

Examples of Applying Mesopic Factors in Roadway Calculations

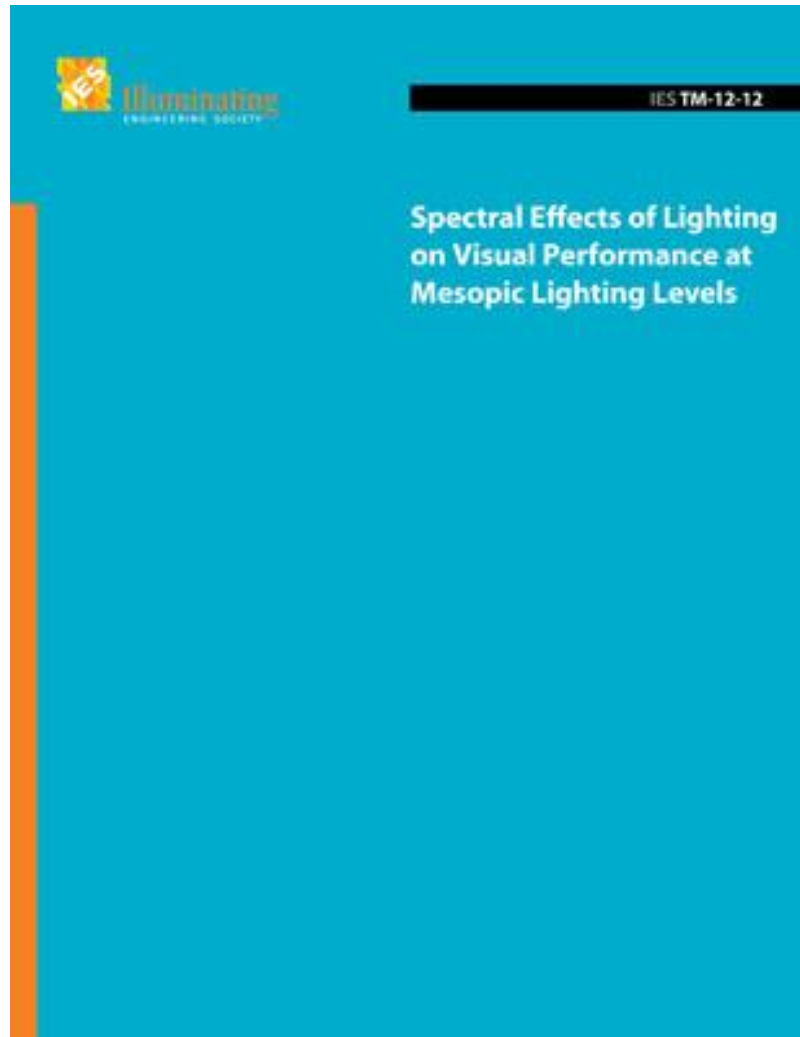
Council for Optical Radiation Measurements
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D. Keith & S. Wentworth

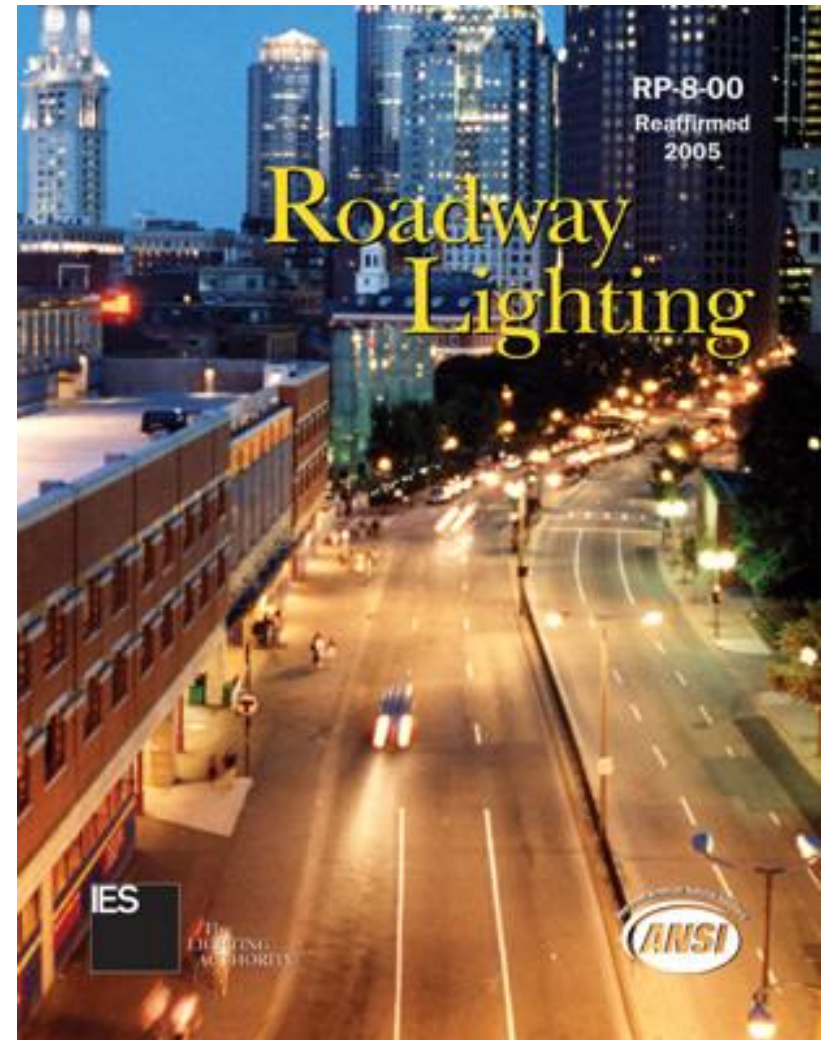
Overview

- What happens when different approaches are used to incorporate mesopic factors into roadway calculations?
- How do different design luminance ranges & sources' Scotopic / Photopic (S/P) ratios interact with calculation methods?

Overview: put TM12 into RP-8?



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Factors as defined in TM-12

- 'Effective Luminance Factor (ELF)' defined as
$$\text{ELF} = \frac{\text{equivalent mesopic luminance}}{\text{photopic luminance}}$$
 - function of photopic luminance & S/P ratio
 - range: 0.005 cd/m² to 5 cd/m²
 - at 5 cd/m², factors converge to 1.0
 - at 0.005 cd/m² and lower, factors = S/P ratio
- ANSI/IES definition of mesopic: 0.034 to 3.4 cd/m²
(‘Nomenclature & Definitions ..’, ANSI/IES RP-16-05)

Factors as proposed for RP-8

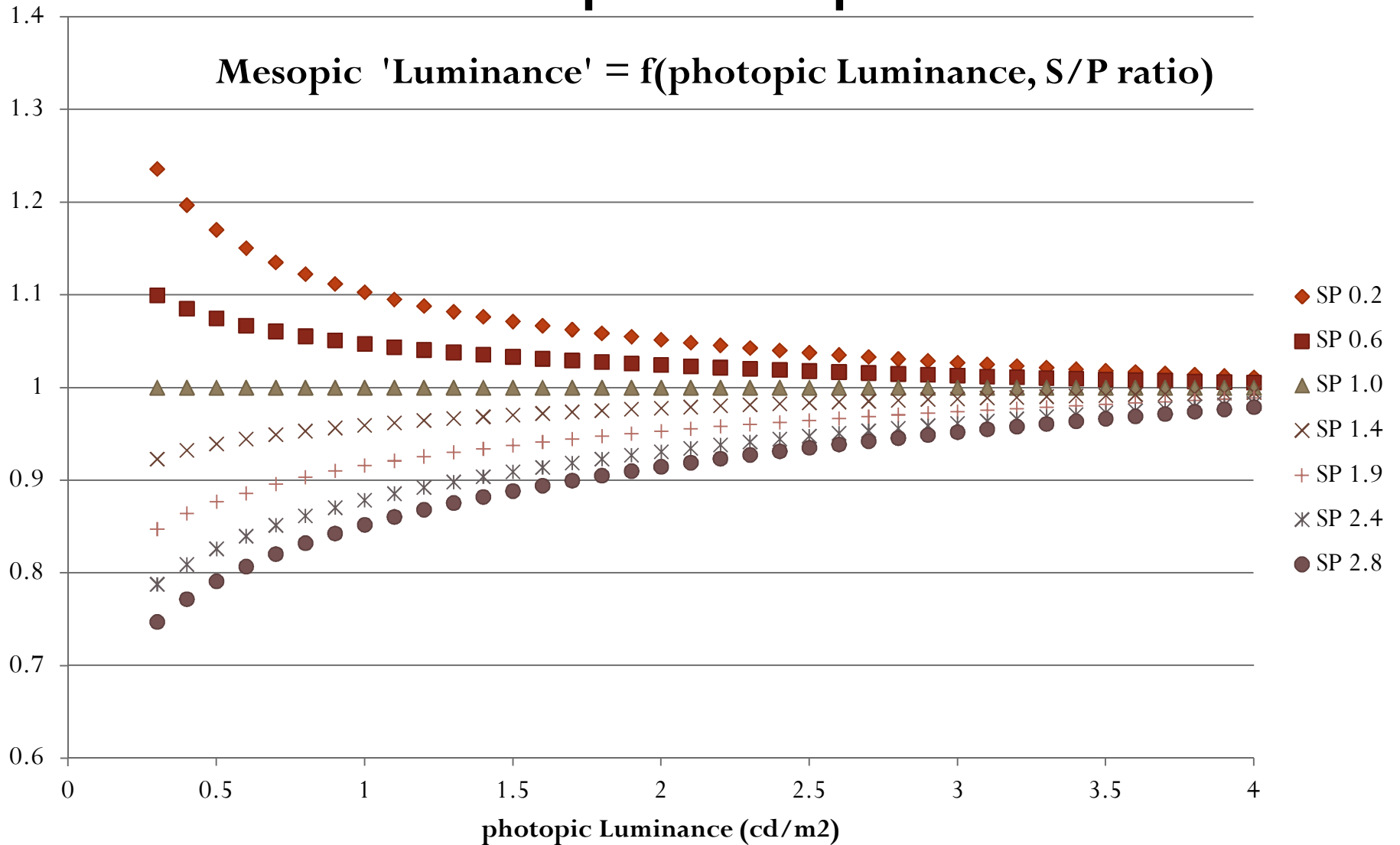
- ‘Mesopic Factor’ defined for proposed RP-8 as

