \epsilon; \beta; \lambda)$$




# SPECTRAL Quantities



# SPECTRAL Quantities for roads

- Radiance coefficient

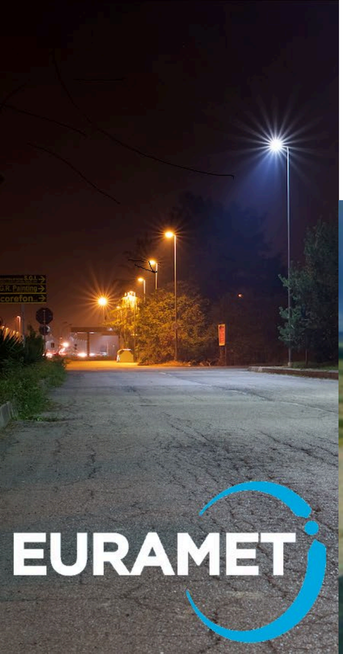
$$q_e = \frac{L_e}{E_e}$$

No portable instruments

- Spectral Reflectance

$$\rho(\lambda) = \frac{d\Phi_r(\lambda)}{d\Phi_i(\lambda)}$$

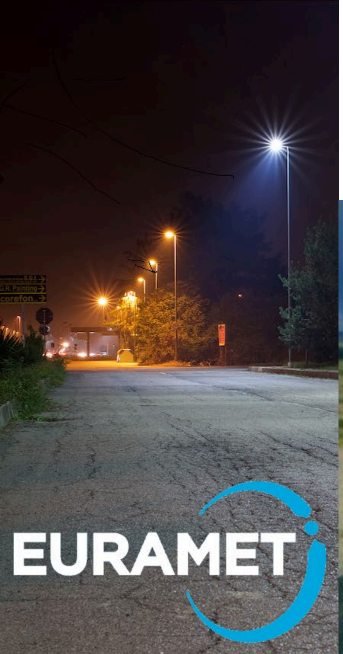
A lot of portable instruments



# SPECTRAL Peculiarities

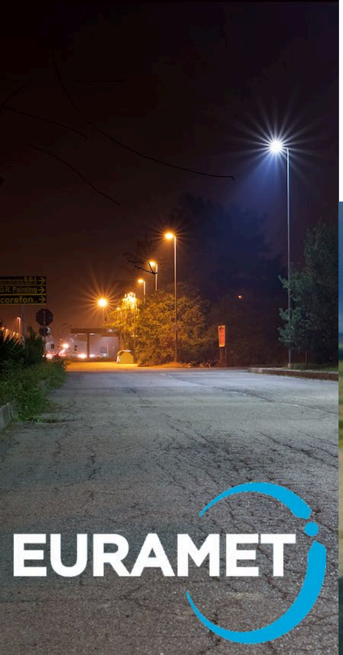
The knowledge of road spectral reflectance is useful for different application not limited to road lighting.

Roads are suitable non-variant targets or pseudo-invariant targets during the calibration/validation of remotely-sensed images. For this reason remote sensing (imaging and hyperspectral) is widely used additionally to the on site and laboratory spectral reflectometry

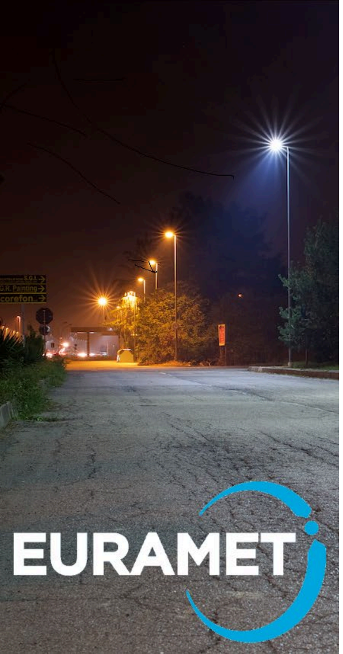


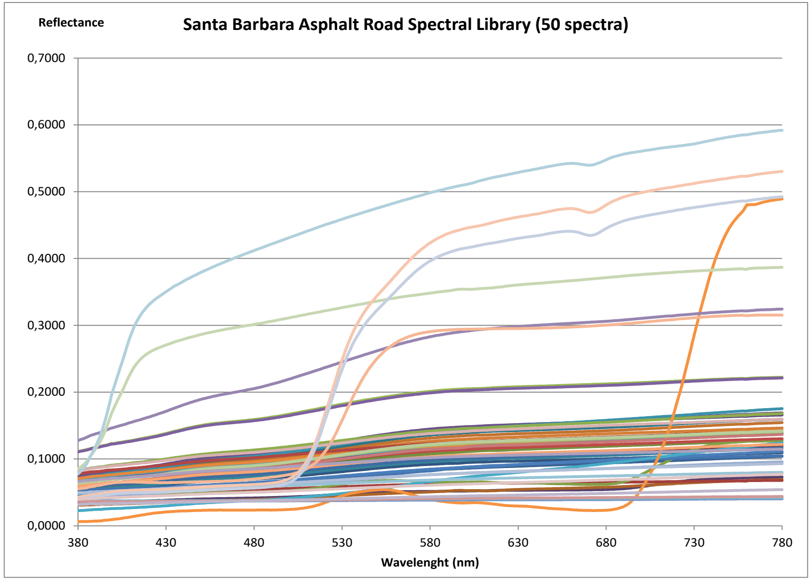
# SPECTRAL Peculiarities

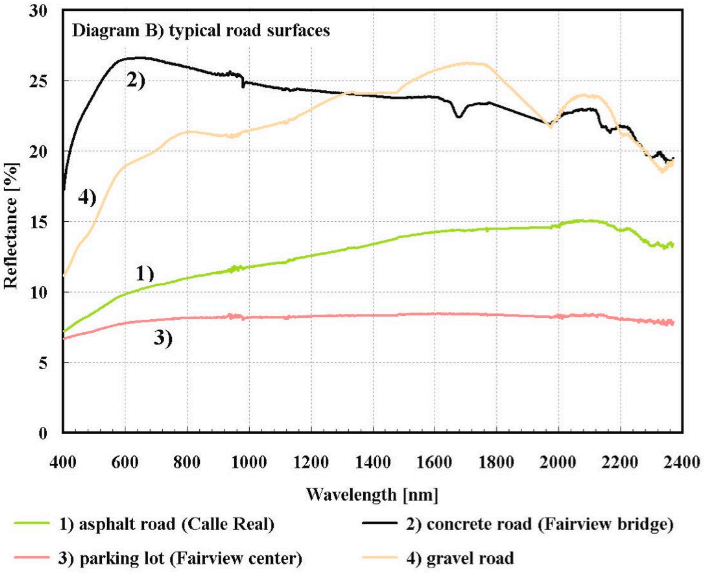
Large database are available on-line like:
http://www.geo-informatie.nl/Projects/Santa_Barbara_Urban_Spectral_Library/urbanspec/road_spec.htm



