NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Quality Assurance of Transportation Materials and Construction—Part II

March 3, 2025

1:00 – 2:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING
RCEP
REGISTERED CONTINUING EDUCATION PROGRAM

Purpose Statement

This webinar will share how to develop and monitor limits and pay adjustments for a PWL specification. Presenters will discuss how to develop proper incentives and disincentives within a PWL specification; how to balance risks and pay factors in PWL specifications; and how to monitor and conduct retrospective analysis, maintaining specification limits and evaluating risks on an ongoing basis.

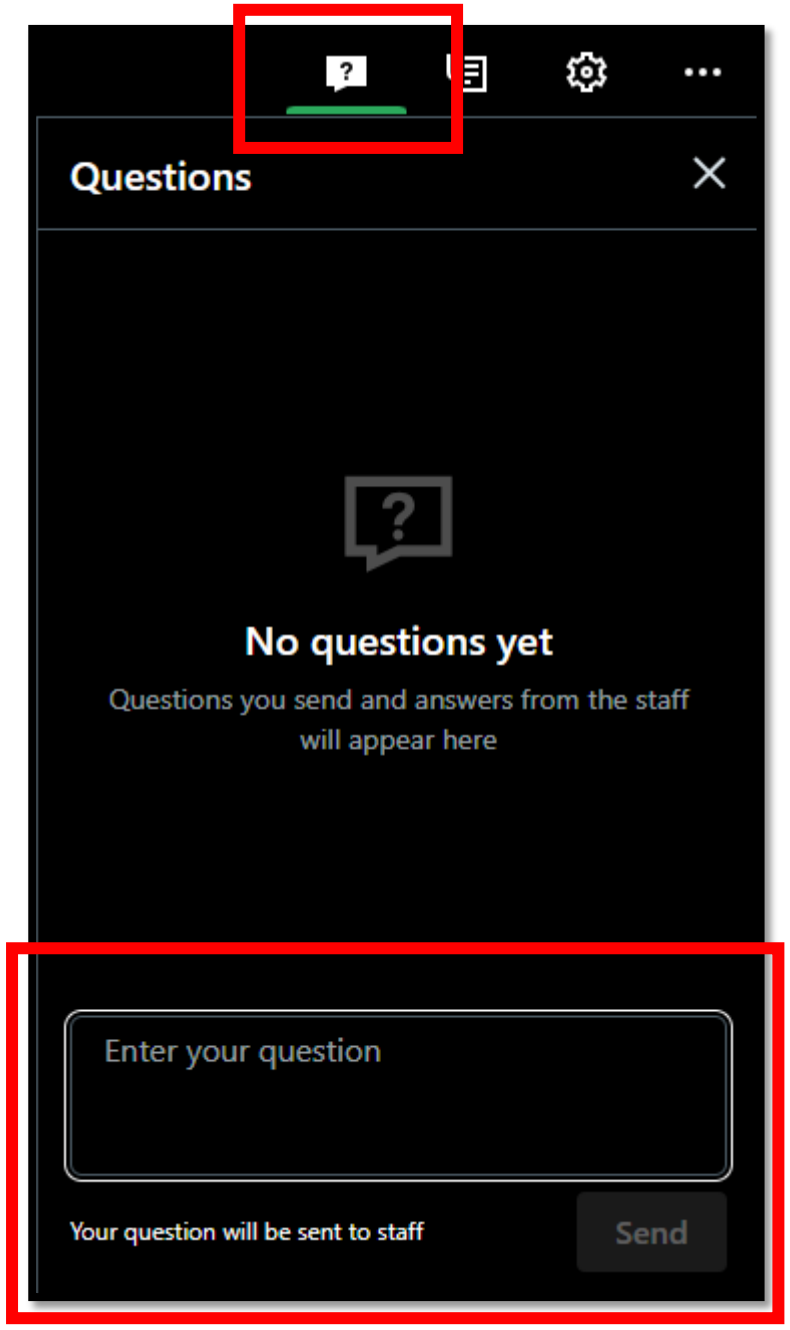
Learning Objectives

At the end of this webinar, you will be able to:

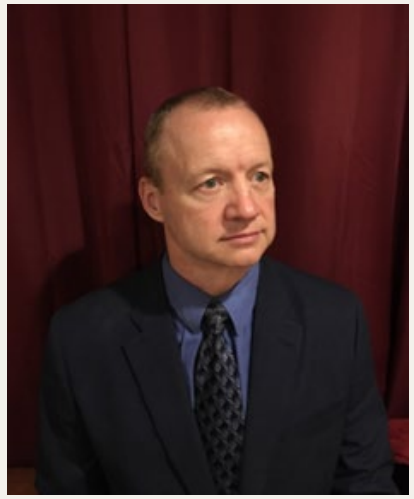
- Develop and update limits for a PWL specification
- Balance risks and pay factors in a PWL specification
- Monitor and perform retrospective analysis to maintain specification limits

Questions and Answers

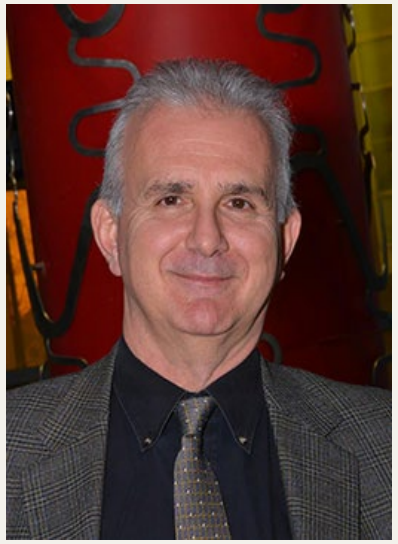
- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



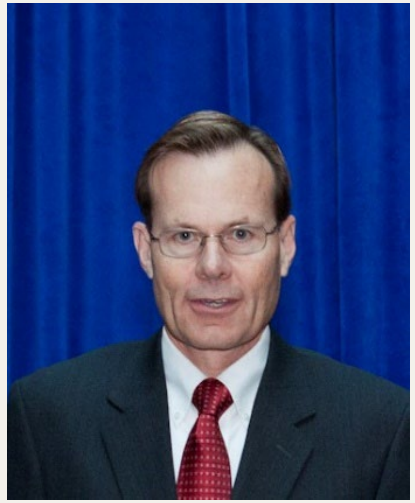
Today's presenters



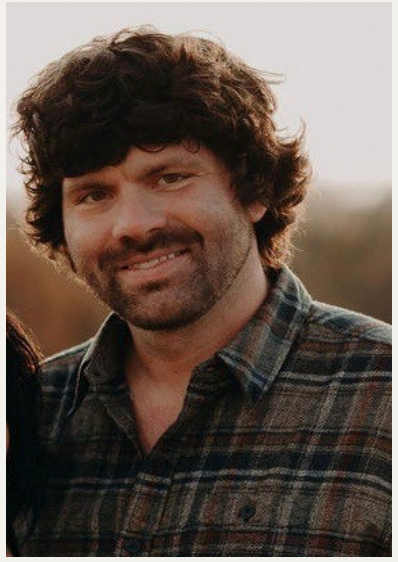
Mark Felag
mfelag@hotmail.com
Mark E. Felag, PE, LLC



Dimitrios Goulias
dgoulias@umd.edu
University of Maryland



Dennis Dvorak
Ddvorak59@gmail.com
Federal Highway Administration
Resource Center



Mike Copeland
Michael.Copeland@itd.idaho.gov
Idaho Transportation Department

NATIONAL ACADEMIES *Sciences Engineering Medicine*

Developing and Updating Specification Limits for PWL Specifications

Dennis Dvorak

Standard Practice for

Acceptance Sampling Plans for Highway Construction

AASHTO Designation: R 9-05 (2022)

Technically Revised: 2005 Reviewed but Not Updated: 2022

Tech Subcommittee: 5c, Quality Assurance and Environmental

Optimal Procedures for Quality Assurance Specifications

Publication No. FHWA-RD-02-095

https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/pccp/02095/02095.pdf

Source: FHWA

Setting Limits Depends on Data

- Are your pavements performing well?
- Does your data reflect performance?