$$MF = \frac{\text{photopic luminance}}{\text{equivalent mesopic luminance}}$$

- function of photopic luminance & S/P ratio
 - tabulated range: 0.3 cd/m² to 5 cd/m²
 - reiterative calculation procedure provided with range extended down to 0.005 cd/m²
 - at 5 cd/m², factors converge to 1.0
- this presentation, developed for the Roadway Committee, uses the MF version of these factors so
‘Lmesopic’ = Lphotopic / Mesopic Factor

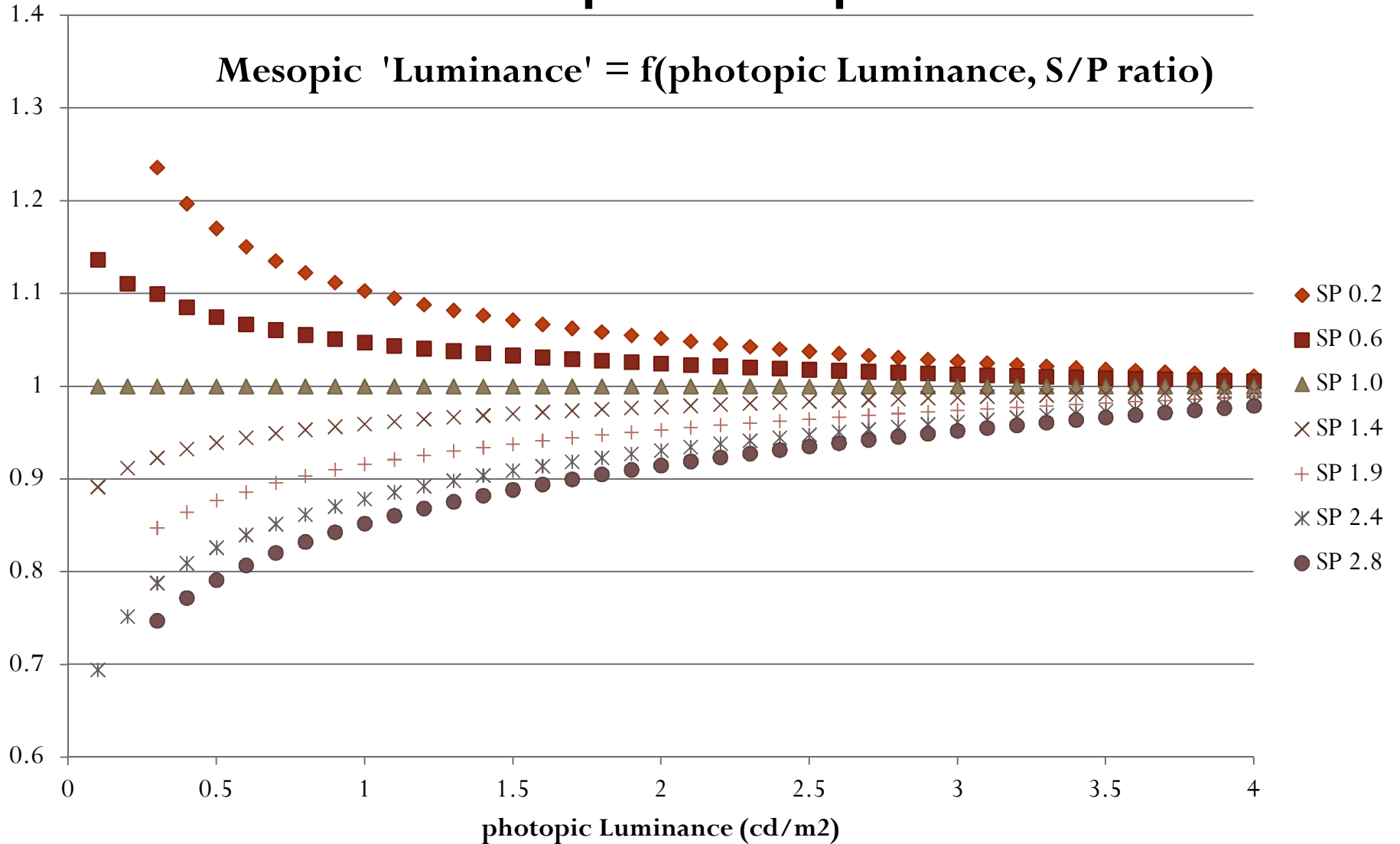
IES RP-8 Mesopic Factors

Mesopic 'Luminance' = $f(\text{photopic Luminance, S/P ratio})$



IES RP-8 Mesopic Factors

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Typical Scotopic/Photopic (S/P) Ratios

- CIE Illuminant A 1.41 (incandescent at 2856K)
- CIE Illuminant D65 2.46 (daylight at 6500K)
- HPS 0.6 to 0.7 (2000K to 2200K)
- Mercury Vapor (ctd) 1.2 (3700K)
- Fluorescent (& Induction) 1.1 to 1.8 (2700K to 5000K)
- Ceramic MH 1.3 to 1.5 (2900K to 3600K)
- 'Conventional' MH 1.4 to 1.8 (3100K to 4300K)
- LED (neutral to cool) 1.7 to 2.1 (4500K to 6300K)

(sources: CIE and NOAA/National Geophysical Data Center)

Luminance Values from RP-8 Table 3

Road	Conflict Area	Lavg	Lavg/Lmin	Lmax/Lmin	Lvmax/Lavg
Expressway	High	1.0	3	5	0.3
	Low	0.6	3.5	6	0.3
Major	High	1.2	3	5	0.3
	Low	0.6	3.5	6	0.3
Collector	High	0.8	3	5	0.4
	Low	0.4	4	8	0.4
Local	High	0.6	6	10	0.4
	Low	0.3	6	10	0.4

Luminances RP-8 Table 3 (cd/m²)

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Methodologies for Applying Factors

- Average of all roadway pavement points (**Avg**)
 - Determine one factor using the mathematical average of photopic values for all roadway pavement calculation points
 - L_{avg} changes, all other values remain the same
 - Grid treated as having overall adaptation $\sim L_{avg}$

Methodologies for Applying Factors

- Each Point Individually (~TM-12) (**Pnts**)
 - Determine a factor using the photopic luminance value at each roadway pavement calculation point
 - Each value shifts independently: average, maximum, minimum and uniformity ratios
 - Each point is treated as if visibility is solely dependent on the luminance of that point
 - No adaptation level is established

Methodologies for Applying Factors

- Modified Veiling Luminance (**LvM**)
 - Determine one factor for the pavement luminances using the mathematical average of photopic values for all roadway pavement calculation points (same as Avg)
 - Determine one factor for the veiling luminance using the maximum veiling luminance value
 - L_{avg} and L_{vMax} each change , separately
 - pavement uniformity ratios remain the same
 - for LvRatio (LvR) use photopic value of average luminance
 - because this is a foveal phenomenon
 - grid treated as having overall adaptation $\sim L_{avg}$ then compared to adjusted veiling luminance value for ratio LvR

High Luminance, Low S/P Ratio

Design **demo**
S/P Ratio **0.6**

Ver:	Base	Avg	Pnts	LvM (rd)	LvM (vl)
Factor	1	1.047	n.a.	1.047	1.099
Lavg	<u>1.017</u>	0.972	0.972	0.972	
Lmax	2.749	2.627	2.709	2.627	
Lmin	0.368	0.352	0.340	0.352	
Lam	2.764	2.764	2.870	2.764	
Lmm	7.470	7.470	7.971	7.470	
LvMax	0.306	0.292	0.279		0.279
LvR	0.300	0.301	0.287		0.274

Low Luminance, Low S/P Ratio

Design **demo_low**
S/P Ratio **0.6**

Ver:	Base	Avg	Pnts	LvM (rd)	LvM (vl)
Factor	1	1.074	n.a.	1.074	1.140
Lavg	<u>0.508</u>	0.473	0.475	0.473	
Lmax	1.374	1.279	1.322	1.279	
Lmin	0.184	0.171	0.159	0.171	
Lam	2.761	2.761	2.980	2.761	
Lmm	7.467	7.467	6.317	7.467	
LvMax	0.153	0.142	0.134		0.134
LvR	0.300	0.301	0.284		0.264