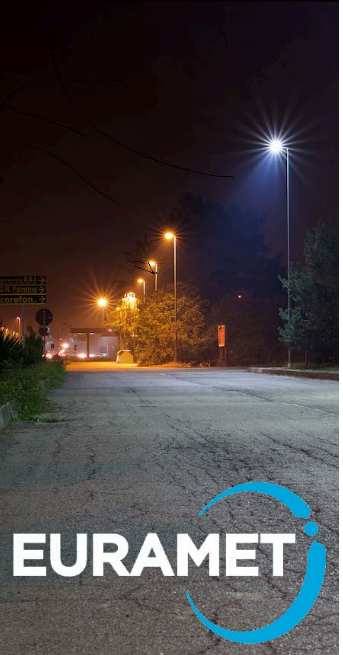
SURFACE






EURAMET



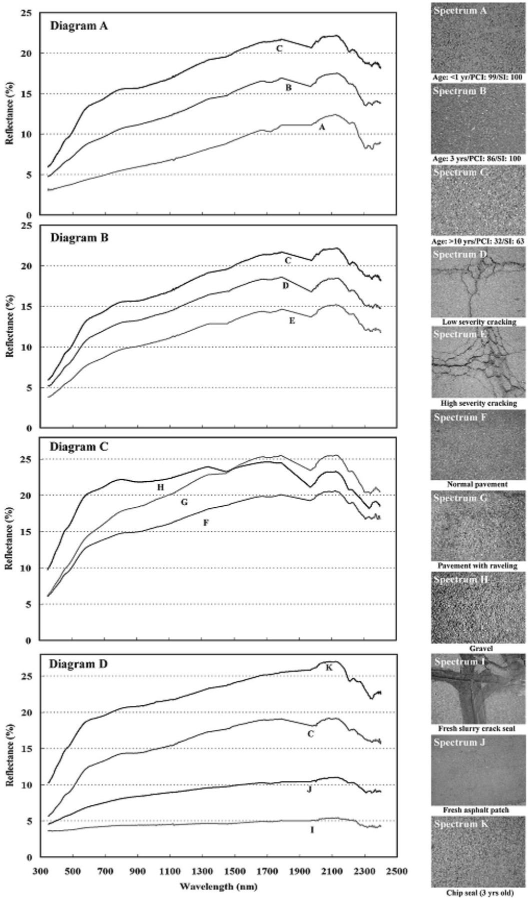
# SPECTRAL Peculiarities

Ageing

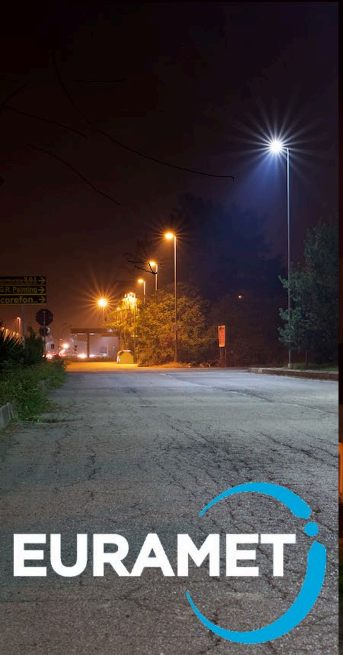
Damages - cracks

Damages - raveling

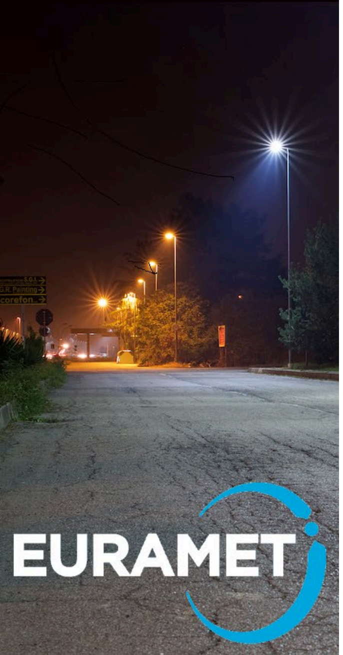
Maintenance



# SPECTRAL Peculiarities – SURFACE Tasks



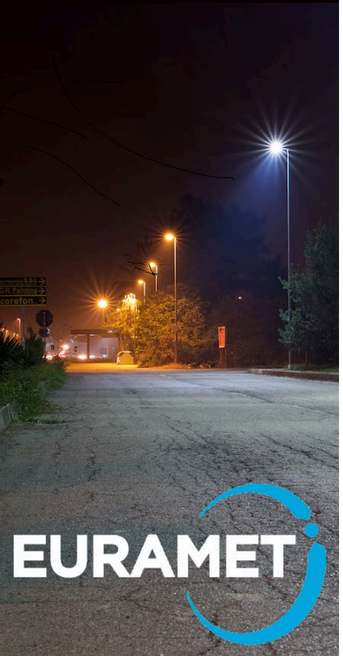
# SPECTRAL Peculiarities – SURFACE Tasks



