Safety performance based departures from geometric design requirements

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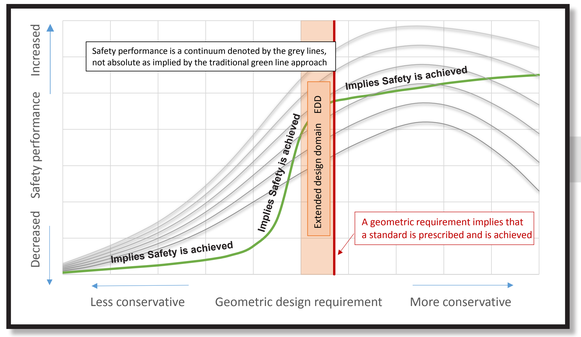
Authors
Dr Shane Turner
Keith Weale
Jeremy O'Neill

This is a worked example showing the different results for stopping sight distance and crest vertical curvature when using a probabilistic approach versus the traditional deterministic (manuals and guidelines) approach.

TRADITIONAL DETERMINISTIC APPROACH



Manuals and Guidelines

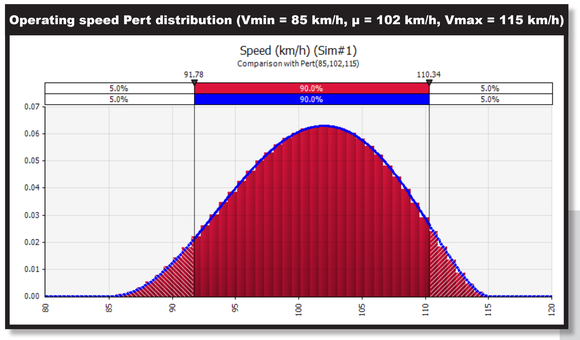
Example of deterministic design parameters for a motorway

Design Speed	Perception & Reaction Time	Deceleration Coefficient	Stopping Sight Distance	Driver Eye Height	Object Height	Crest Curvature
V	*RT*	*d*	*S*	h_1	h_2	*K*
km/h	s		m	m	m	m/1%
110	2.5	0.26	260	1.1	0.2	151
110	2.5	0.36	209	1.1	0.2	97
110	2.5	0.46	180	1.1	0.2	72

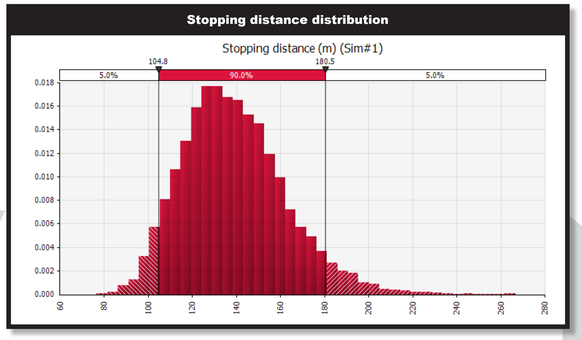
Compare the Results

PROBABILISTIC APPROACH

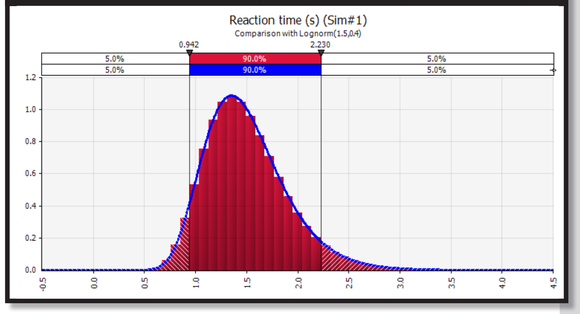
Operating speed Pert distribution (Vmin = 85 km/h, μ = 102 km/h, Vmax = 115 km/h)



Stopping distance distribution



Perception and reaction time lognormal distribution (μ = 1.5 s, σ = 0.4 s)