High Luminance, High S/P Ratio

Design **demo**

S/P Ratio **2.4**

Ver:	Base	Avg	Pnts	LvM (rd)	LvM (vl)
Factor	1	0.880	n.a.	0.880	0.789
Lavg	<u>1.017</u>	1.156	1.145	1.156	
Lmax	2.749	3.125	2.880	3.125	
Lmin	0.368	0.418	0.461	0.418	
Lam	2.764	2.764	2.486	2.764	
Lmm	7.470	7.470	6.252	7.470	
LvMax	0.306	0.348	0.388		0.388
LvR	0.300	0.301	0.335		0.381

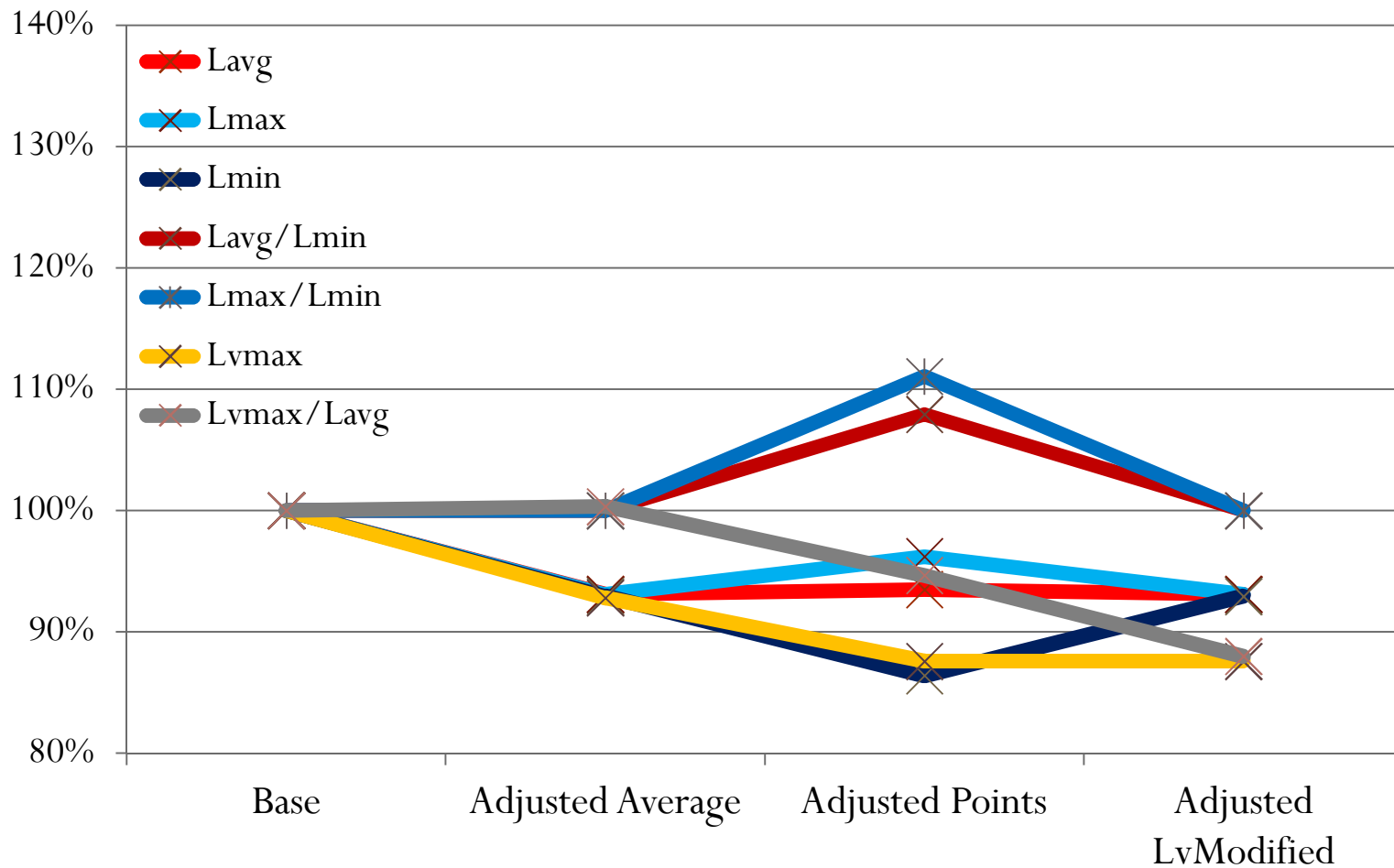
Low Luminance, High S/P Ratio

Design **demo_low**
S/P Ratio **2.4**

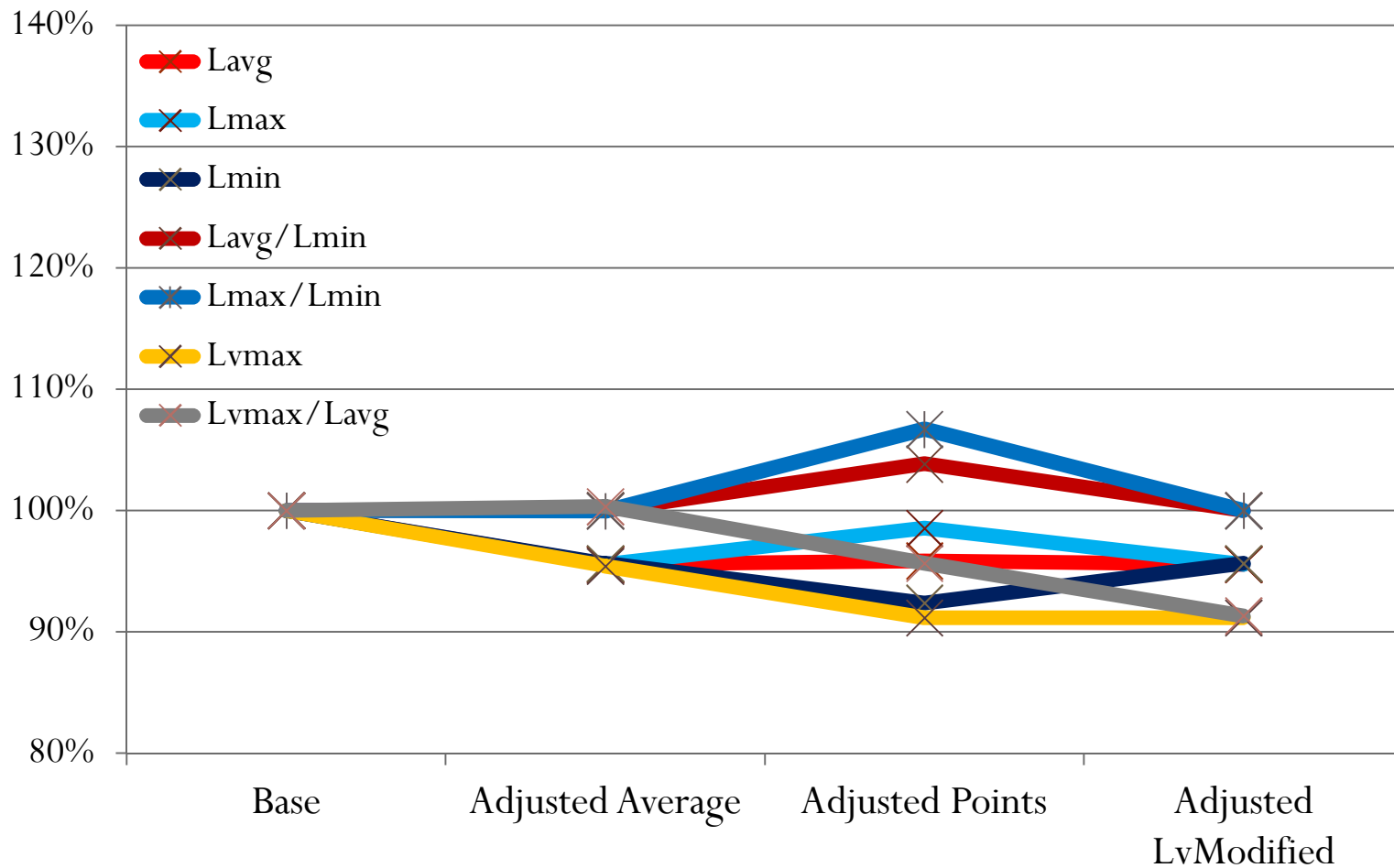
Ver:	Base	Avg	Pnts	LvM (rd)	LvM (vl)
Factor	1	0.827	n.a.	0.827	0.737
Lavg	<u>0.508</u>	0.614	0.608	0.614	
Lmax	1.374	1.661	1.518	1.661	
Lmin	0.184	0.222	0.240	0.222	
Lam	2.761	2.761	2.530	2.761	
Lmm	7.467	7.467	6.317	7.467	
LvMax	0.153	0.185	0.208		0.208
LvR	0.300	0.301	0.338		0.409

