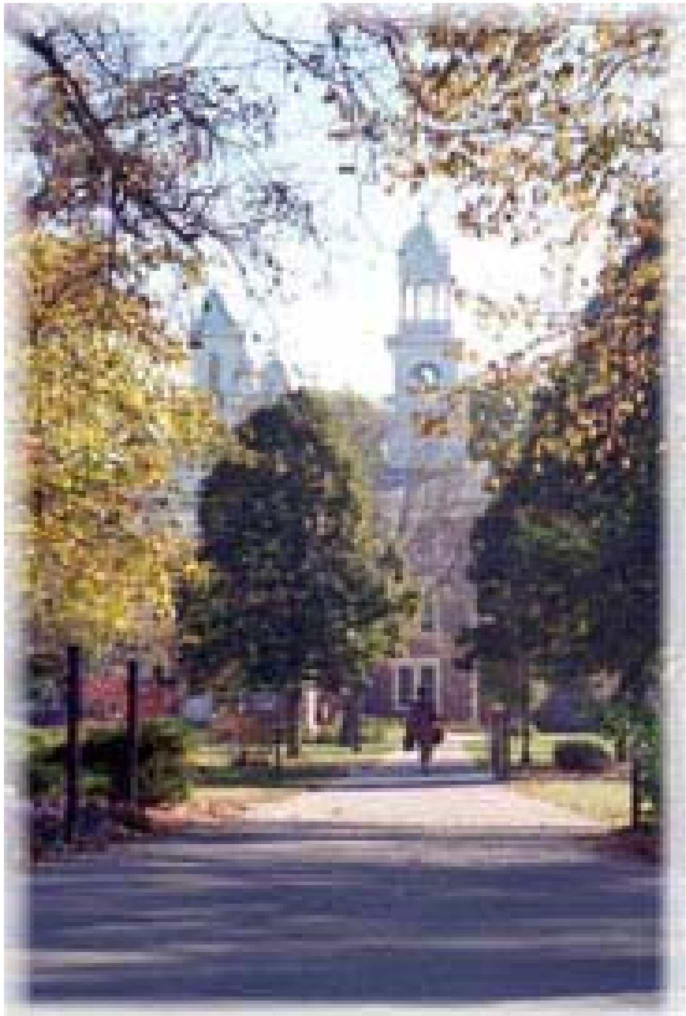

Heimstra Laboratories
University of South Dakota

NHTSA Headlamp Glare Workshop

Nighttime Visual Information Requirements

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Adequate Visual Information Needed to Support Primary Operational Tasks

- Steering/Lanekeeping
- Hazard Detection
- Warning Sign Legibility

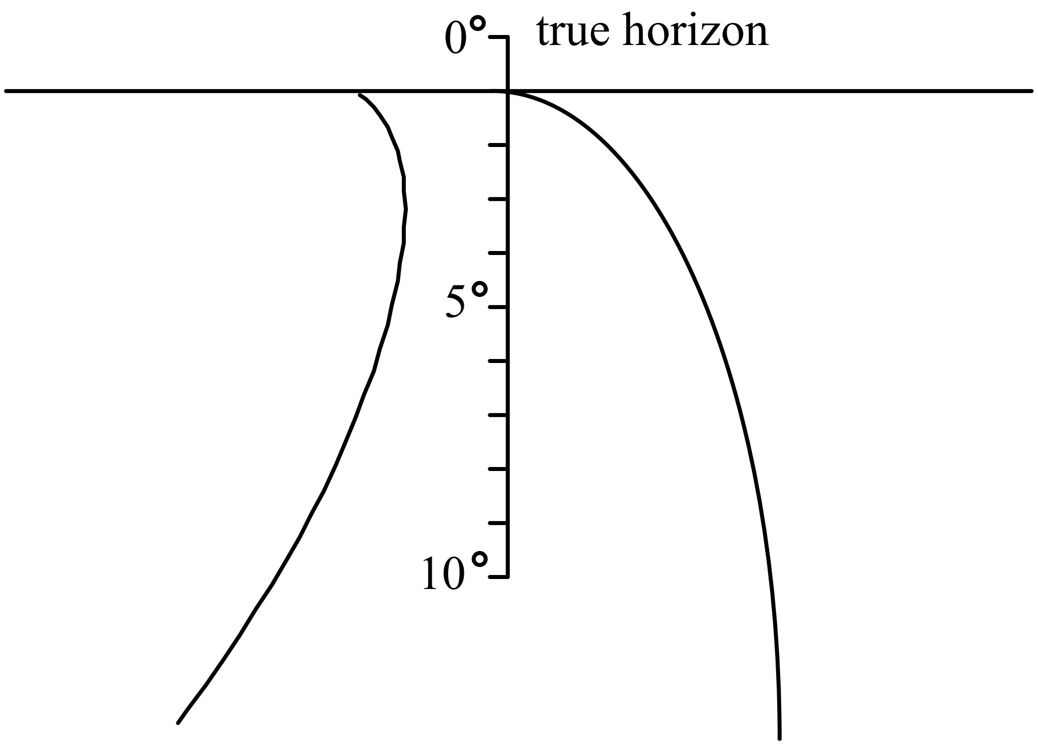
1. Steering/Lanekeeping

Dual-Processes Steering Model
(Donges, 1978)

- <u>Short-Range Visual Process</u>
  - Peripheral Vision (ambient flow)
  - Closed-loop compensatory tracking
    - Bottom-up perceptual process
  - Robust re: luminance/contrast
- <u>Long-Range Visual Process</u>
  - Central Vision
  - Open-loop anticipatory preparation
    - Top-down cognitive process
  - Heavy luminance/contrast requirements

Donges, E. (1978). A two-level model of driver steering behavior. <u>Human Factors</u>, 20(6), pp. 691-707.