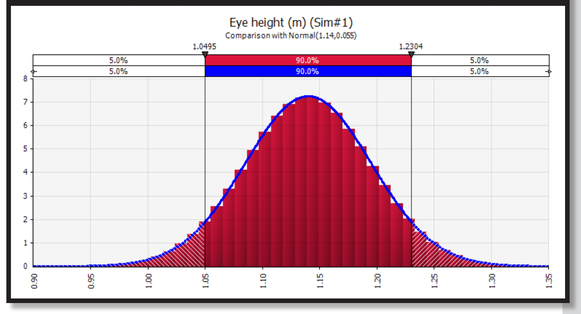
Monte Carlo Simulation

Stopping sight distance formula

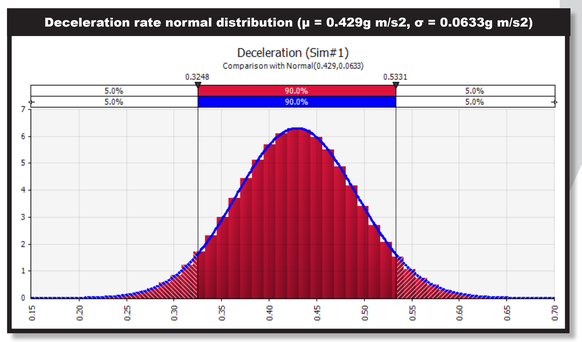
$$SSD = \frac{R_t V}{3.6} + \frac{V^2}{254(d + 0.01a)}$$

SSD = stopping sight distance (m)
RT = driver perception and reaction time (s)
V = vehicle speed (km/h)
d = deceleration coefficient
a = longitudinal gradient (%)

Driver eye height normal distribution (μ = 1.14 m, σ = 0.055 m)



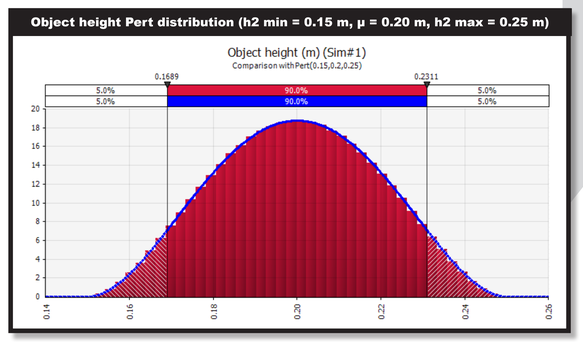
Deceleration rate normal distribution (μ = 0.429g m/s2, σ = 0.0633g m/s2)



*** These distributions can all be modified by design, for example:**

- reduce speed with side friction
- decrease reaction time by increasing driver awareness with street lighting
- increase deceleration rates with high friction surfaces

Object height Pert distribution (h2 min = 0.15 m, μ = 0.20 m, h2 max = 0.25 m)



Monte Carlo Simulation

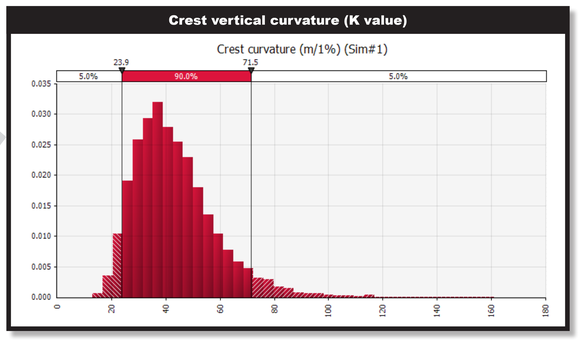
Crest vertical curvature formula

$$K = \frac{S^2}{200\,(\sqrt{h_1} + \sqrt{h_2})^2}$$

K = vertical curvature (m/1%)
S = distance (m)
h1 = driver eye height (m)
h2 = observed object height (m)

	Operating speed distribution	Perception & reaction time distribution	Deceleration coefficient distribution	Resultant SSD distribution	Driver eye height distribution	Object height distribution	Resultant crest curvature distribution
	V	*RT*	*d*	*S*	h_1	h_2	*K*
	km/h	s		m	m	m	m/1%
0.1%	87	0.6	0.23	85	0.97	0.15	16
0.5%	88	0.7	0.27	92	1.00	0.16	18
1.0%	89	0.8	0.28	95	1.01	0.16	19
5.0%	92	0.9	0.32	105	1.05	0.17	24
10.0%	94	1.0	0.35	111	1.07	0.17	27
50.0%	101	1.4	0.43	137	1.14	0.20	41
90.0%	109	2.0	0.51	169	1.21	0.23	63
95.0%	110	2.2	0.53	181	1.23	0.23	71
99.0%	113	2.7	0.58	204	1.27	0.24	91
99.5%	113	2.8	0.59	214	1.28	0.24	99
99.9%	114	3.3	0.62	232	1.31	0.25	116

Crest vertical curvature (K value)



The next steps

- **The probability of stopping in time can now be correlated with a known crash history on a representative road, so that a particular probability will correlate with an expected number of fatal crashes per 100,000 vehicle kilometres.**
- **Future designers will target a safety outcome and therefore a specified probability of stopping, instead of relying on the assumption that using the default design speed, reaction time, and deceleration rate will always achieve that outcome.**