Comparison by Luminance

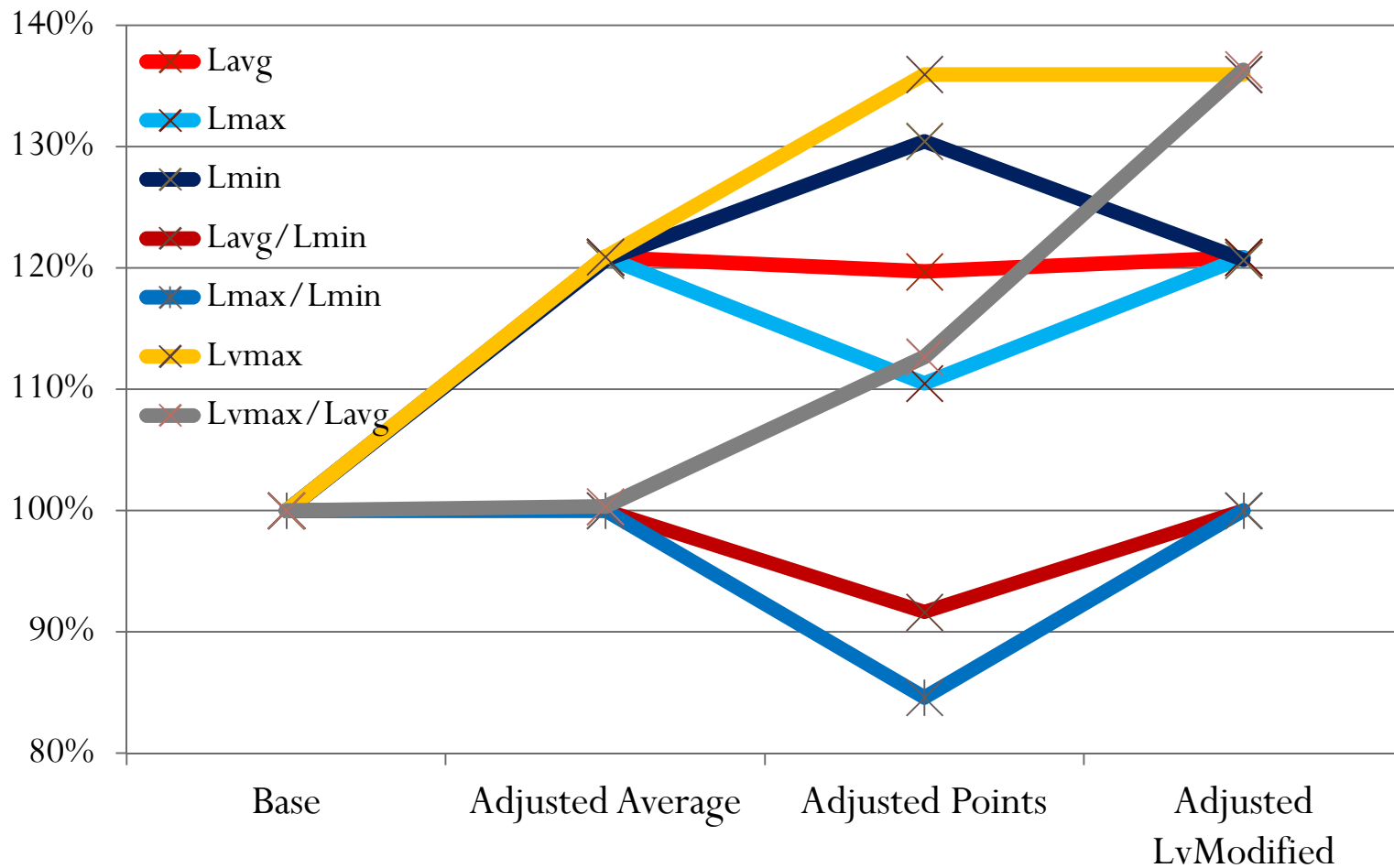
Lavg = 0.5 cd/m², 0.6 S/P Ratio



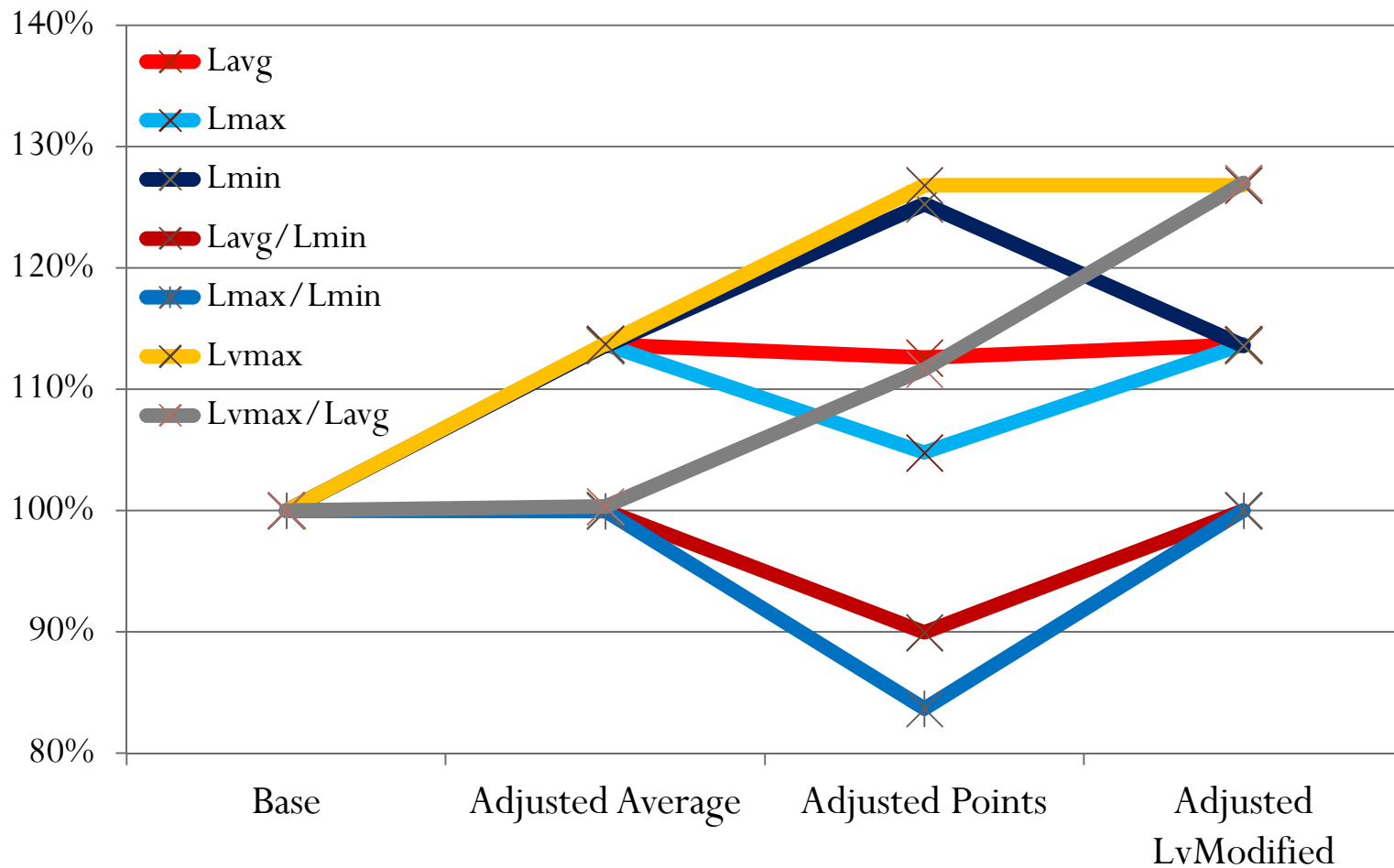
Lavg = 1.0 cd/m², 0.6 S/P Ratio



Lavg = 0.5 cd/m², 2.4 S/P Ratio



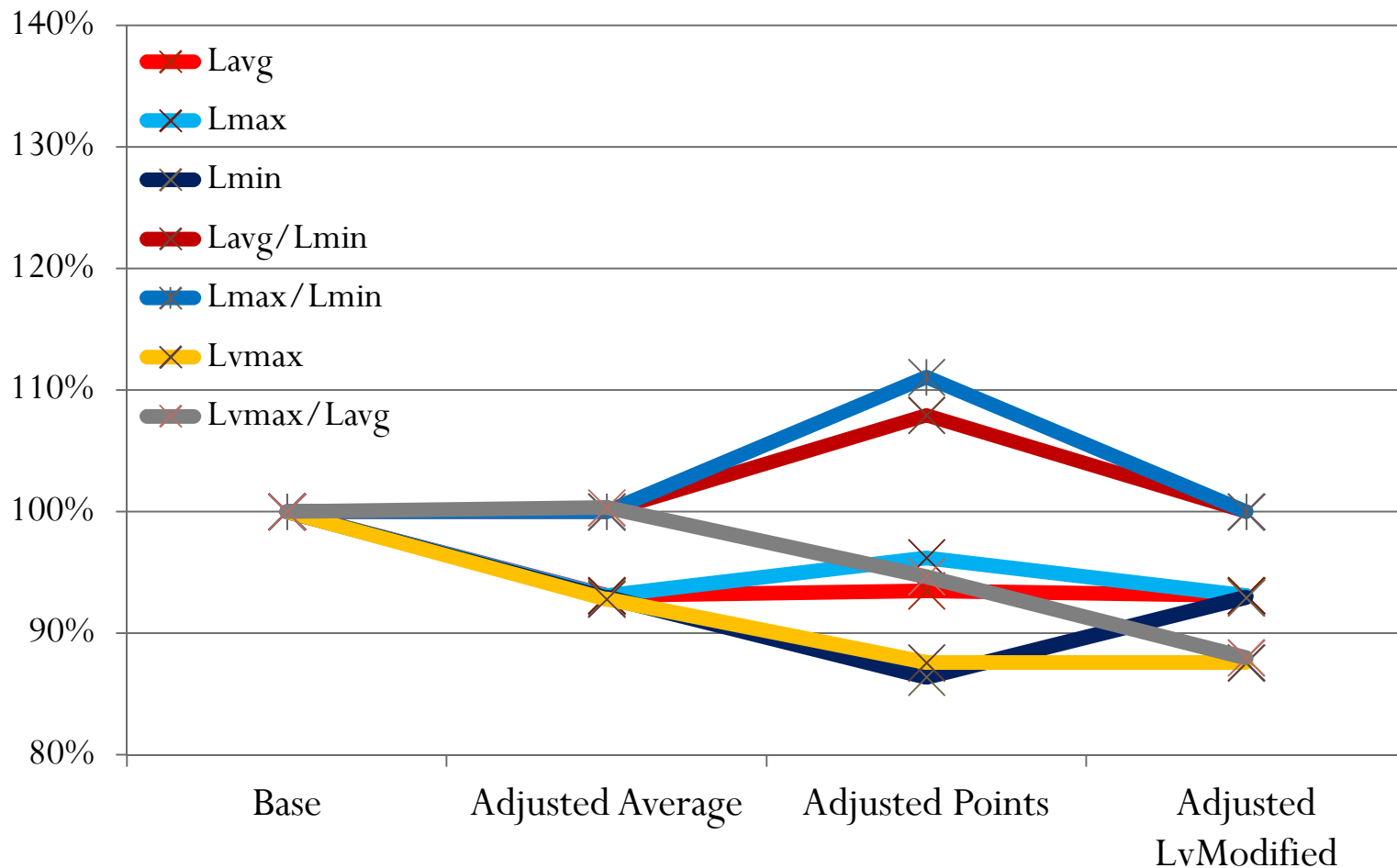
Lavg = 1.0 cd/m², 2.4 S/P Ratio



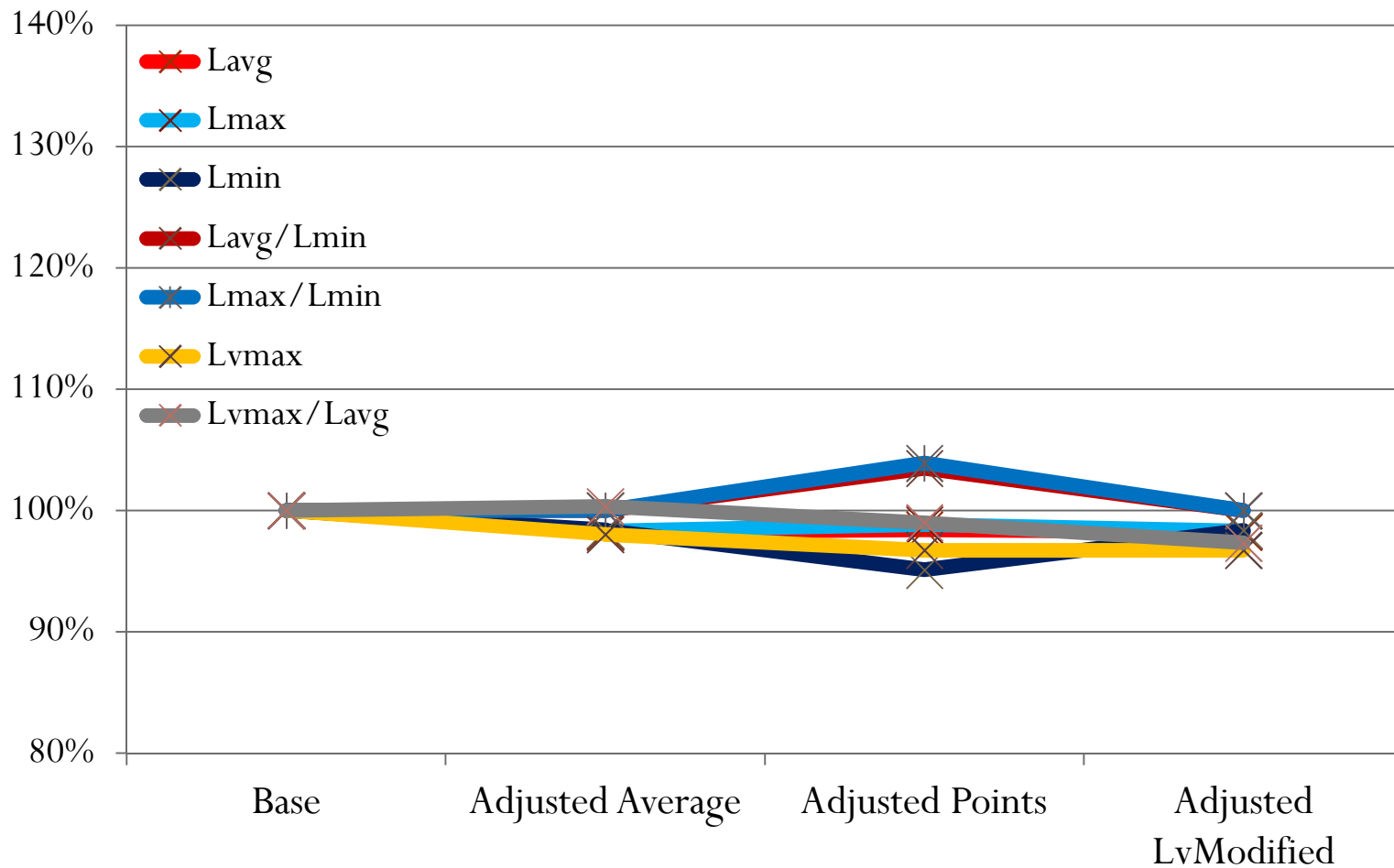
