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TÜVRheinland®
Precisely Right.

PWI Lunch & Learn
Probabilistic Gauging

Dr David Johnson FREng

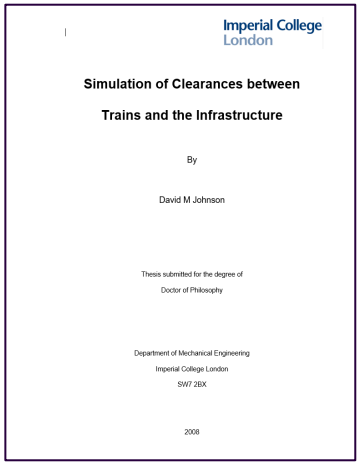
28th October 2025

The Journey

ARTIS CONJECTANDI
PARS PRIMA,
Complectens
Tractatum Hugenii de Ratiociniis
in Ludo Aleæ,
Cum Annotationibus
JACOBI BERNOULLI.

CHRIST. HUGENII
ad
FRANC. SCHOOTENIUM
Præfatio.

1713



Imperial College London

Simulation of Clearances between Trains and the Infrastructure

By

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Thesis submitted for the degree of
Doctor of Philosophy

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Imperial College London
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2008

2002

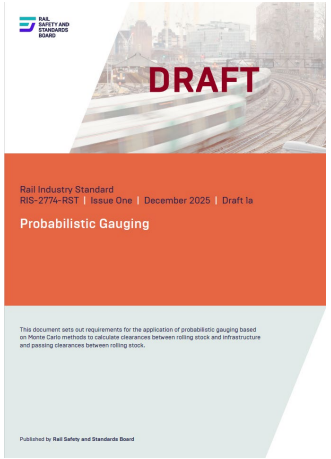
Rail Safety & Standards Board

Research Programme

Engineering

Reducing uncertainties in structure gauging (summary report)

2005



DRAFT

Rail Industry Standard
RIS-2774-RST | Issue One | December 2025 | Draft 1a

Probabilistic Gauging

This document sets out requirements for the application of probabilistic gauging based on Monte Carlo methods to calculate clearances between rolling stock and infrastructure and passing clearances between rolling stock.

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2025

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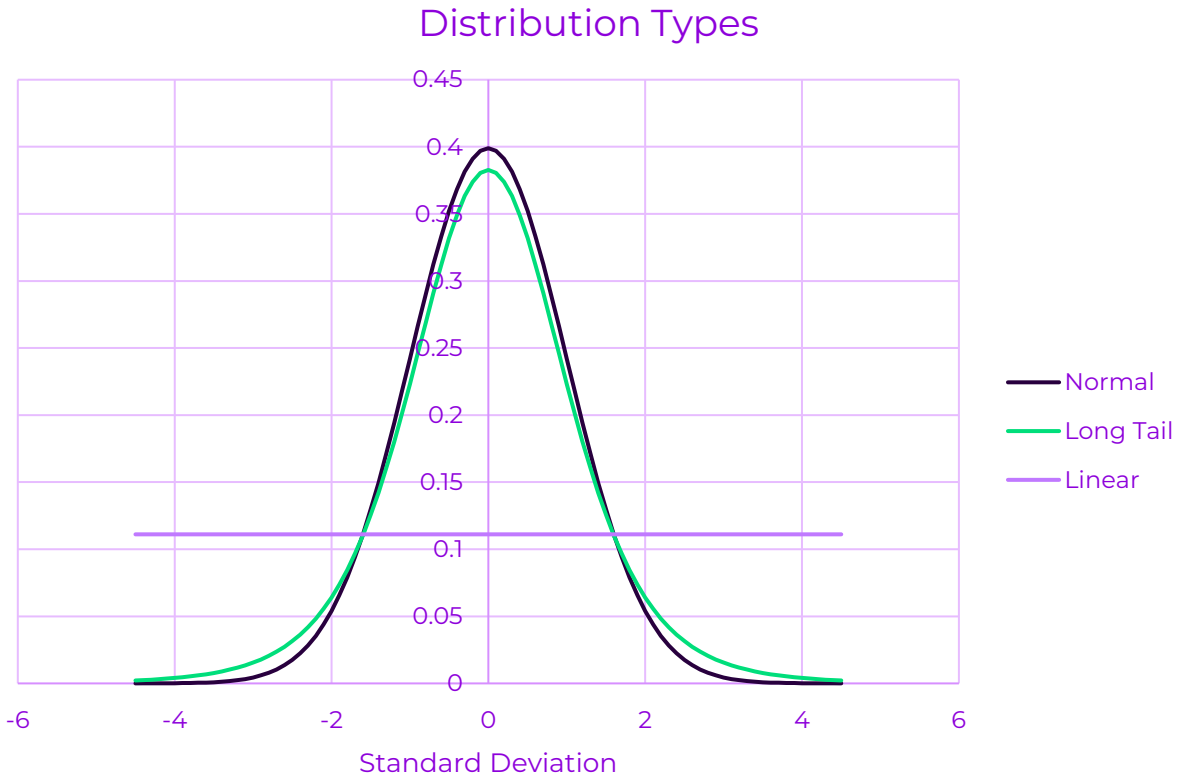
Statistical Basis