Land & Horwood (1998)
Partial Visual Occlusion Paradigm



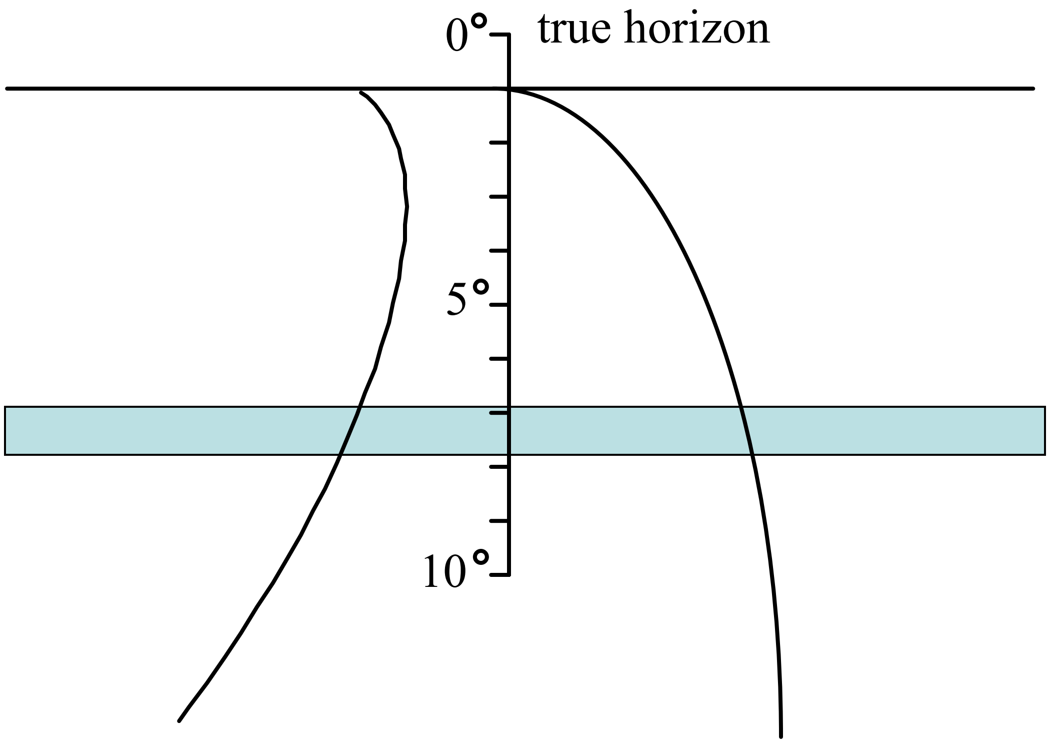
limited view to wide horizontal slice that sampled only 1-deg vertically

varied vertical offset of visual sample and driving speed

measured steering performance

Land, MF & Horwood, J. (1998). How speed affects the way visual information is used in steering. Vision in Vehicles. 6. pp. 43-50

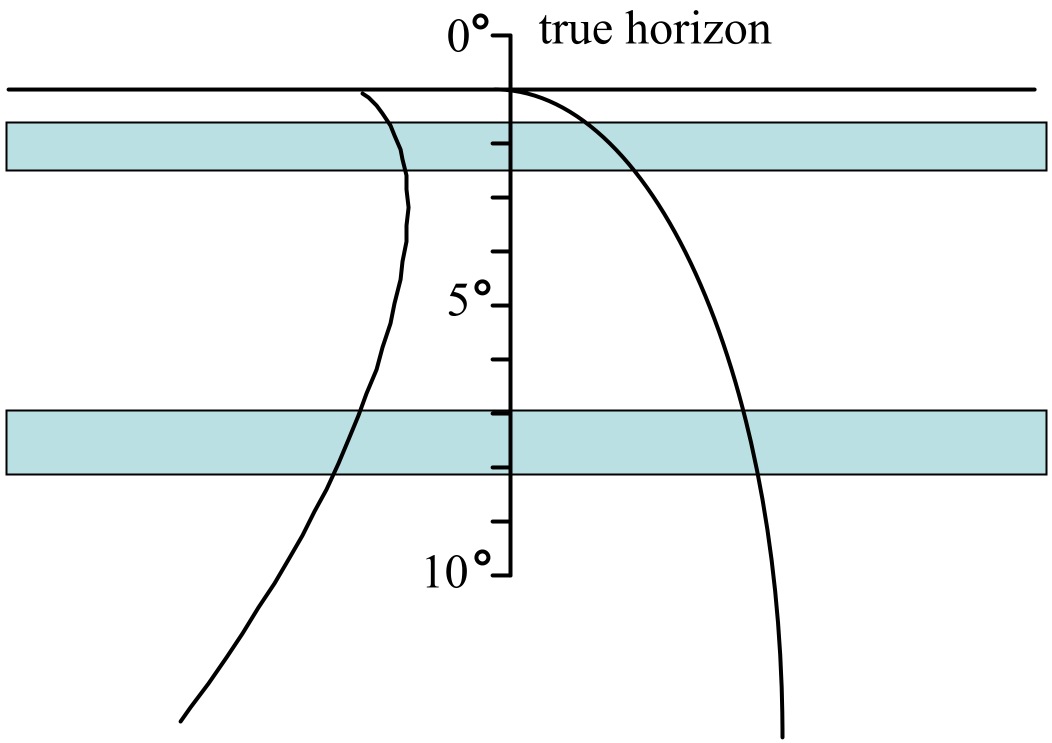
Land & Horwood (1998)