Source influences

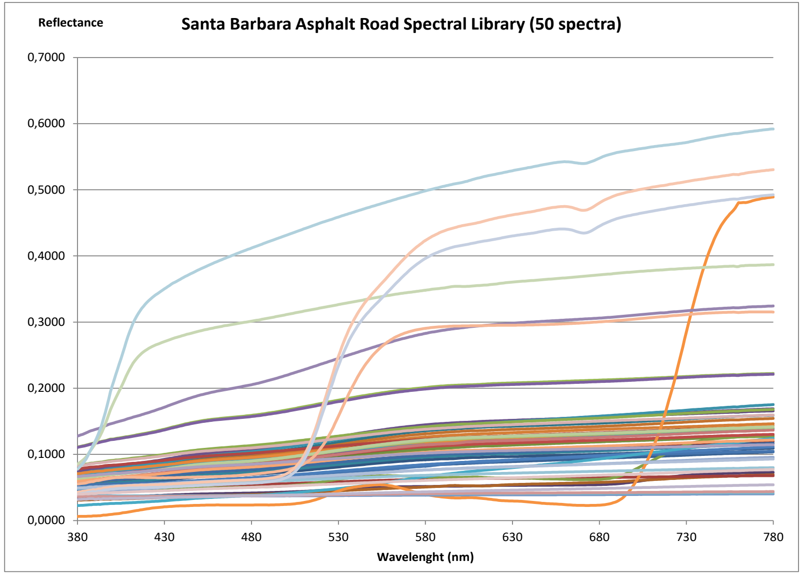
Impact on uncertainties

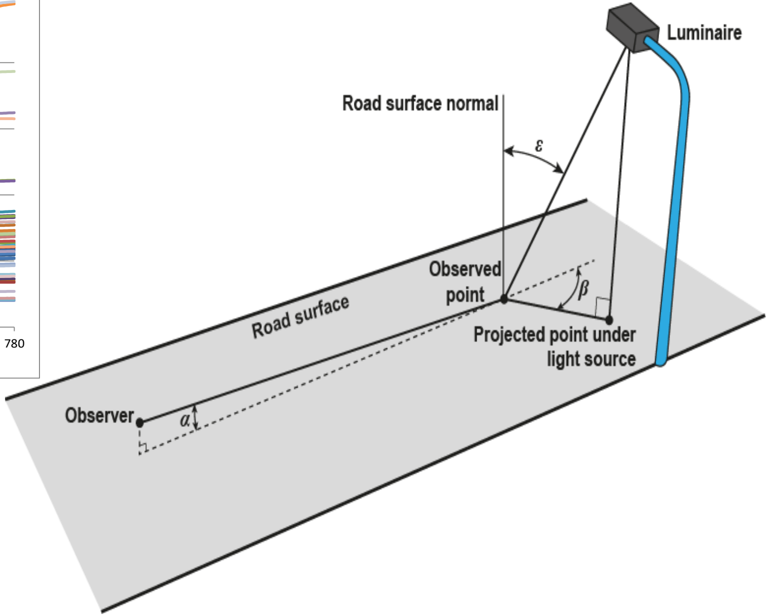
Lighting design



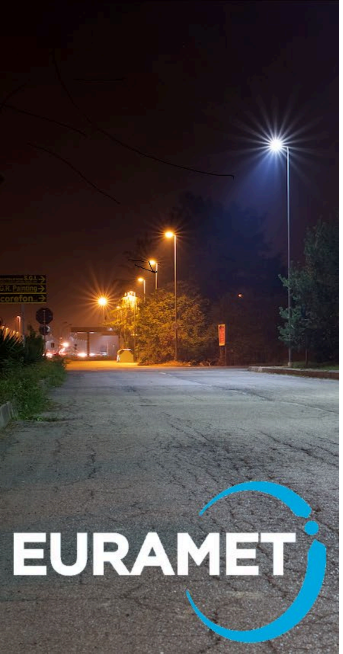
# SPECTRAL Peculiarities – SURFACE Tasks


# Road surfaces spectra



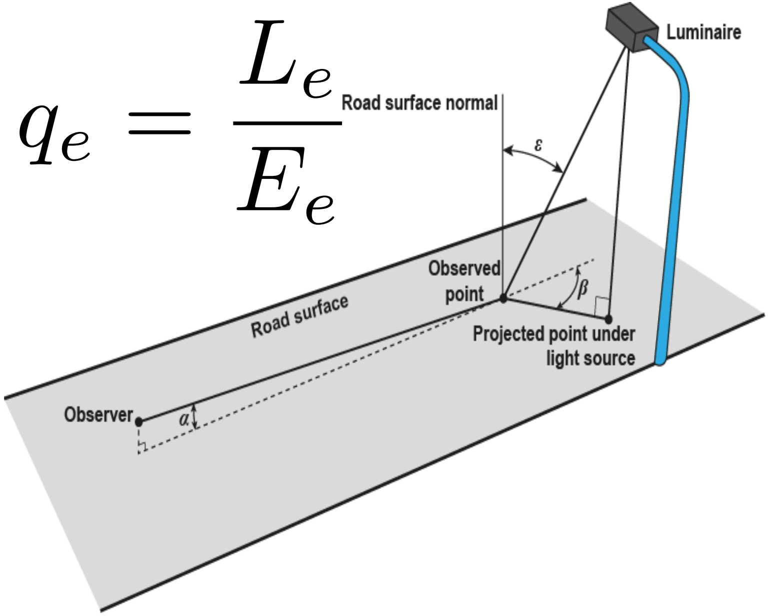
# Road surfaces spectra



Issues with the measurement devices:

$$\rho(\lambda) = \frac{d\Phi_r(\lambda)}{d\Phi_i(\lambda)}$$

$$q_e = \frac{L_e}{E_e}$$

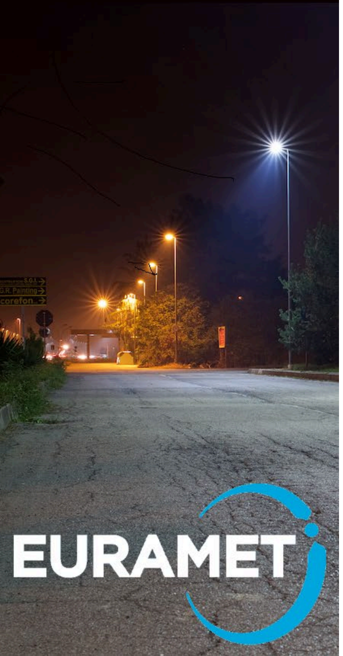


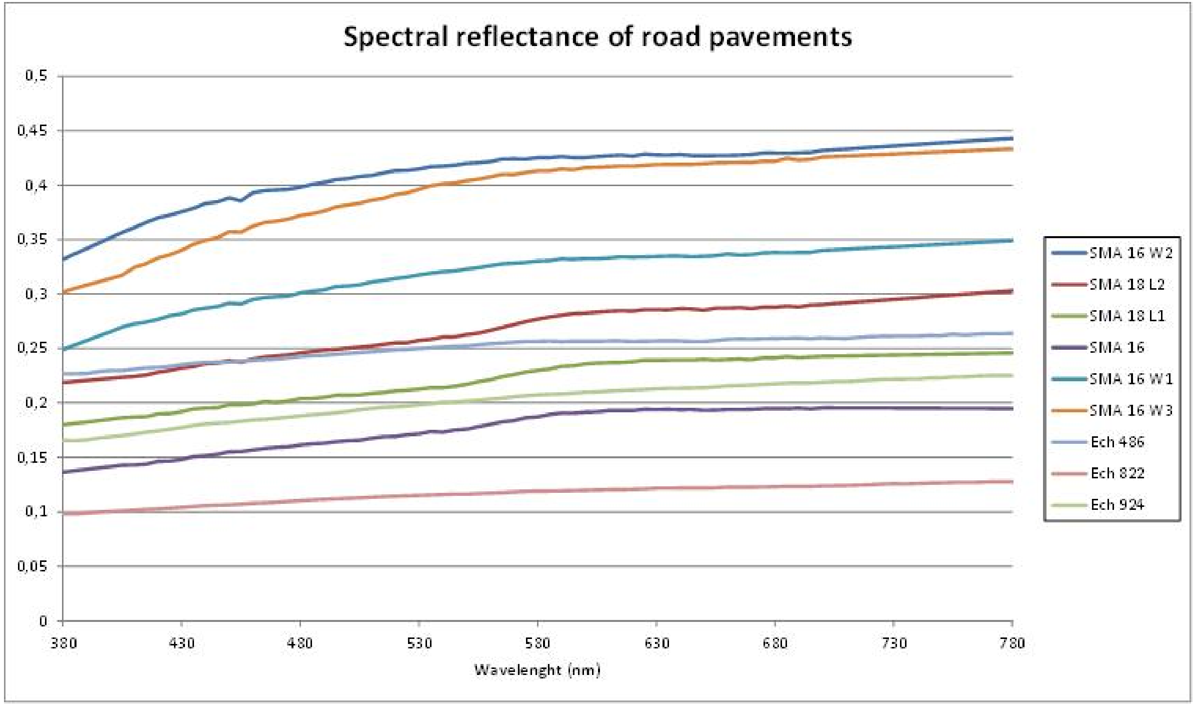

Different measurement geometries

Challenge of Hyperspectral camera

Using radiometer of given aperture

# Road surfaces spectra





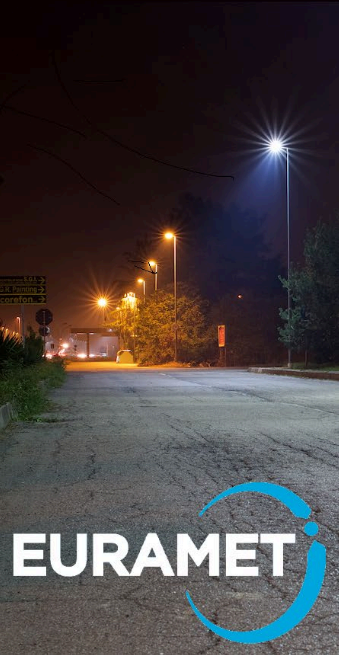

IFSTTAR measurements +

**Effects of pavement lightness and colour on road lighting performance**


*Aleksanteri Ekrias*, Anne-Mari Ylinen, Marjukka Eloholma, Liisa Halonen*

*Helsinki University of Technology, Department of Electronics, Lighting Unit, PO Box 3000, FIN-02015 HUT, Finland*

** Corresponding author, Tel.: +358 50 3160988, Fax: +358 9 4514982, E-mail address: aekrias@cc.hut.fi*



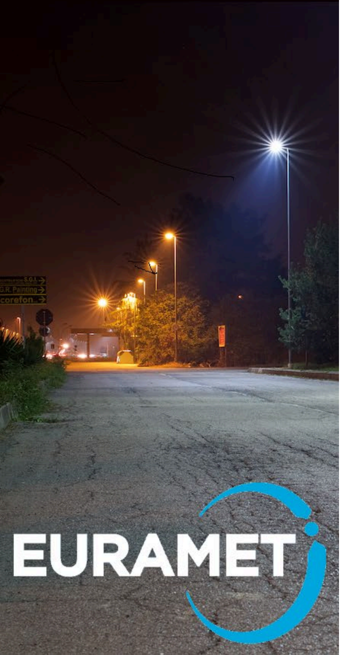
# Relative Luminance Coefficient

To compare spectra effects we defined:

$$Cr = \frac{\int_{380}^{780} R(\lambda) \times SPD\ (\lambda) \times\ V\ (\lambda) \times d\lambda}{\int_{380}^{780} SPD(\lambda) \times V\ (\lambda) \times d\lambda}$$

- $V\ (\lambda)$ : CIE spectral luminous efficiency
- $SPD(\lambda)$ : Relative spectral power density of the light source
- $R(\lambda)$ : spectral luminance coefficient of the pavement.

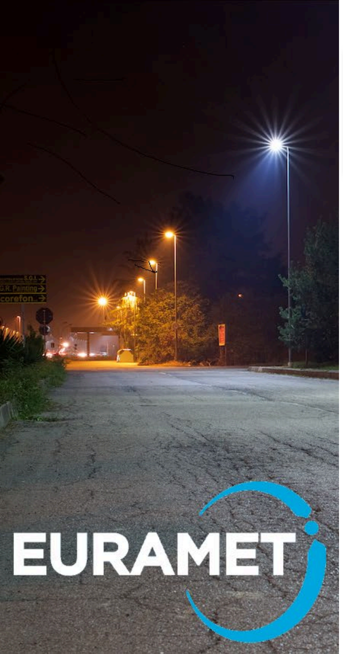
# Source influences on measured values




Every light source would produce, with regards to its Spectral Power Distribution (SPD), different measured values of the luminance coefficient of pavements of not spectrally neutral reflectance

From the review of currently available instruments for road surface measurements it was established that **no common lighting source** is generally used.
Available instruments use LED, discharge lamps and incandescent lamps (CIE standard illuminant A).