Specification Limits

- Simplified Definition:
  - The value(s) placed on a quality characteristic that defines satisfactory material.

  - Density…… 92%
  - Asphalt Content…… Target AC ± 0.3%
  - Compressive Strength…… 4000 psi

Acceptable Quality Level (AQL)

Acceptable Quality Level (AQL)

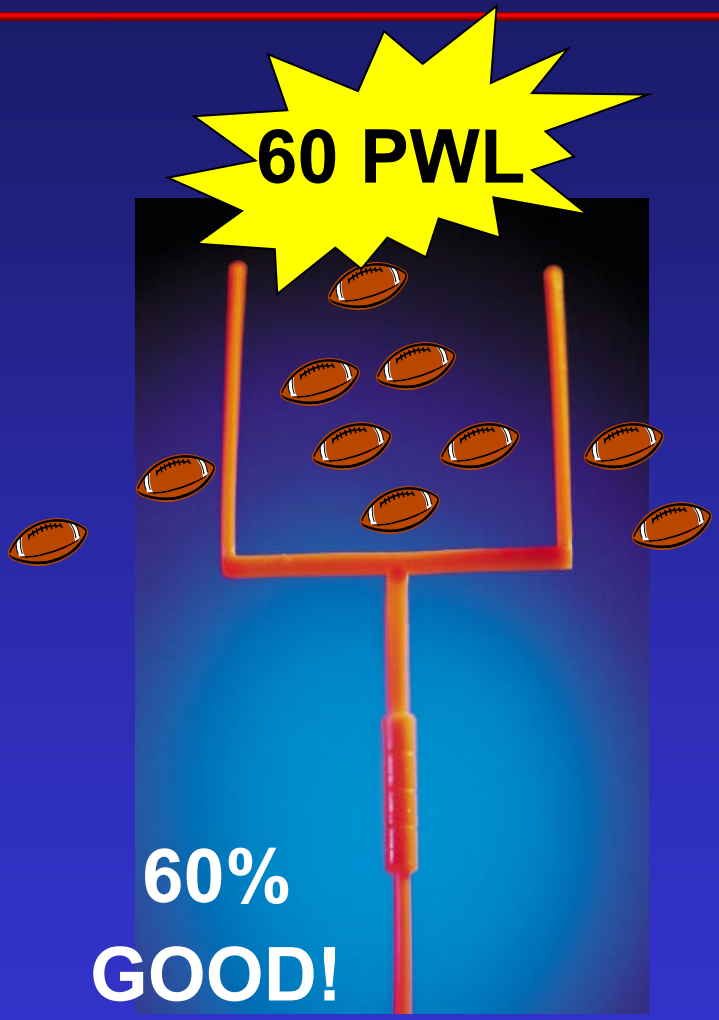
- Simplified definition
  - That [true] PWL value at which the contractor should get 100% payment
- Commonly used AQL value
  - 90 PWL

Specification Limits and AQL

- Assuming good performance, use the material and construction data
- Specification limits are determined in conjunction with AQL
- AQL and specification limits are used together to define the material that we want on the project