Comparison by S/P Ratio

Luminance at 0.5 cd/m²

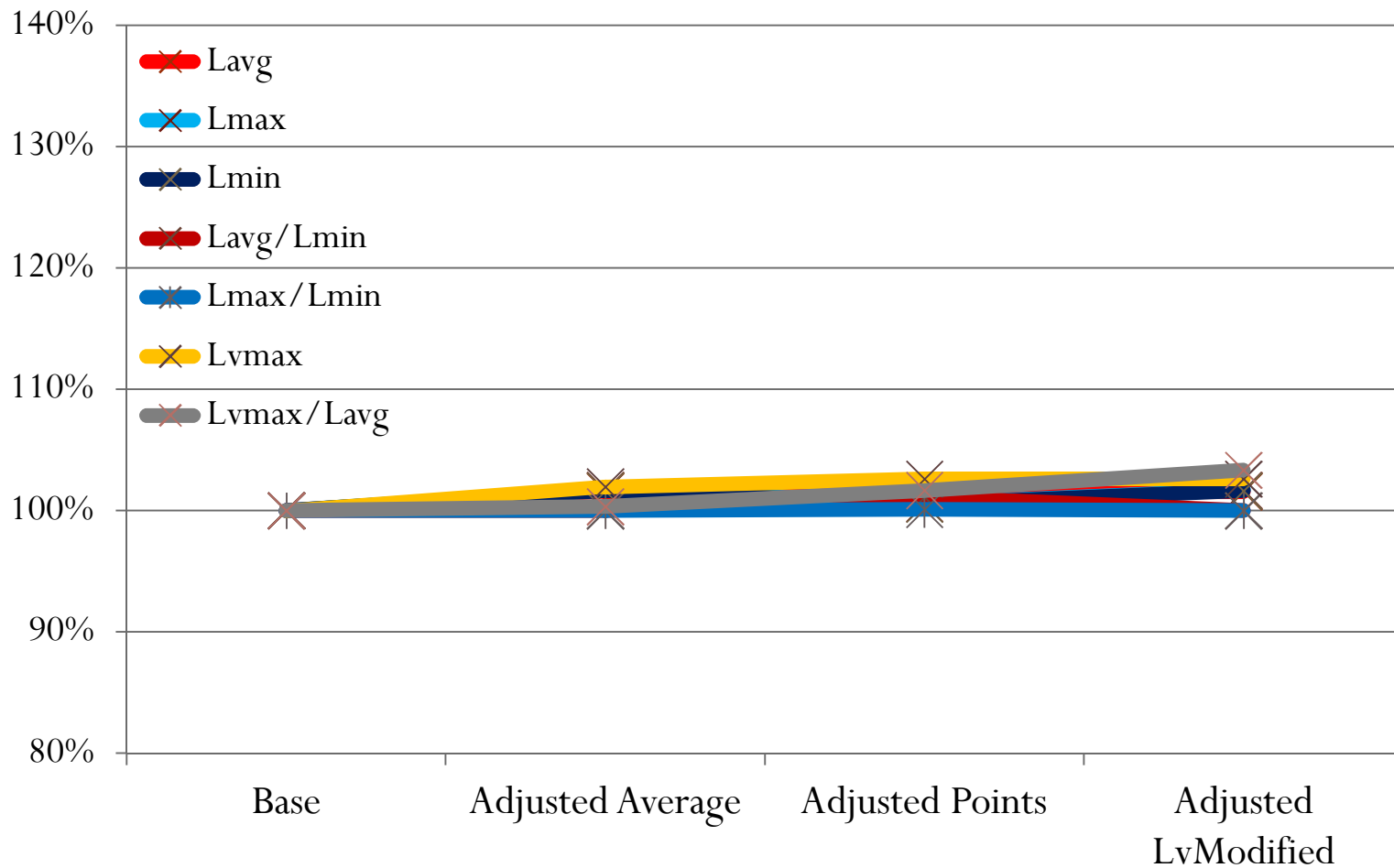
Lavg = 0.5 cd/m², 0.6 S/P Ratio



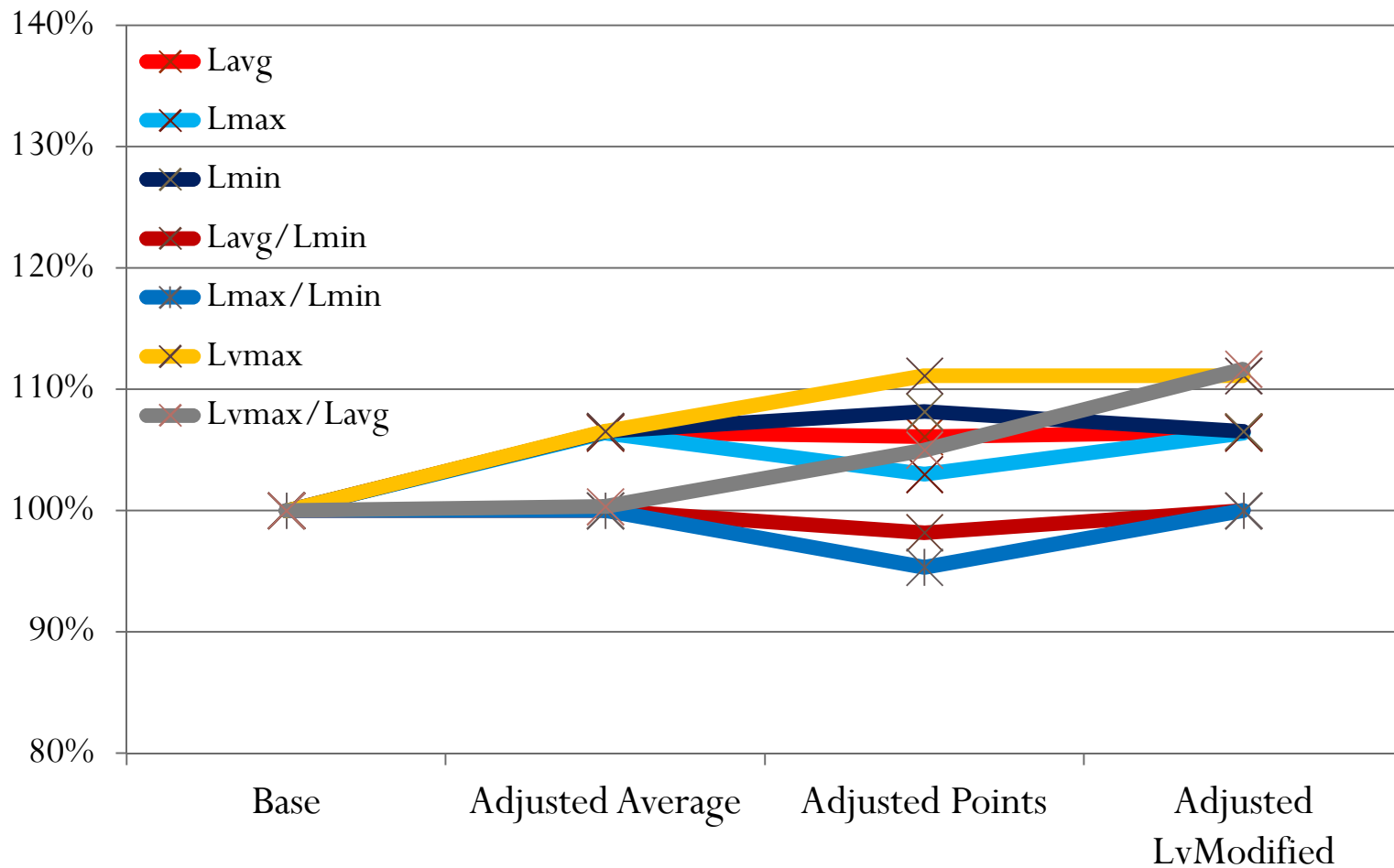
Lavg = 0.5 cd/m², 0.9 S/P Ratio



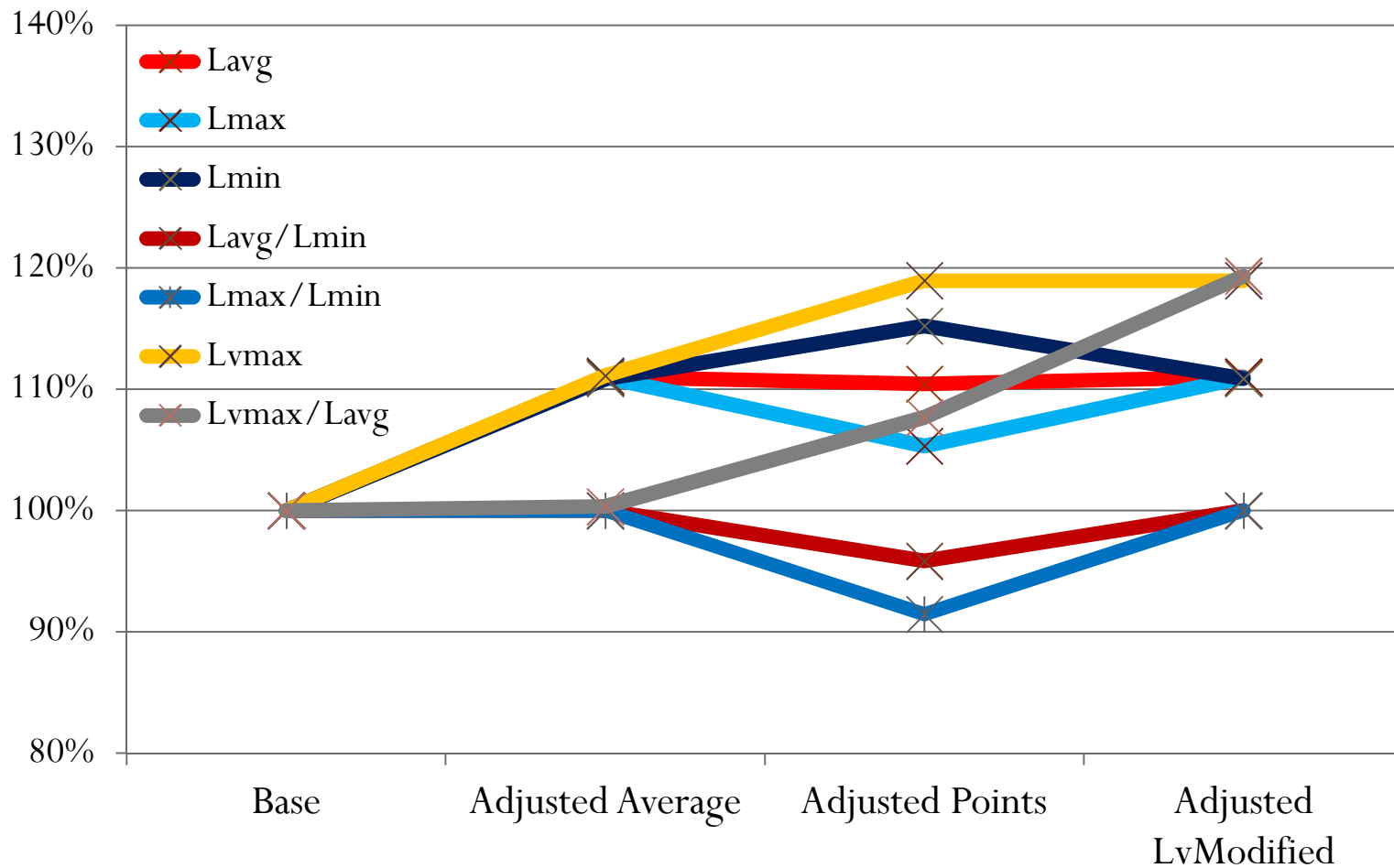
Lavg = 0.5 cd/m², 1.1 S/P Ratio