# Source influences on measured values

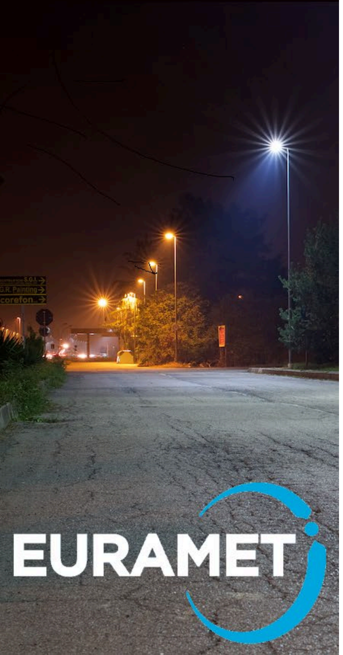


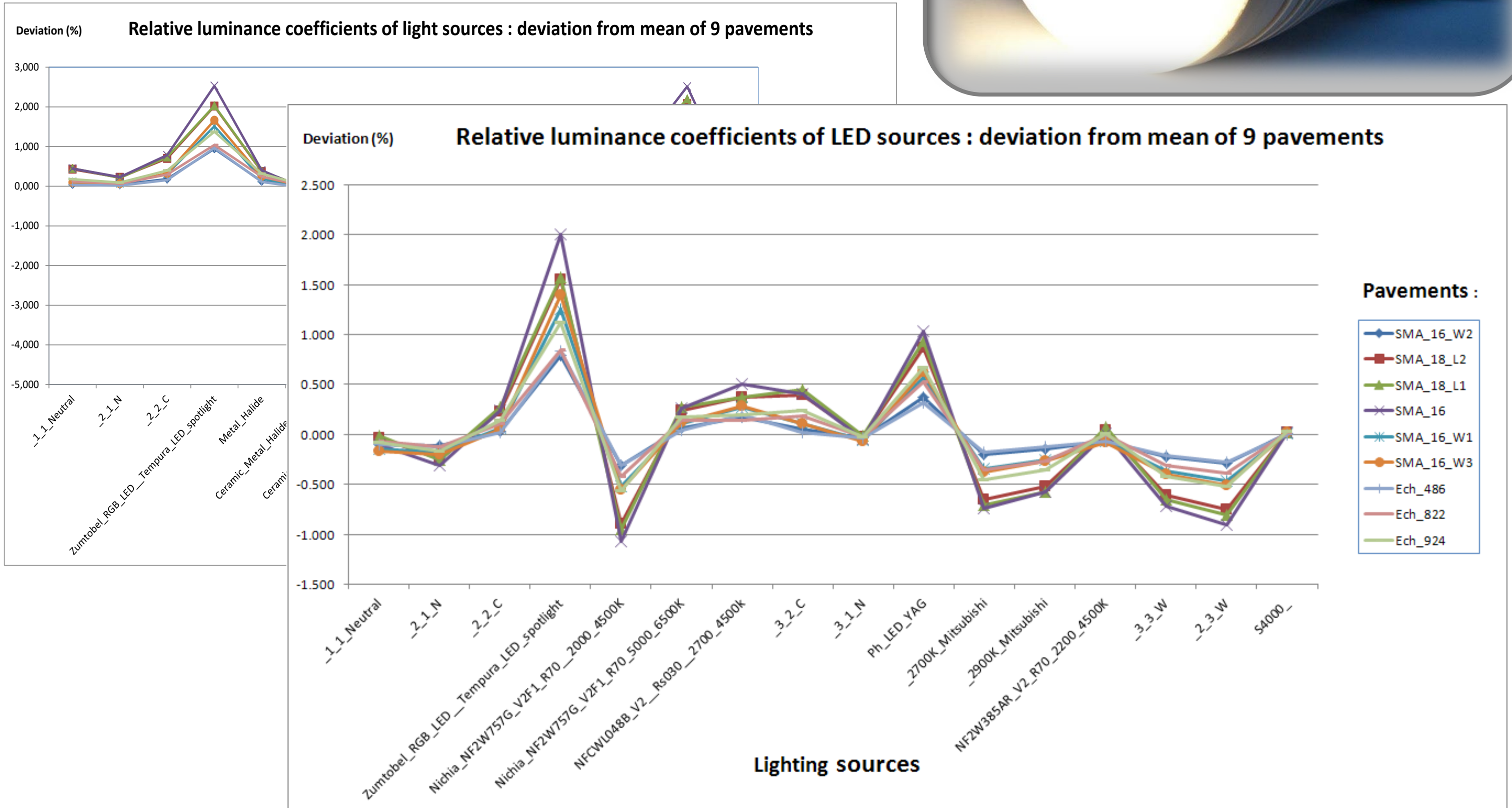
Test set sources:
Database of 185 lighting sources SPD