At slow driving speeds:

Drivers equaled baseline (i.e., full-field) performance when provided a single slice of visual field located approximately 7-deg below the horizon

Land & Horwood (1978)



At Higher Driving Speeds:

Baseline steering could only be achieved by adding a 2nd visual sample that was much closer to the horizon

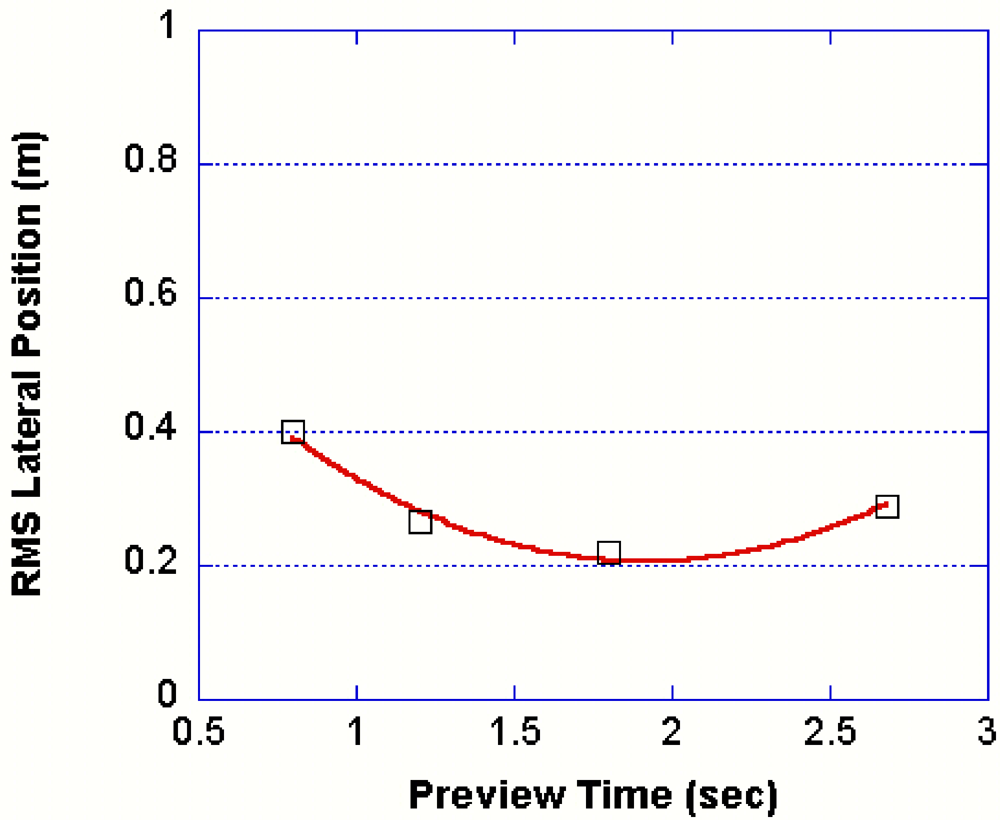
Hence, both near (compensatory tracking) and far (anticipatory preparation) visual information was needed to achieve "normal" steering performance

How much PREVIEW TIME is necessary to meet the visual information requirements of the Short-range and Long-range inputs?

- Short-range Process: **2-3 sec**
  (RMS lateral position)
- Long-range Process: **5 sec** (???)
  (curve entry/exit prepositioning)

Rumar, K. & Marsh, DK. (1998). Lane markings in night driving: A review of past research and of the present situation. UMTRI-98-50. University of Michigan Transportation Research Insititute. Ann Arbor, MI.

COST 331 (1999)
Short-Range Minimum Requirement



Lane position variability as a function of Forward Preview Time (VTI Driving Simulator)

Steering performance reaches asymptotic level at 1.8-2.0 sec

Recommended minimum Preview Time = 2.0 sec

Verified in complementary field studies

COST 331 – Requirements for Horizontal Road Markings
http://www.cordis.lu/cost-transport/src/cost-331.htm

Variable Preview Time Scenarios

(COST 331 Study)

Zwahlen & Schnell (2000)

Minimum Preview Time of **3.65 sec** required to fully meet driver's short-range visual guidance requirements