- Every gauging variable is statistical
- Each one has a probability distribution

Examples

Measuring Accuracy = Normal
Vehicle Movement = Long Tail
Wheel Wear = Linear



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Statistical Basis

Typical Values

Variable	Mean (mm)	Standard Deviation (mm)
Measuring Accuracy	0	3
Lateral Movement 1000mm ARL	0	15
Wheel Wear	12	4

Traditional Absolute Gauging

Variable	Mean (mm)	SD (mm)	Max SD	Covers	Mean + Max SD (mm)	Distribution
Measuring Accuracy	0	3	3	99.8%	9	Normal
Lateral Movement 3000mm ARL	0	45	4.5	99%	202.5	Long Tail
Wheel Wear	12	4	3	100%	24	Linear
Vertical Movement Laden	25	5	4.5	99%	47.5	Long Tail
Suspension Creep	12	3	3	99.8%	21	Normal
Vehicle Build Tolerance (BOD)	0	3	3	99.8%	9	Normal
Etc., etc.						

↓

Gauging Software

↓

Clearance (mm) = 10mm (say)

Traditional Absolute Gauging

Variable	Mean (mm)	SD (mm)	Max SD	Covers	Mean + Max SD (mm)	Distribution
Measuring Accuracy	0	3	3	99.8%	9	Normal
Lateral Movement 3000mm ARL	0	45	4.5	99%	202.5	Long Tail
Wheel Wear	12	4	3	100%	24	Linear
Vertical Movement Laden	25	5	4.5	99%	47.5	Long Tail
Suspension Creep	12	3	3	99.8%	21	Normal
Vehicle Build Tolerance (BOD)	0	3	3	99.8%	9	Normal
Etc., etc.						

↓

Gauging Software

↓

Clearance (mm) = 10mm (say)

Traditional Absolute Gauging (Pragmatic)

Variable	Mean (mm)	SD (mm)	Max SD	Covers	Mean + Max SD (mm)	Distribution
Measuring Accuracy	0	3	2	95%	6	Normal
Lateral Movement 3000mm ARL	0	45	2.12	95%	95.4	Long Tail
Wheel Wear	12	4	3	100%	24	Linear
Vertical Movement Laden	25	5	2.12	95%	95.4	Long Tail
Suspension Creep	12	3	3	99.8%	21	Normal
Vehicle Build Tolerance (BOD)	0	3	3	99.8%	9	Normal
Etc., etc.						

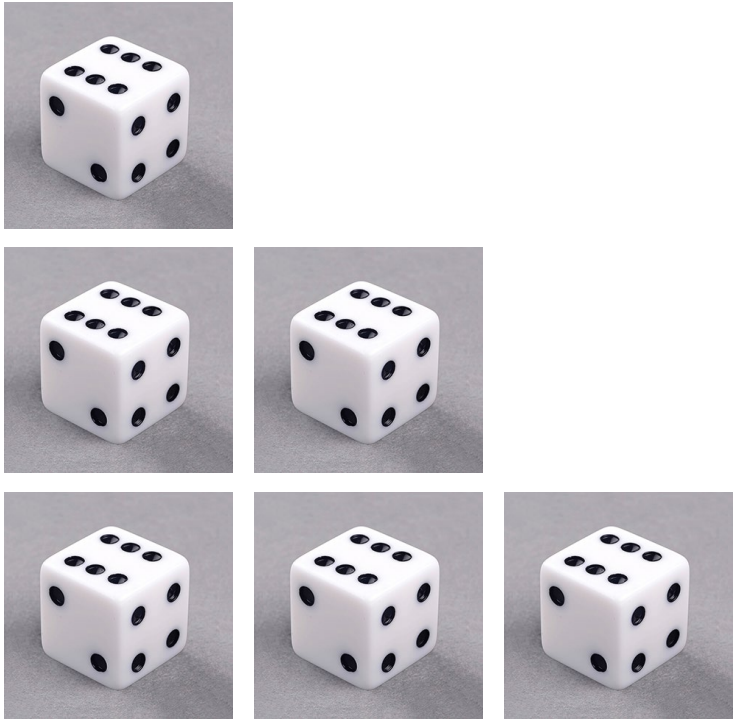
Gauging Software

Clearance (mm) = 100mm (say)