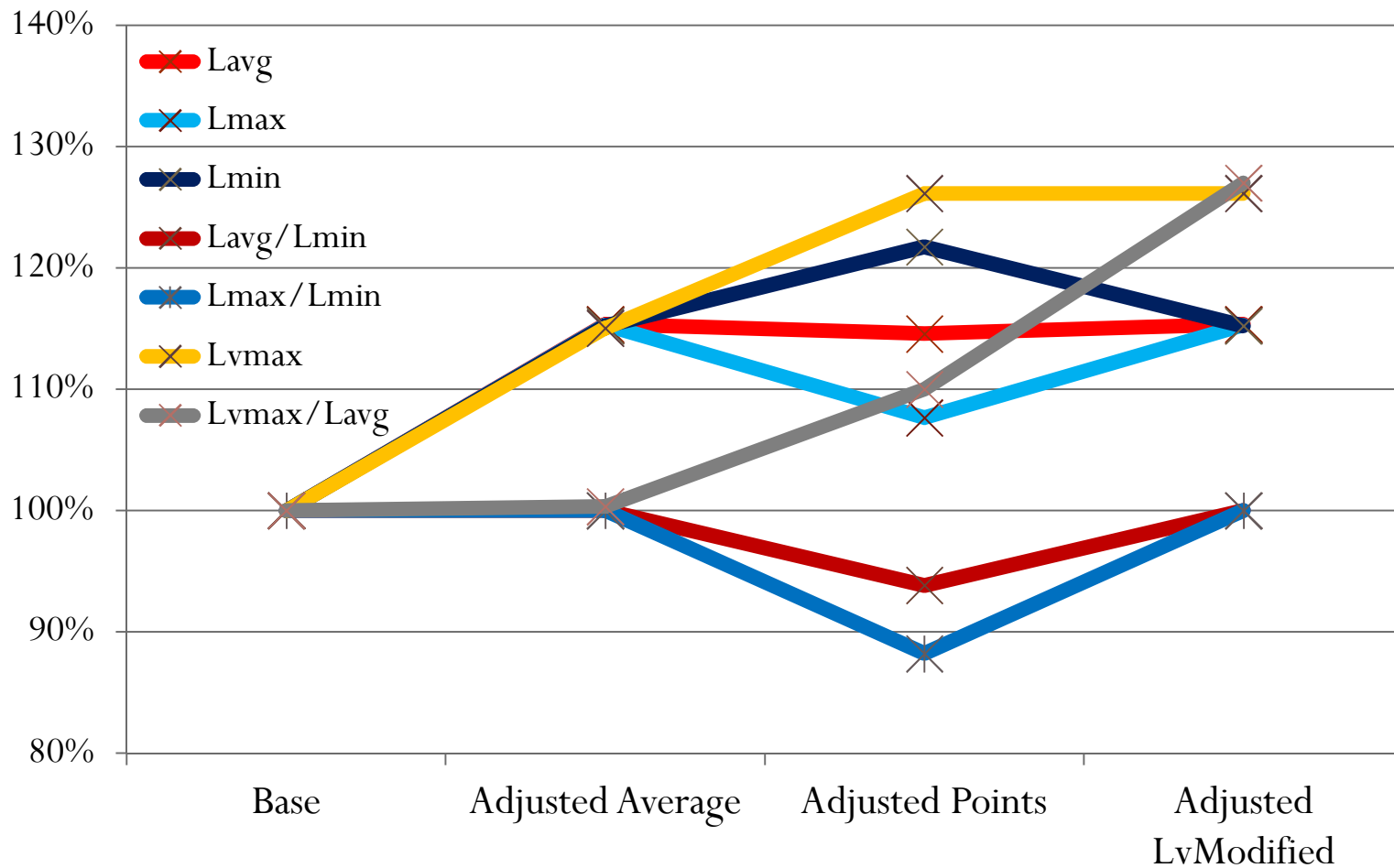
Lavg = 0.5 cd/m², 1.4 S/P Ratio



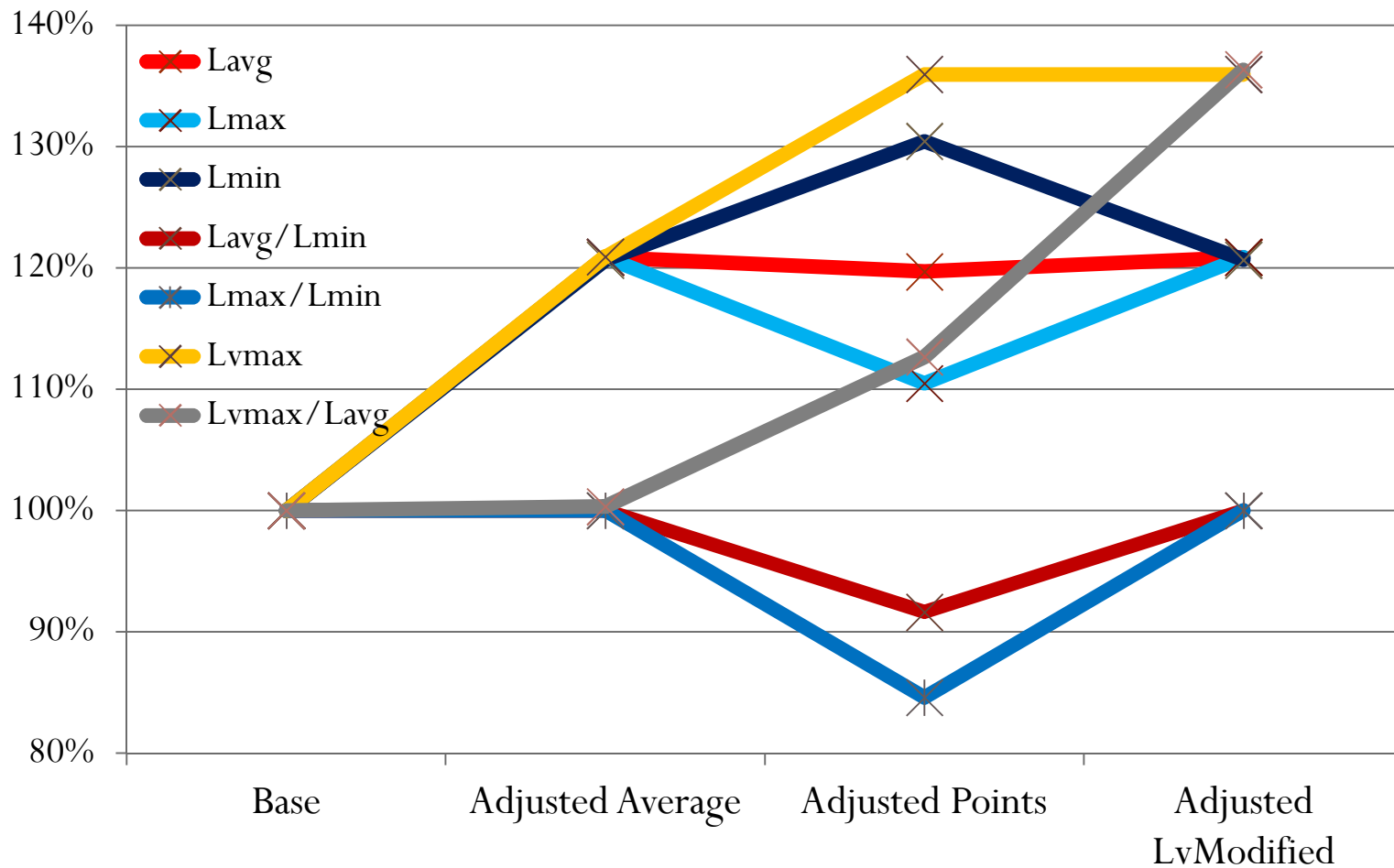
Lavg = 0.5 cd/m², 1.7 S/P Ratio



Lavg = 0.5 cd/m², 2.0 S/P Ratio



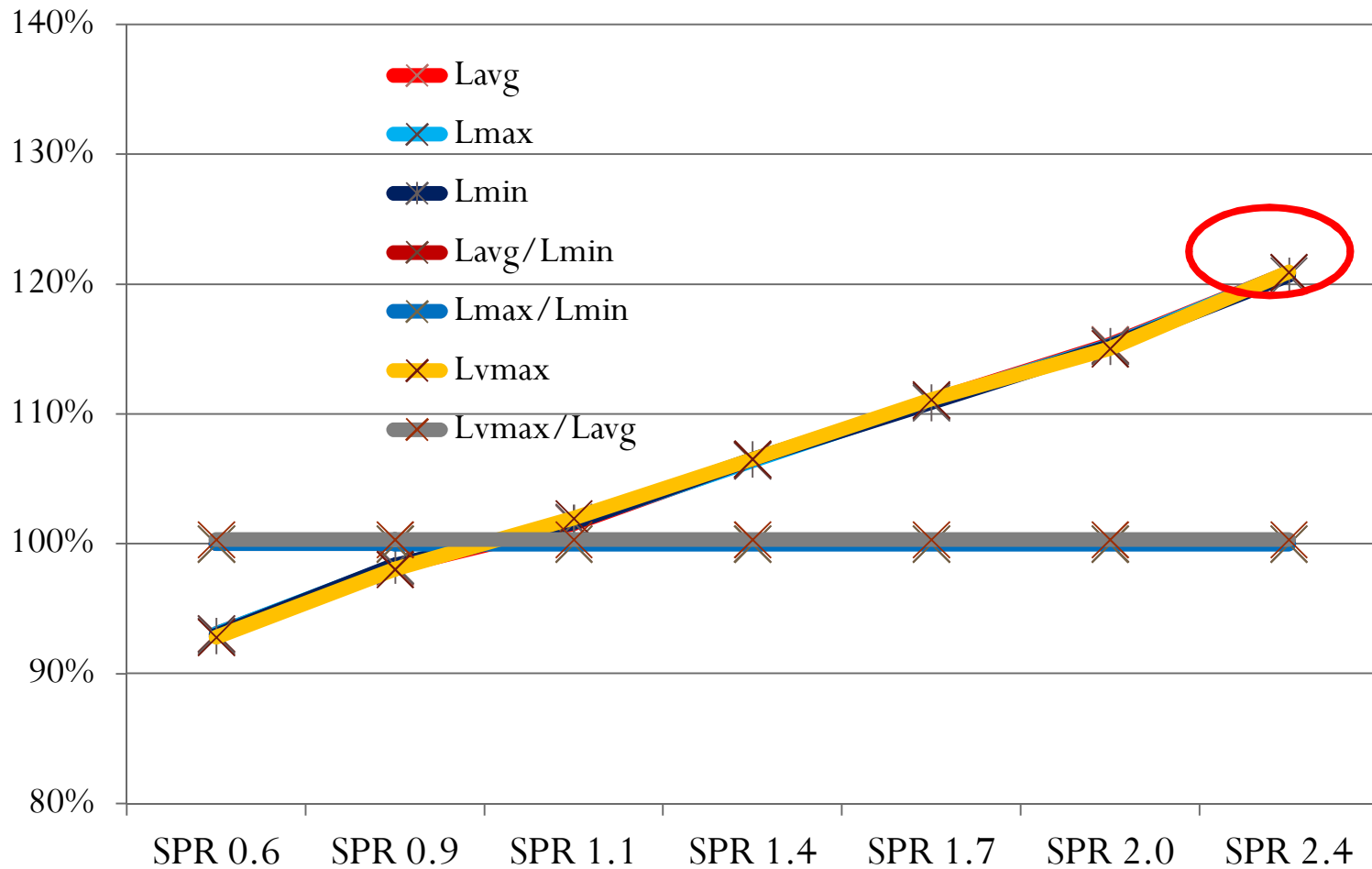
Lavg = 0.5 cd/m², 2.4 S/P Ratio



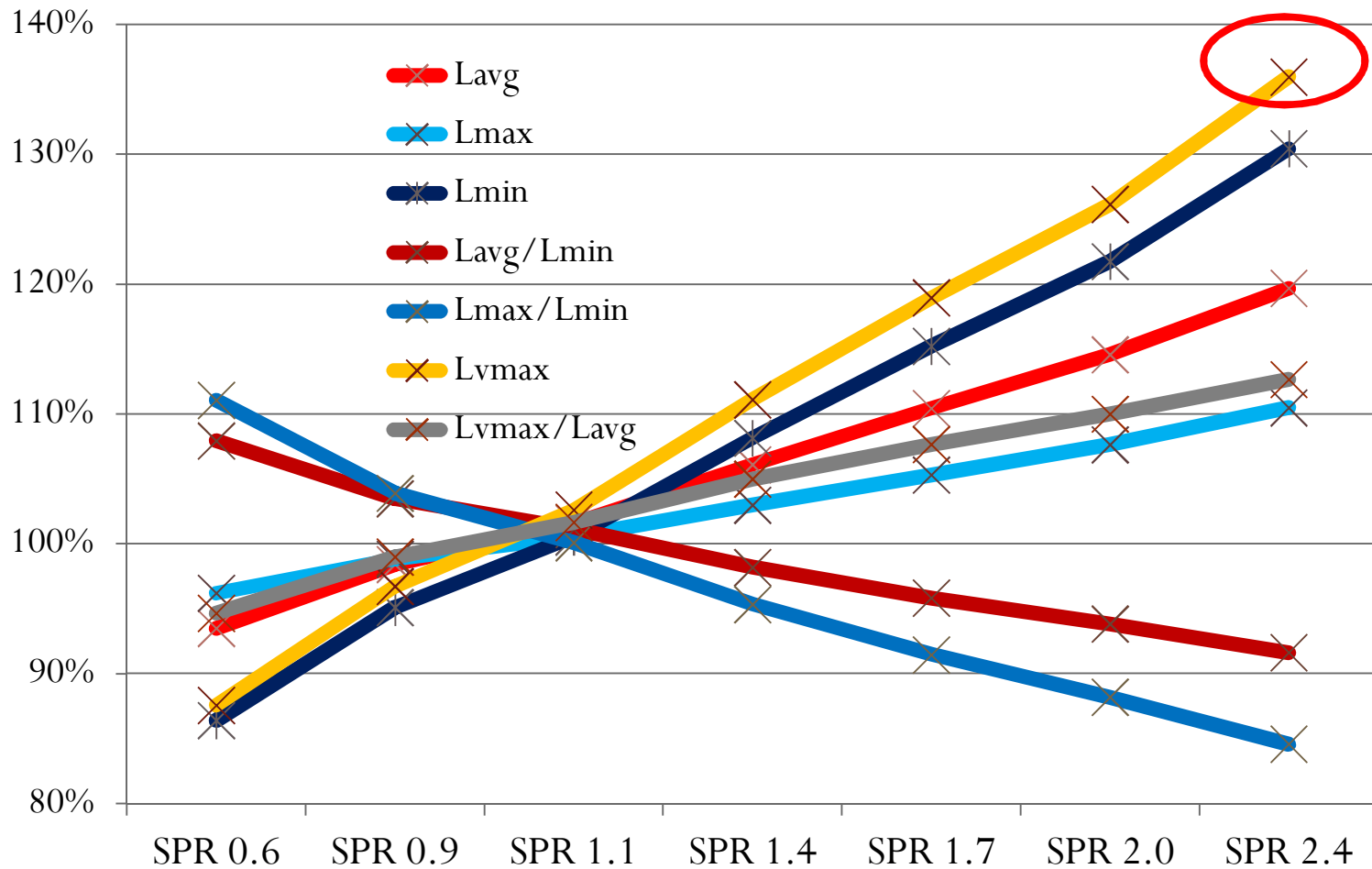
Comparison by Methodology