Football Analogy

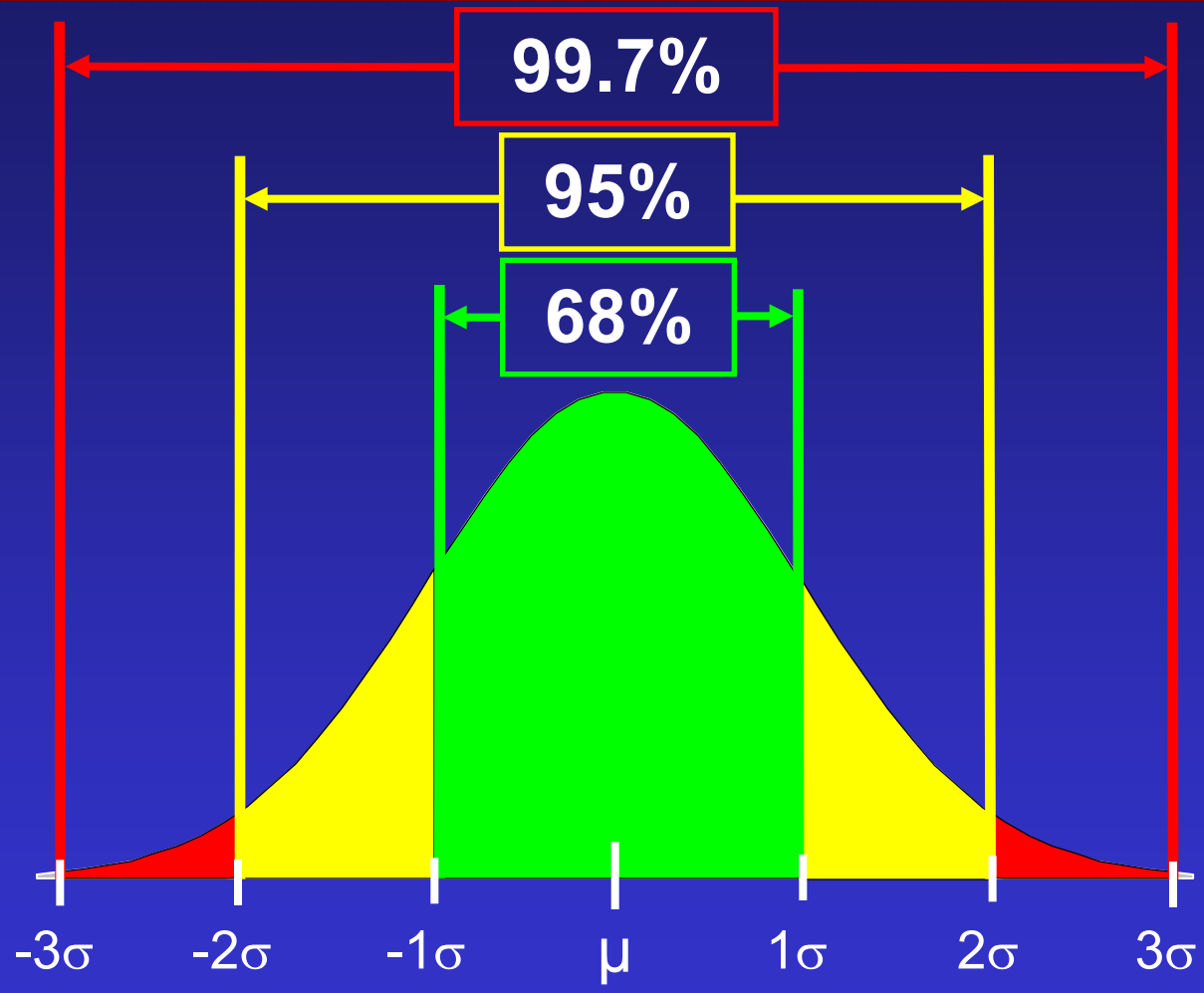
Spec Limits and Goal Posts are Similar



(within the limits)