Basic Probability

1 in 6 = 16.67%
Probability of NOT 6 = 83.33%

Basic Probability



1 in 6 = 16.67%
Probability of not 1 x 6 = 83.33%

1 in 36 = 2.77%
Probability of NOT 2 x 6 = 97.23%

1 in 216 = 0.46%
Probability of NOT 3 x 6 = 99.54%

Risk of Exceedance

(Lateral) Variable	Max SD	Covers	Risk
Measuring Accuracy	2	95%	0.5%
Lateral Movement 3000mm ARL	2.12	95%	4.6%
Wheel Wear	3	99.9%	0.1%
Vertical Movement Laden	2.12	95%	4.6%
Suspension Creep	3	99.8%	0.2%
Vehicle Build Tolerance (BOD)	3	99.8%	0.2%
Etc., etc.			

Risk = 0.005 x 0.046 x 0.001 x 0.002 x …

Real Case Probability of Exceedance P(e):

0.000000000000000506 or

1 in 1,976,284,584,980,230

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Probability > Risk

P(e) = 0.00000000000000050600

5-minute headway, 18 hours / day, 6 vehicles / train

= 1,296 vehicle passes / day
= 473,040 vehicle passes / year
= 4,177,838,206 years / exceedance

Probability of exceedance today:
1 in 1,524,911,000,000

Probability of world ending today:
1 in 3,650,000 (Global Catastrophic Risk Institute and Future of Humanity Institute)

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Probability > Risk

P(e) = 0.00000000000000050600

Maximum exceedance = 35mm

Why 100mm clearance required?

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Probabilistic Absolute Gauging

Variable	Event 1	Event 2	Event 3	Event 4	Event 5	Event 10,000
Measuring Accuracy	+4	-1	-6	+7	+2	
Lateral Movement 3000mm ARL	-80	+21	+66	+51	-30	
Wheel Wear	+12	+7	0	+18	+21	
Vertical Movement Laden	+16	-1	+8	+22	+44	
Suspension Creep	+2	+3	+14	+7	+18	
Vehicle Build Tolerance (BOD)	-8	-1	+3	-3	-5	
Etc., etc.						

Gauging Software

Clearance (mm)	**117mm**	**113mm**	**96mm**	**122mm**	**105mm**	**101mm**

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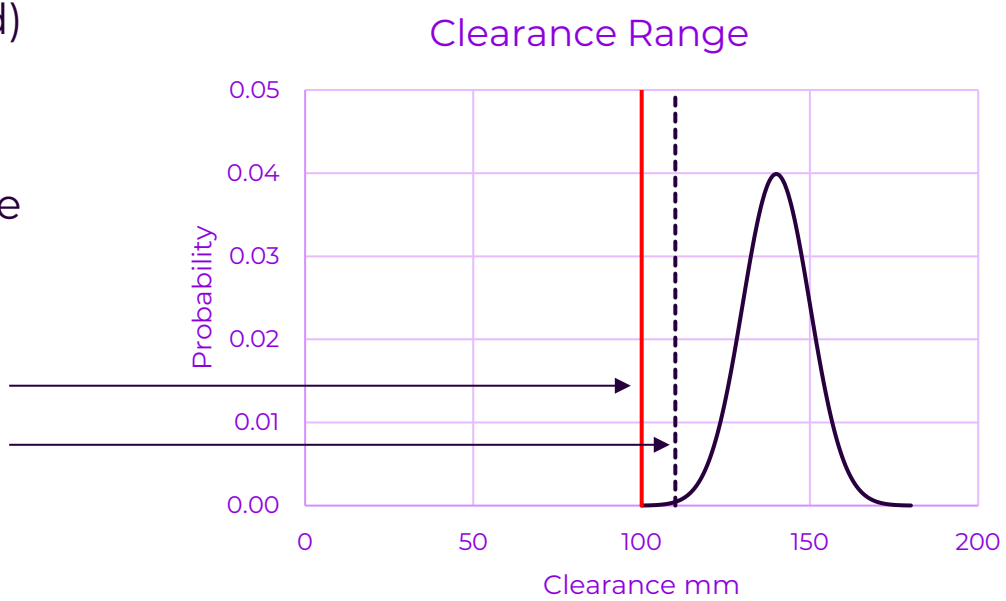
Probabilistic Absolute Gauging

- Dynamic Movements (±4.5sd)
- Multiple Vehicle Tolerances (±3sd)
- Measuring Tolerance (±3sd)

- Fixed Track Movement Allowance (±45mm) – Why?...