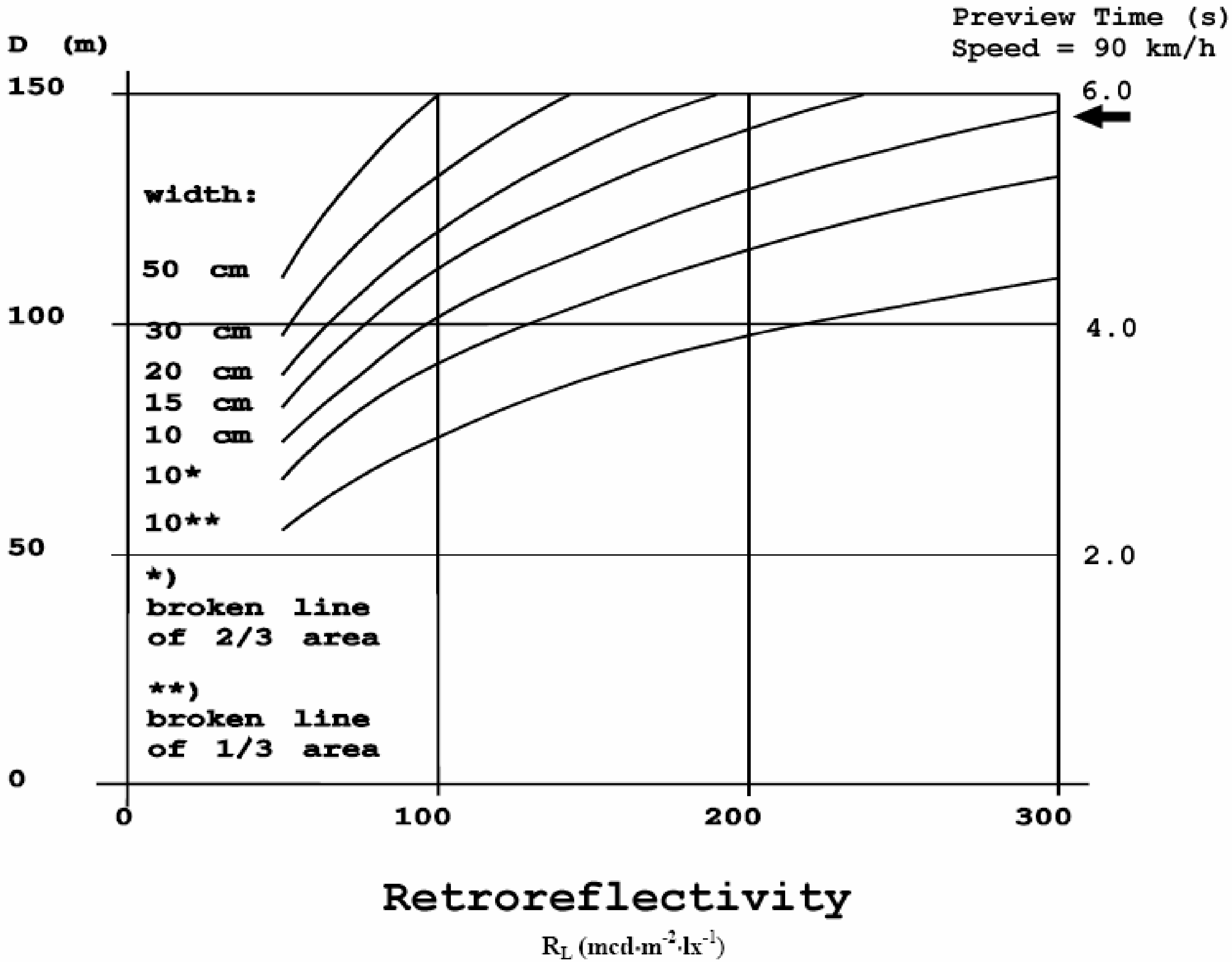
(85th percentile licensed driver – 62 year-old)
(3.0 s + 0.65 mean saccade latency)

Zwahlen, HT & Schnell, T. (2000). Minimum In-Service Retroreflectivity of Pavement Markings. TRB Paper No. 2000-1479. Washington, DC: TRB.
(analytical study based upon *proprietary* C.A.R.V.E. model)

Can we provide these necessary <u>Preview Times</u> given the available headlamp and pavement marking technology?

COST 331 Model Prediction

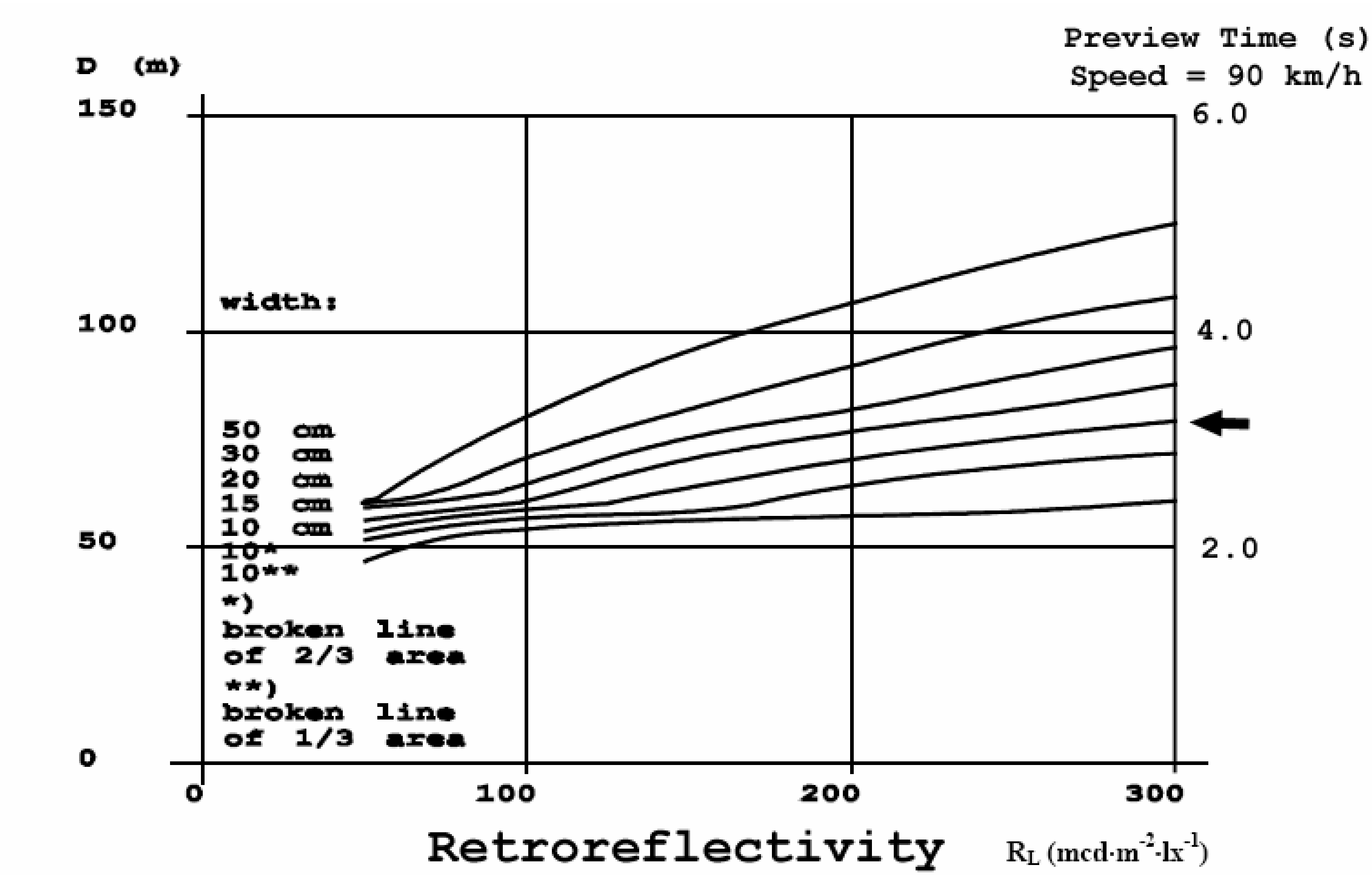
(High-beam; 10000 cd)