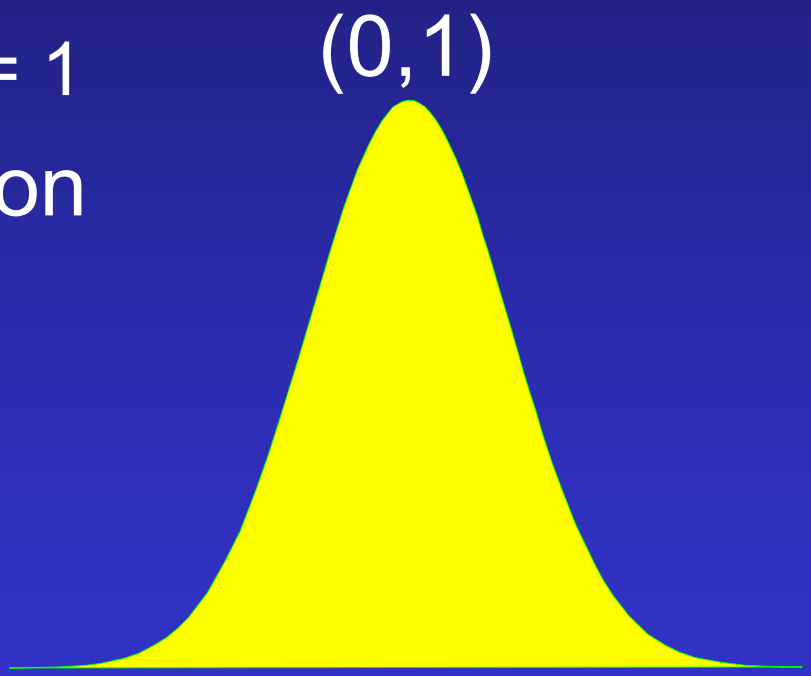
(within the limits)

Standard Deviation



Standard Normal Distribution

- A normal distribution where
  - Mean (μ) = 0