Test set pavements:
Database of 9 road surfaces radiant coefficient

Mean $C_r$ values, relative deviation

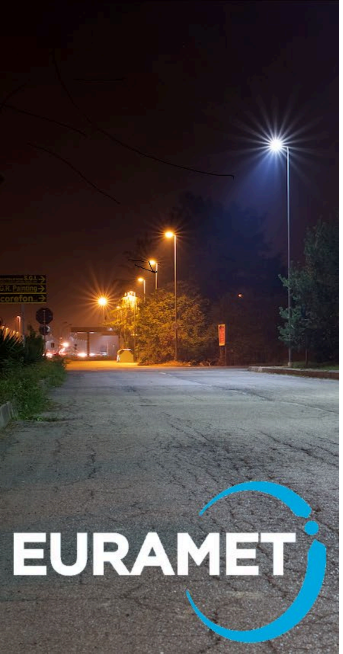
# Source influences on measured values






EURAMET

# Cumulated deviations



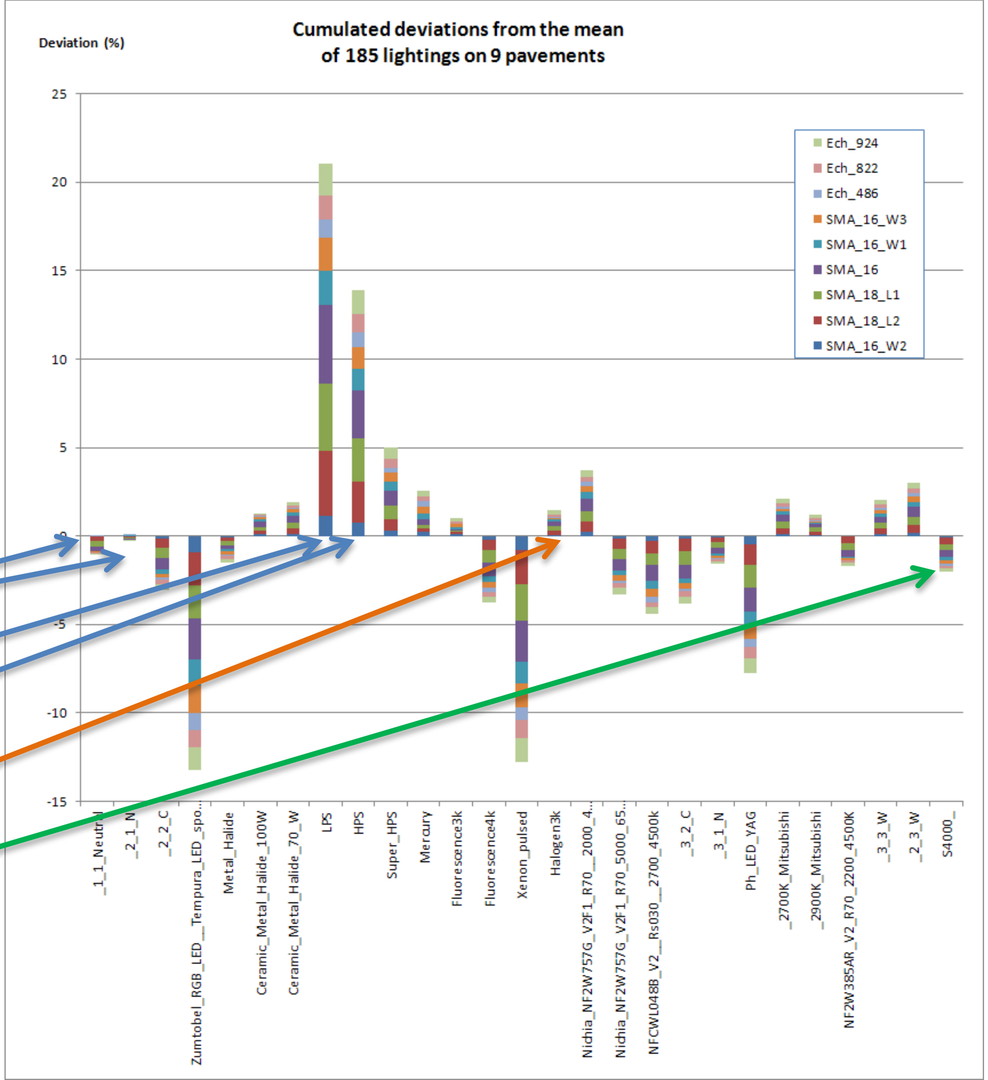
Neutral LED

LPS

HPS

Halogen

S4000

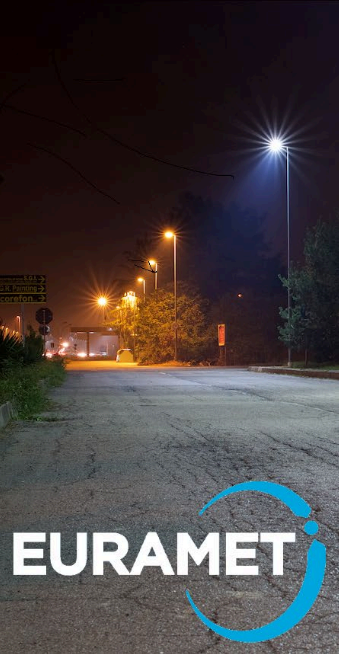


# Source influences
# Conclusions

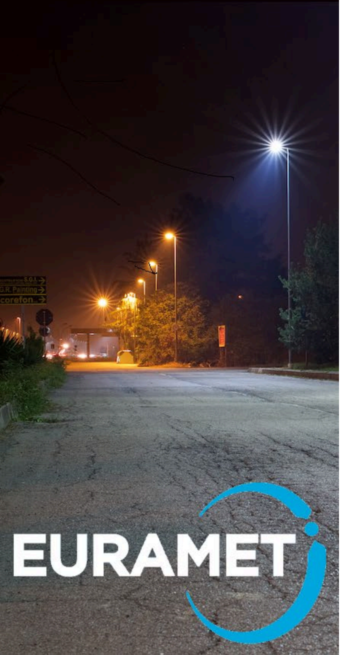
***RGB LED, Low Pressure Sodium, High Pressure Sodium** and **Xenon***
*Pulsed lightings present the **largest deviations** from the mean, from -3% up to +4%, and dispersions with respect to pavements*

*Metal Halide (CCT=3610 K) and Halogen (CCT = 3000 K) lightings present the lowest deviations from the mean and dispersions with respect to pavements. Absolute deviation is < 0.15% for halogen and ≤0.1% for HM.*

***Neutral LEDs** present the **lowest deviations** from the mean (±0.3 %) and dispersions with respect to pavements and that for all lightings deviation are comprised in the interval [-1%, +2%].*



# Source influences on uncertainty values

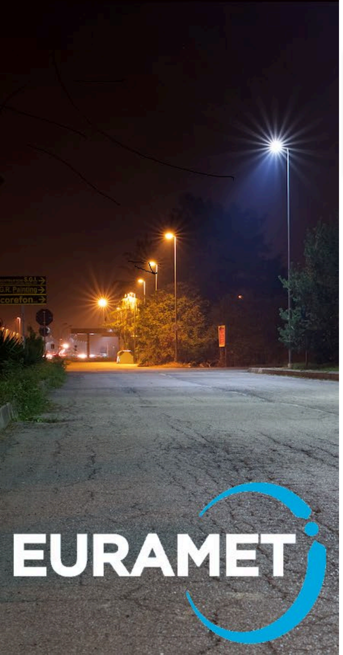


To better understand how to propagate uncertainties related to the effect of spectral distributions

To observe the statistical effect of lighting spectra on the determination of the luminance coefficient,

Path toward Uncertainty Analysis and software for Uncertainty calculations

# Source influences on uncertainty values



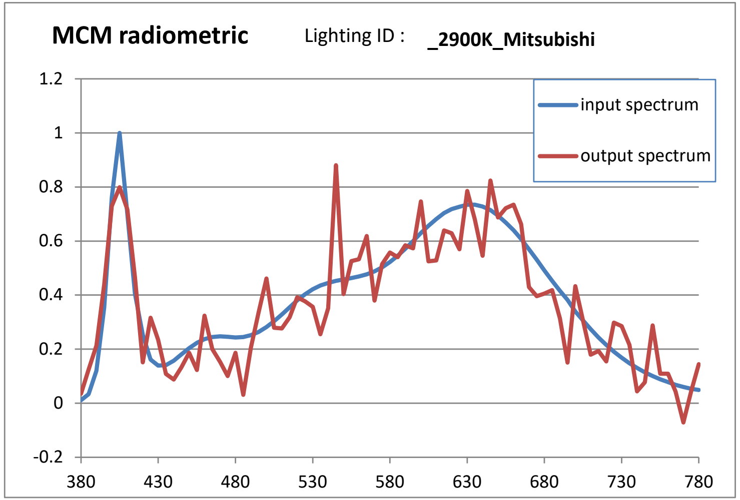
Test set sources:
Database of 185 lighting sources SPD