Representative in-service half-life values

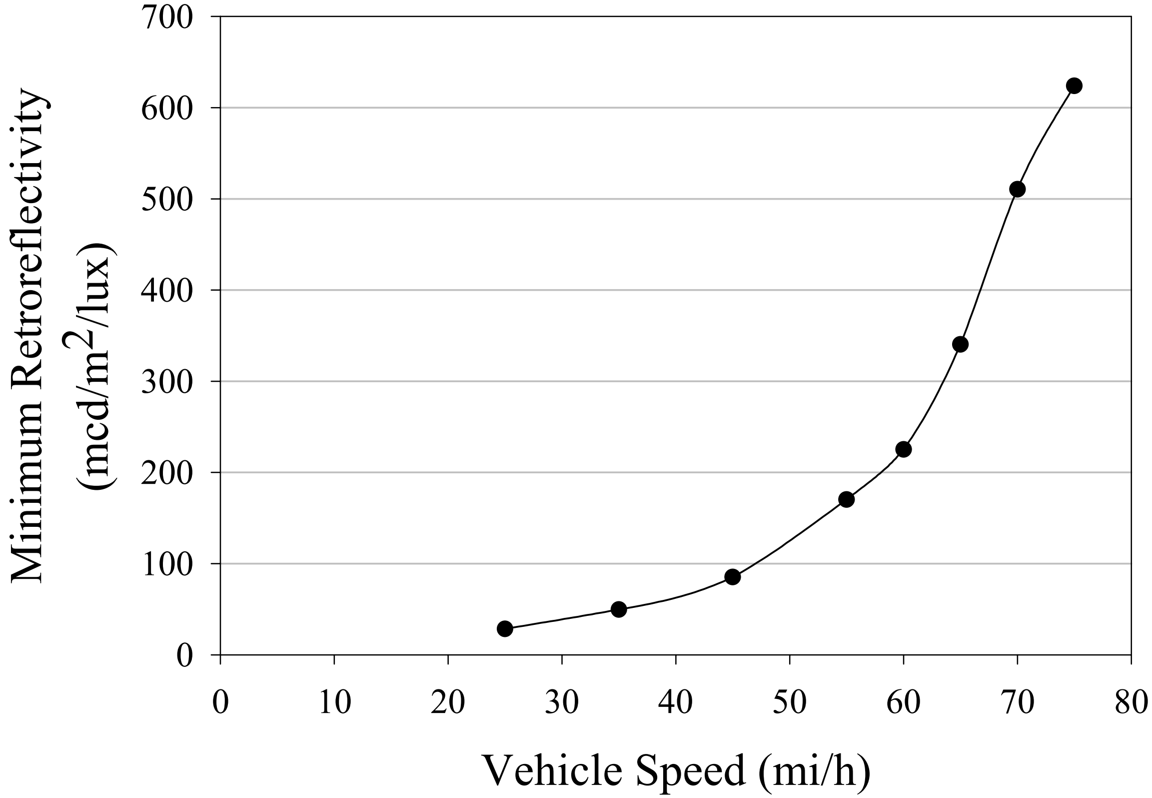
COST 331 Model Prediction

(representative EU <u>low-beam</u>)



Retroreflectivity Required to Achieve 3.65 sec Preview Time

(Zwahlen & Schnell, 2000 – C.A.R.V.E. Model)
(typical US low-beam headlamps)