  - Standard deviation (σ) = 1
- Also called “Z” distribution



Z-Table

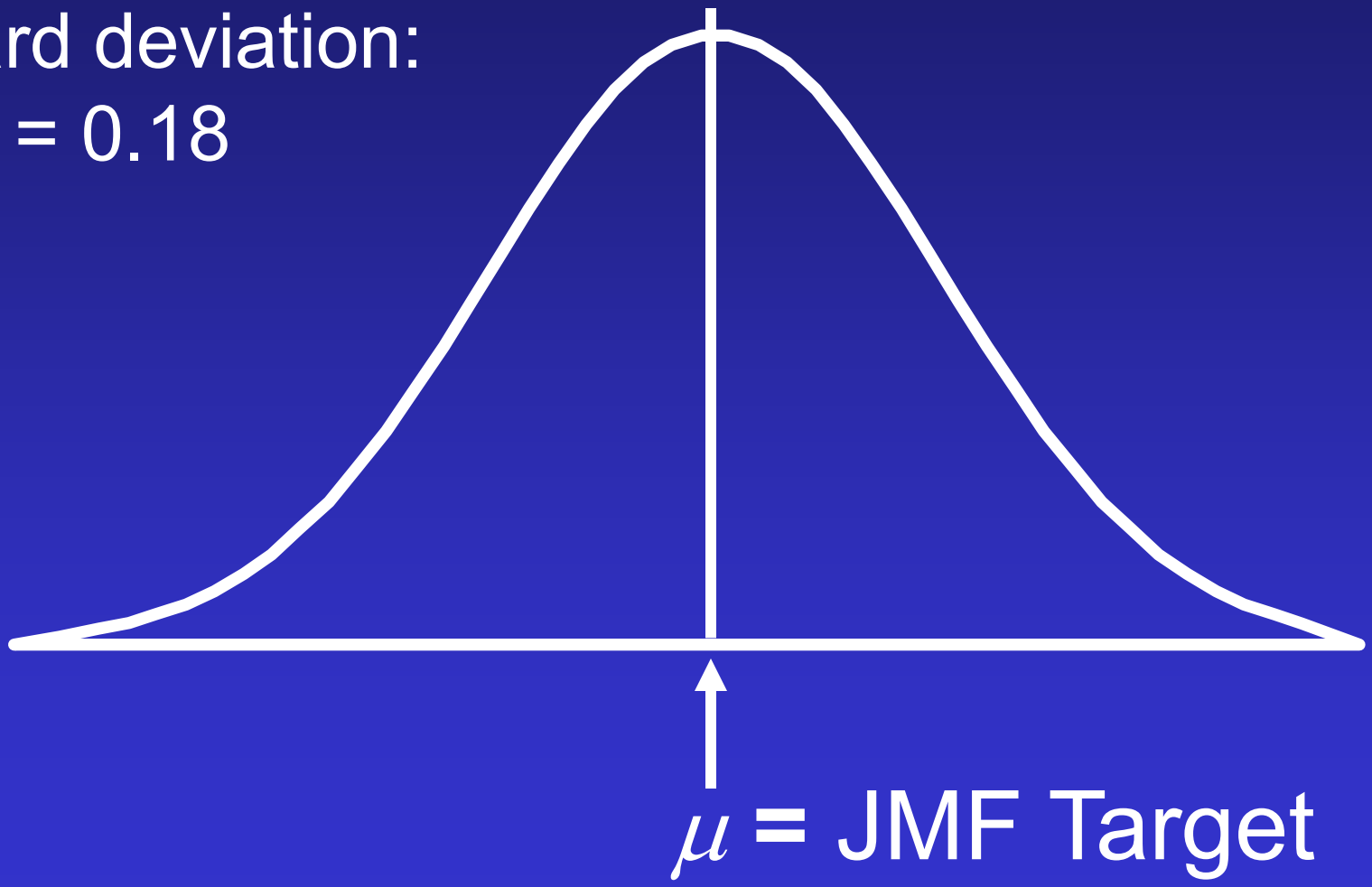
$\pm Z\sigma$ Regions for Selected Areas Under the Normal Distribution