- Traditional Clearance = 100mm
- 3sd Clearance (99.7%) = 110mm*



*Illustrative Value – dependent on vehicle

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Probabilistic

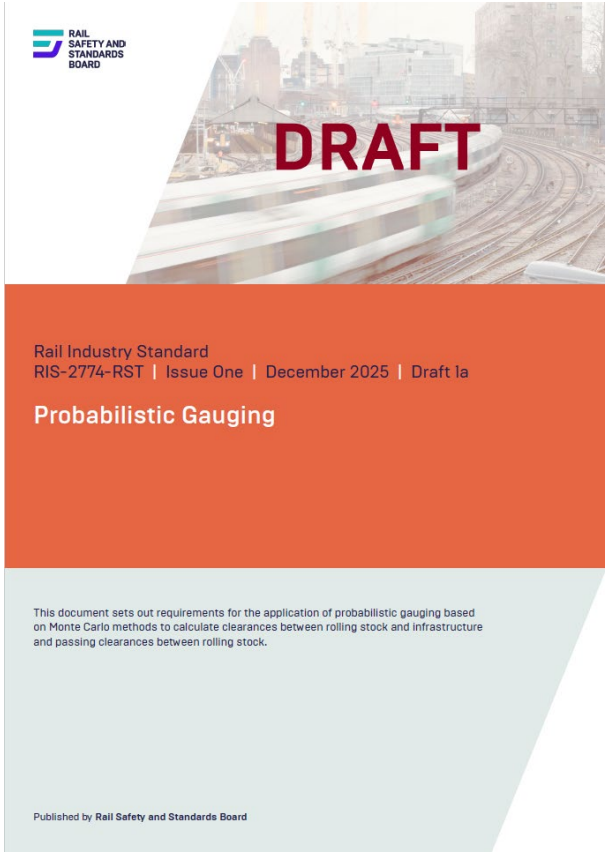
- Used by nuclear industry
- Used by energy industry
- Used by aviation and aerospace industry
- Used by automotive industry

The rail industry does not consider gauging to carry a credible risk.

What value do we ascribe to the space occupied by air?

- Reducing track maintenance costs
- Reducing route upgrade costs
- Reducing platform gaps
- More freight paths for container traffic
- More continuous 25kV electrification

Probabilistic = Quantified risk



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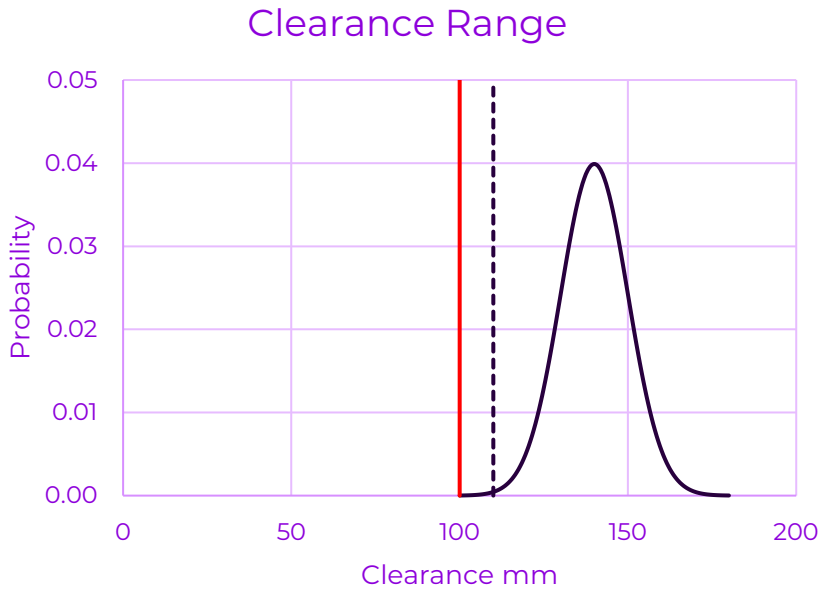
Probabilistic Absolute Gauging

- Industry estimate of cost of providing route clearance c. £1M per mm per track mile in 2000. (£1.7M in 2025)
- £300M benefit delivered by applying probabilistic gauging to electrification schemes in Scotland (2024)



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