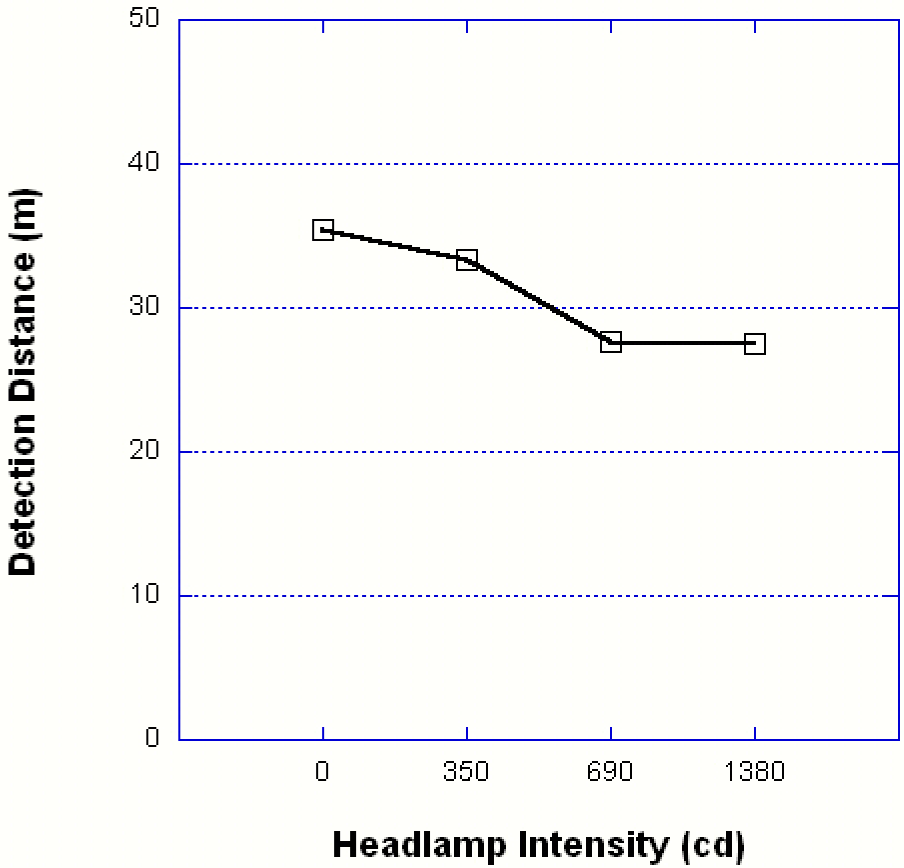
2. Hazard Detection

Roadside Pedestrian represents "worst case" scenario

- Dire consequences of detection failure
- Low contrast, non-reflective stimulus

At what distance can “alerted” drivers detect low-contrast roadside pedestrians under low-beam illumination?

Theeuwes, Alferdinck & Perel (2002)
Pedestrian Detection
with vs. without opposing headlamp glare



- 50 m opposing glare source
- 350, 690 (EU), 1380 (US) cd low-beam glare source simulation
- 12.5% R pedestrian proxies

- <u>RESULTS</u>:
  very low detection distances (even w/o opposing glare)

- Aktan & Schnell (ITE 2004) demonstrated similar findings in a field study comparing HID versus Halogen low-beam headlamps

- Pedestrian detection distances are probably even shorter in *unalerted* drivers

- Pedestrian fatality risk rises significantly when the sun sets

Regarding pedestrian visibility Theeuwes, et al. conclude that:

"It seems that this is a problem that cannot be solved by designing different beam patterns. Alferdinck and Padmos (1988) stated, 'without permanent road lighting a pedestrian on the road in not sufficiently visible to a motorist, unless a pedestrian wears retroreflectors of sufficient quality' p(16)" p. (106)

Alferdinck, J & Padmos, P. (1988). Lighting Research & Technology, 20, 195-198.

3. Sign Legibility

Minimum Luminance Required for Criterion Legibility Distance?