Area	0.99	0.95	0.90	0.85	0.80
$\pm Z$	2.576	1.960	1.645	1.439	1.282

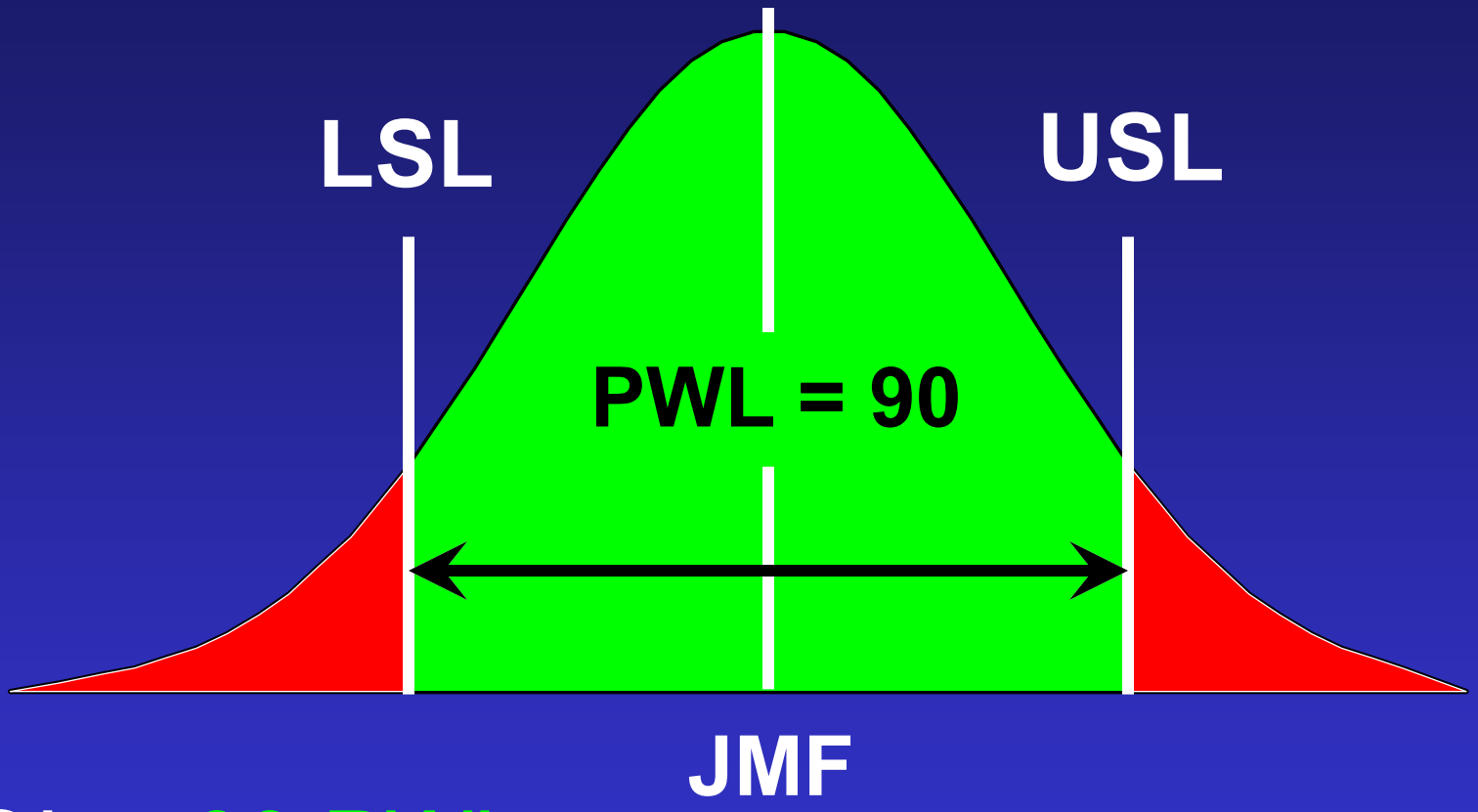
Asphalt Content Example

Typical process standard deviation:

$\sigma = 0.18$



Example (cont'd)