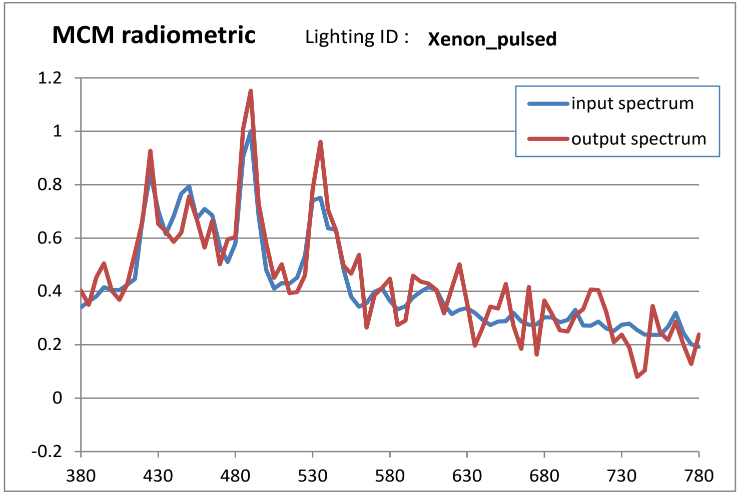
Test set pavements:
Database of 9 road surfaces radiant coefficient

**MCM**

Mean $C_r$ values, standard deviation, interval

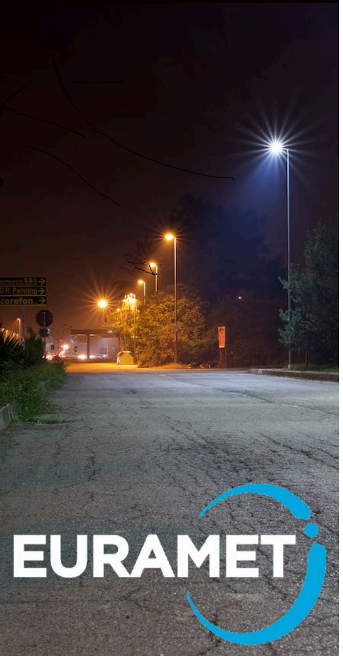
# Source influences on uncertainty values



SURFACE

# Source influences on uncertainty values



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## Variation of the whole Test set sources

| Pavements ID | Mean Value | Standard deviation (%) | Coeff. Interval Max -Min (%) |
|---|---|---|---|
| SMA_16 | 0.1824 | 0.96 | 6.82 |
| Ech_486 | 0.2538 | 0.28 | 1.96 |

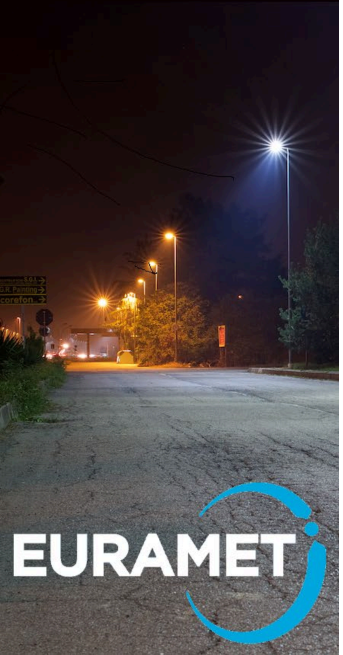
The two most neutral pavements

## MCM Variations of given sources

| Pavements ID | 2900K_Mitsubishi | | | Xenon | | |
|---|---|---|---|---|---|---|
| | Mean Value | Standard deviation (%) | Coeff. Interval Max -Min (%) | Mean Value | Standard deviation (%) | Coeff. Interval Max -Min (%) |
| SMA_16 | 0.182 | 0.198 | 0,86 | 0,178 | 0,191 | 0,895 |
| Ech_486 | 0.254 | 0.054 | 0,30 | 0,252 | 0,059 | 0,265 |

# MCM influences

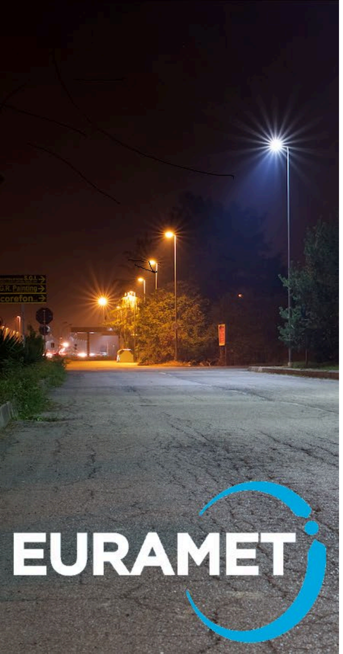
## Conclusions



*The **SPD variations** considered in MCM simulation **do not bring large variations** of luminance coefficients as a large set of actual SPDs, unless applying very strong deviations with no physical meaning.*

***Global shape changes** of SPD have **more impact** than **local** variations.*

*Deviations and discrepancies **depend more on the pavements** characteristics, than on actual SPD variations*