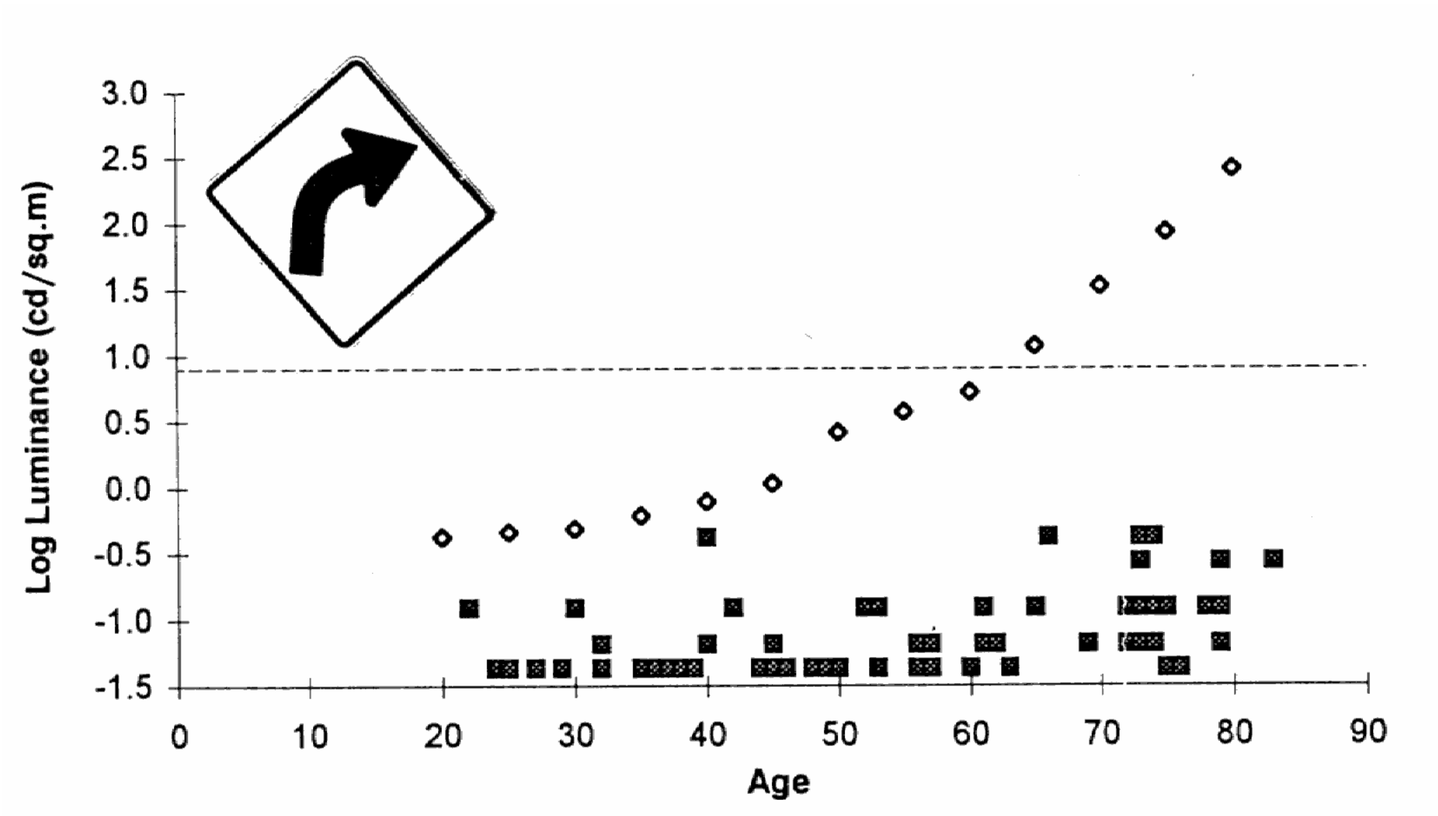
<u>Paniati & Mace (1993)</u>

C.A.R.T.S. Model
minimum luminance requirement ranges from **<u>7 – 15 cd/m^2</u>**
(depending upon MRVD scenario)
(66th percentile driver: acuity=20/20, cs=1.8)

Paniati, JF & Mace, DJ (1993). <u>Minimum retroreflectivity requirements for traffic Signs. FHWA-93-077</u>. Federal Highway Administration, McLean, VA.

CARTS Validation

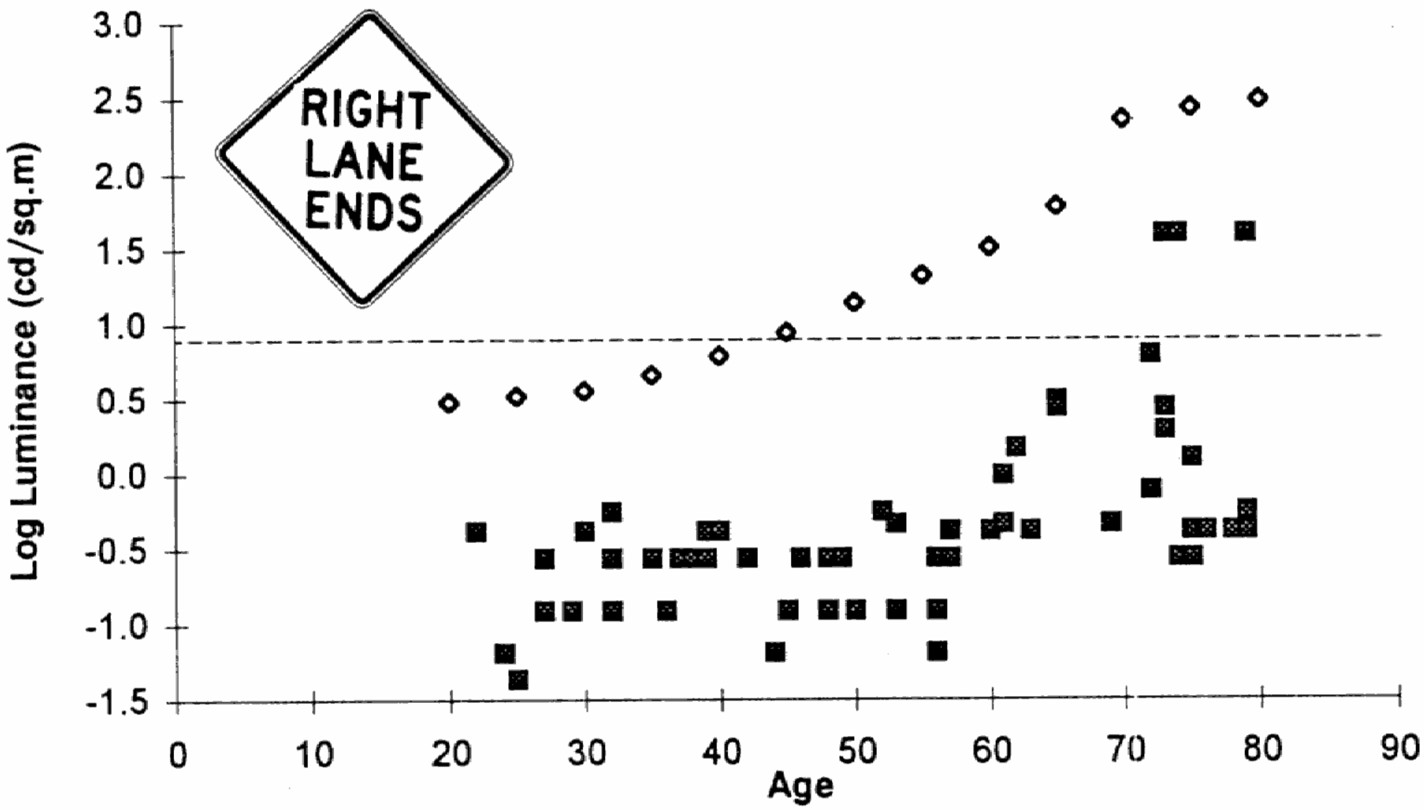
Simmons & Paniati (1995)
(Static Laboratory Study)



Simmons, CJ & Paniati, JF (1995). Developing minimum retroreflectivity values for in-service traffic signs. Compendium of Technical Papers. ITE. pp. 597-600.