Luminance at 0.5 cd/m²

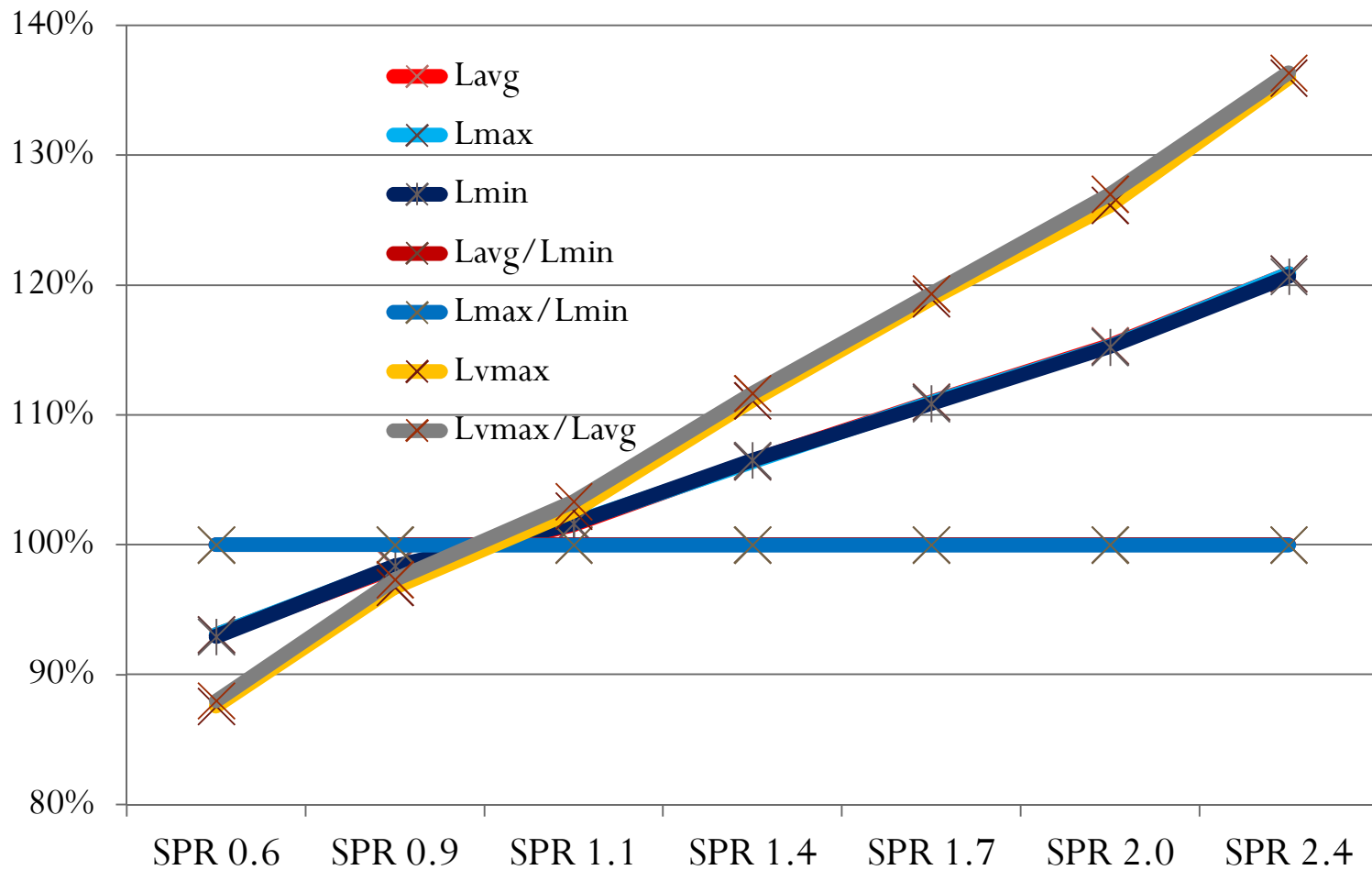
Adjusted Using Average Method



Adjusted Using Point Method



Adjusted LvModified Method



Thanks to CORM!

- & special thanks to Scott Wentworth who helped make this presentation happen
- References:
 - Spectral Effects of Lighting on Visual Performance at Mesopic Lighting Levels+, IES TM-12-12
 - American National Standard Practice for Roadway Lighting+, ANSI/IES RP-8-00
 - Nomenclature and Definitions for Illumination Engineering+, ANSI/IES RP-16-05
 - Laboratory Spectra+, Earth Observation Group, National Geophysical Data Center/NOAA
- any questions?