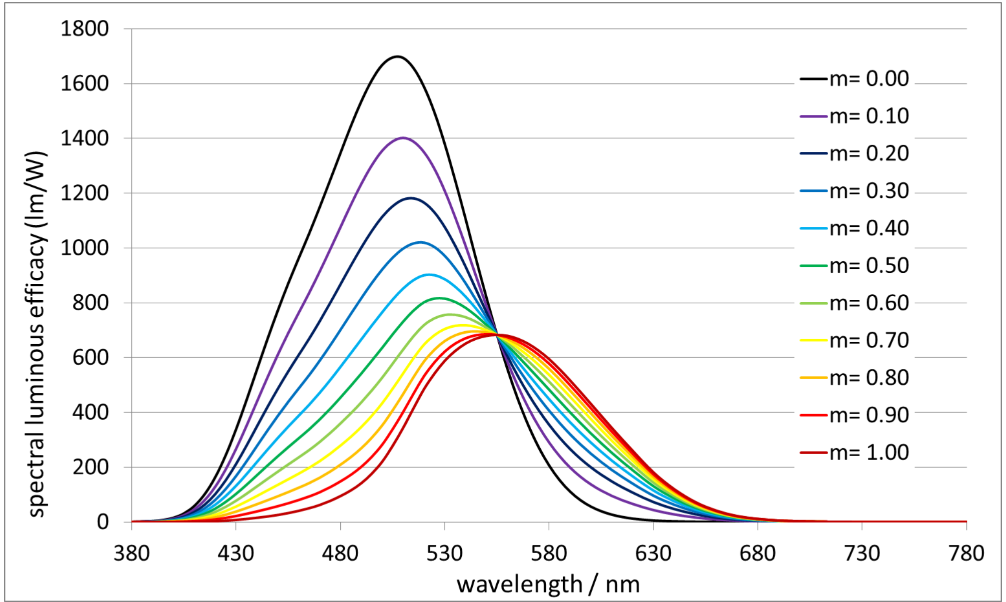


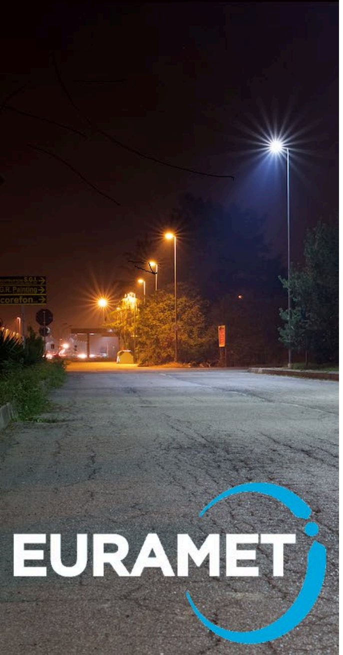
# Mesopic

Challenge:
To define the adaptation conditions

- Luminance adaptation field
- Spectral characteristics of adaptation fiels

Too many issues






# Mesopic

Challenge:
To define the adaptation conditions

- Luminance adaptation field
- Spectral characteristics of adaptation fiels

Too many issues

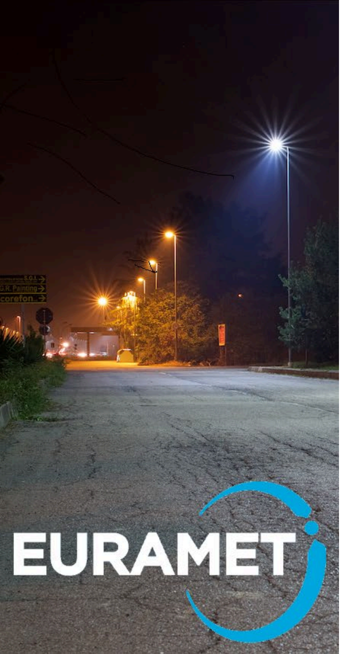
Simplifications:

Adaptation field is only the road

$q_e$ is know

E is known (and scotopic illuminance)

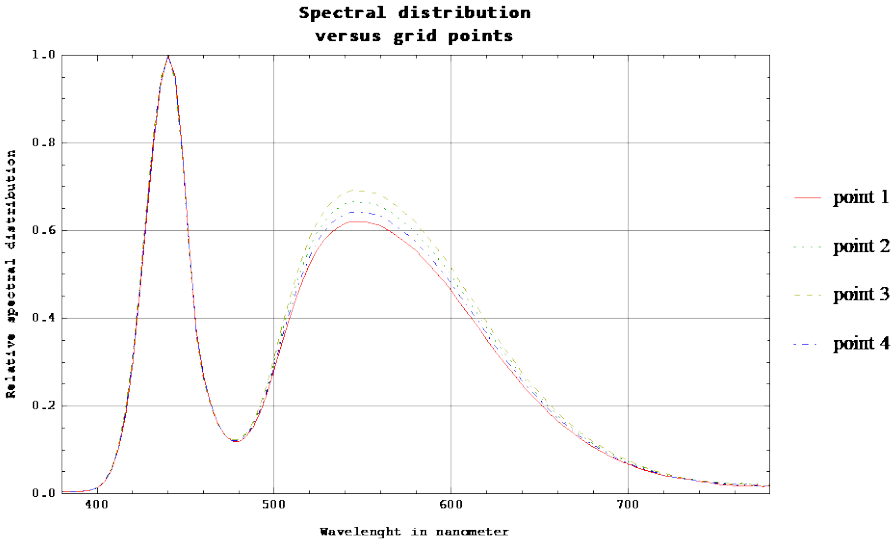
Is possible to calculate adaptation conditions



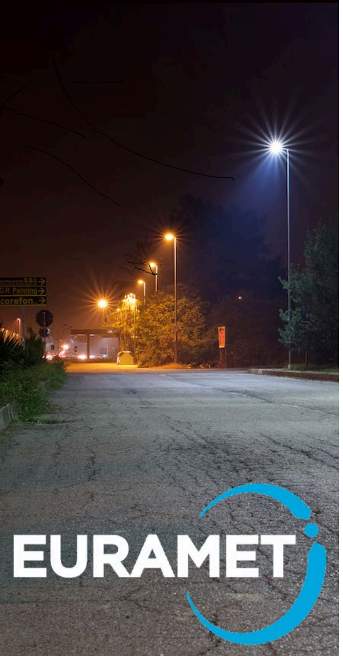
# Mesopic

To do design:

- Luminance adaptation field
- Spectral characteristics of adaptation fiels
- Spectral spatial distribution of the luminaires




Too many issues mesopic design is not used



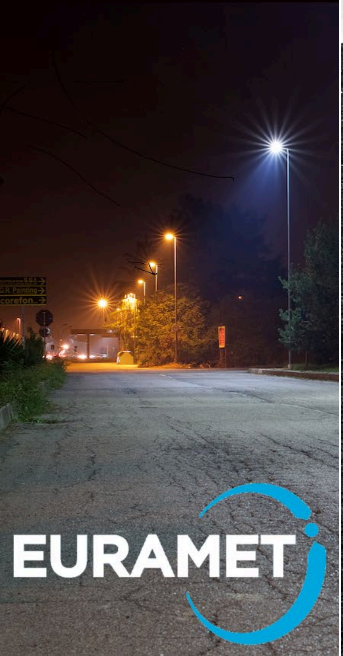

# Mesopic

To do design:

- Luminance adaptation field
- Spectral characteristics of adaptation fiels
- Spectral spatial distribution of the luminaires
- Spectral reflectances


**Tunnel lighting is a simple environment**

SURFACE



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# Thank you for your attention