CARTS Validation

Simmons & Paniati (1995)
(Static Laboratory Study)



CARTS Validation

Graham, et al. (1996)
(Static Field Study)

Sign luminance of **7 cd/m²** achieved MUTCD recommended Legibility Index of 40 ft/in

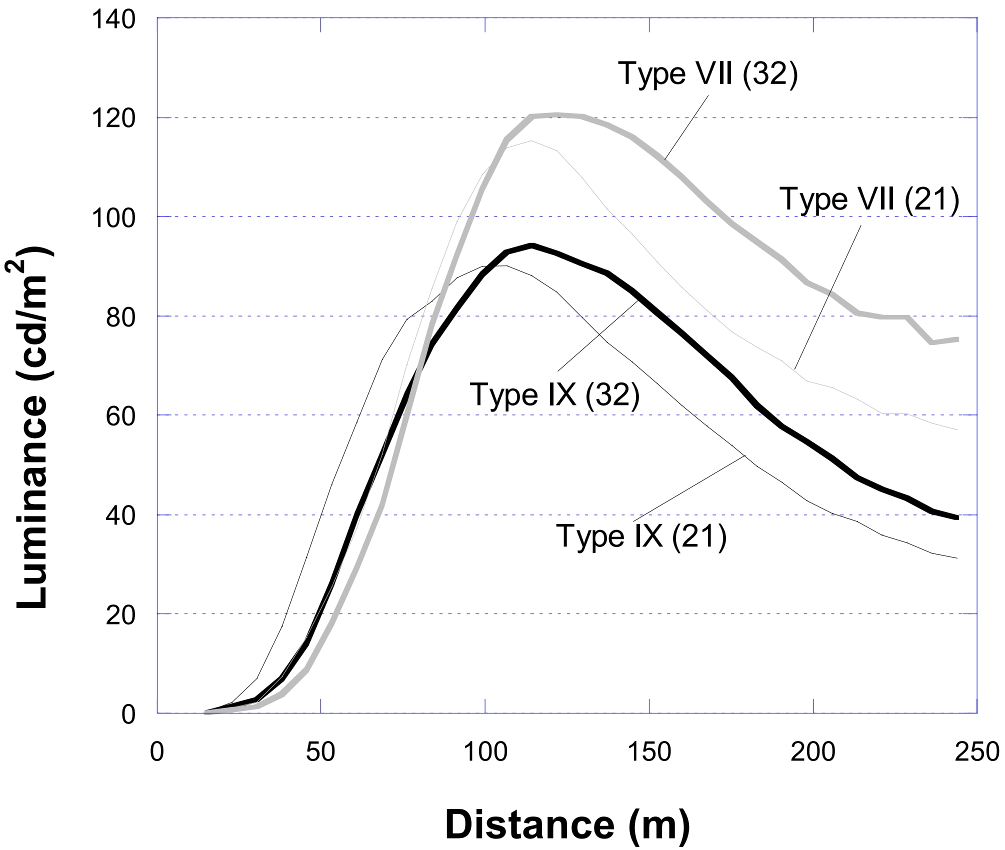
Mean driver age = 70 years

Graham, J. et al. (1996). Luminance of highway signs required by older drivers. Transportation Research Record, 1573, 91-98.

What highway sign luminances can we provide to drivers using representative low-beam headlamps and retroreflective sheeting material?

Sign Luminance as a function observation distance

(1998 Toyota Avalon Halogen)



Schieber, Burns, Myers, Willan and Gilland (2004)

ERGO http://reflectives.averydennison.com/films_ergo2001.html

Dynamic vs. Static Legibility Distance

Schieber, Burns, Myers, Willan & Gilland (2004)

65 MPH Rural Highway; young and older drivers (20/25 acuity)
Eye tracker and realtime D-GPS distance measurements
Three levels of luminance (incl. proposed FHWA minimum)

Sign Reflectance (%)	Dynamic Legibility Distance (m)	Legibility Index (ft/in)	Static[1] Legibility Distance (m)	Dynamic[1,2] PRT (s)
100	59.1	24.2	135	2.0
39	52.4	21.5	132	1.9
15	49.2	20.2	132	2.4

[2] Dynamic PRT (sec) = (Static Distance-Dynamic Distance)/Driving Speed
[1] (follow-up study revealed static LI = 50:1)

Dynamic Highway Sign Reading

(Schieber, et al., 2004)

Qualitative EM Findings

- Schieber, et al. (2004)
  total sign glance time > 4 sec
  first look distance reduced in cluttered scene (especially for older drivers)

  Drivers do not routinely avert their gaze away from oncoming headlamps…If anything, just the reverse is true
- Aktan and Schnell (2004)
  Drivers may gaze at HID lamps longer than halogen lamps

Qualitative EM Findings (continued)

- Zwahlen (1980)
  foveal road preview time = 5 sec (rain: 3 sec)
- Land & Lee (1994)
  fixations converge on “tangent” in (sharp) curves

Zwahlen, HT (1980). Zeitschrift fuer Verkehrssicherheit. Verlag, Rhineland.
Land, MF & Lee, DN (1994). Nature, 369, 742-744.