AQL = 90 PWL

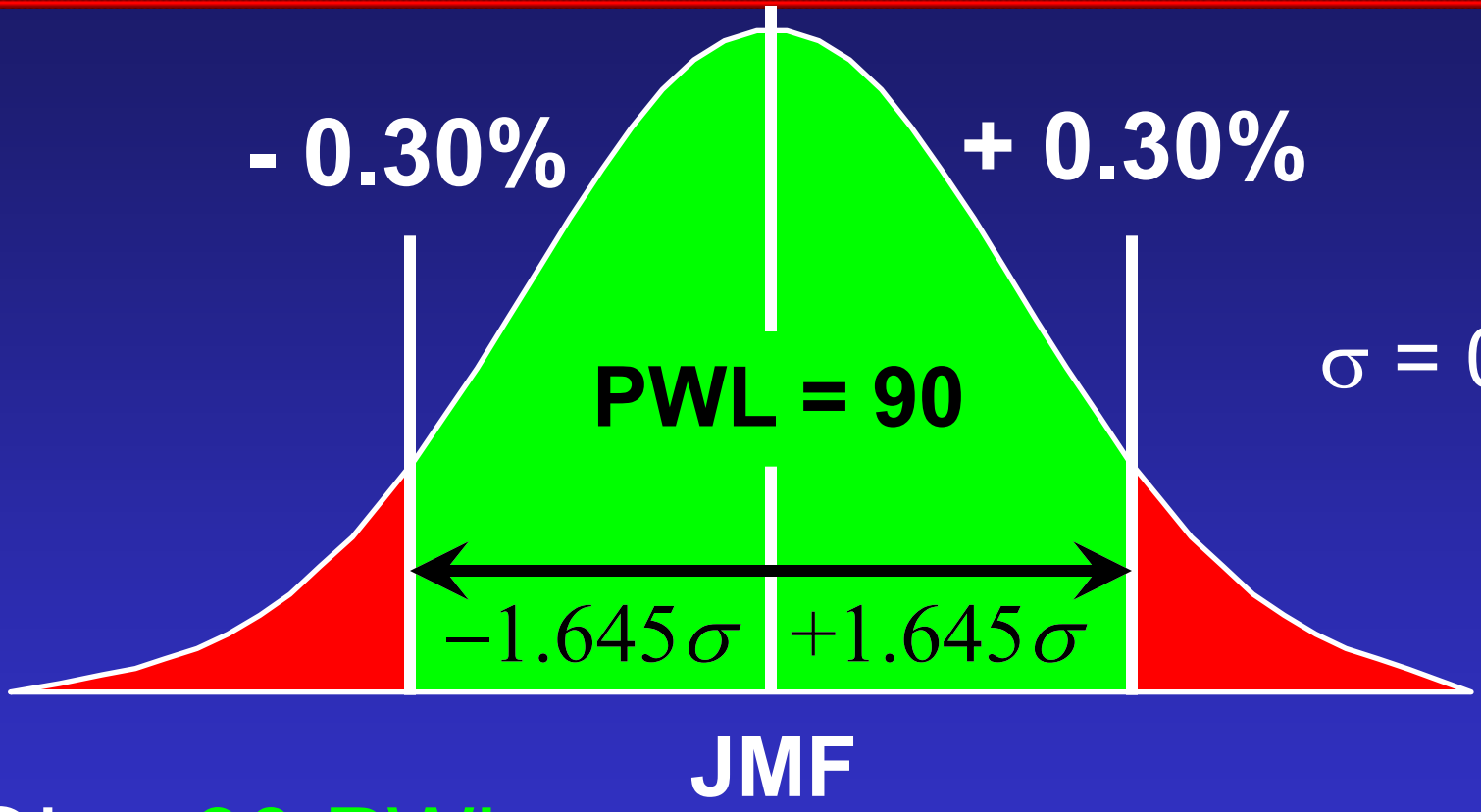
Specification Limit = $\mu \pm (Z * \sigma)$

Example : Z-Table

$\pm Z\sigma$ Regions for Selected Areas Under the Normal Distribution

Area	0.99	0.95	0.90	0.85	0.80
$\pm Z$	2.576	1.960	1.645	1.439	1.282

Example (cont'd)



AQL = 90 PWL

Limits = ± (1.645 × 0.18) or ± 0.30%

Standard Deviation

"Pooled" Standard Deviation

- Standard deviations (s) are not additive
  - Averaging standard deviations is not correct
- Variances (s^2) are additive

"Pooled" Standard Deviation

- calculate pooled variance

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2 + \ldots + (n_k - 1)s_k^2}{n_1 + n_2 + \ldots + n_k - k}$$

- "Pooled" standard deviation (s_p)

$$s_p = \sqrt{s^2_p}$$

Recalibrating PWL Updating Specification Limits

Recalibrating PWL Revising Specification Limits

- Revisit PWL specification limits periodically
  - After Implementation of PWL Specification
  - After Significant Specification Changes
  - After contactors have adjusted processes to meet specification
- Reevaluate based on the entire population of data used for acceptance

Revising Specification Limits

- Adjust Specification Limits As Necessary
  - Average pay factor should be slightly > 1.00
  - The majority of lots should not have maximum incentive or disincentive
  - Adjust the Specification Limits if needed

A. JAMES CLARK
SCHOOL OF ENGINEERING

Balancing Risks & Pay Factors in PWL Specifications

Dr. Dimitrios Goulias
TRB - AKC30 Committee Chair
Quality Assurance Management




TRB 2025 Webinar:

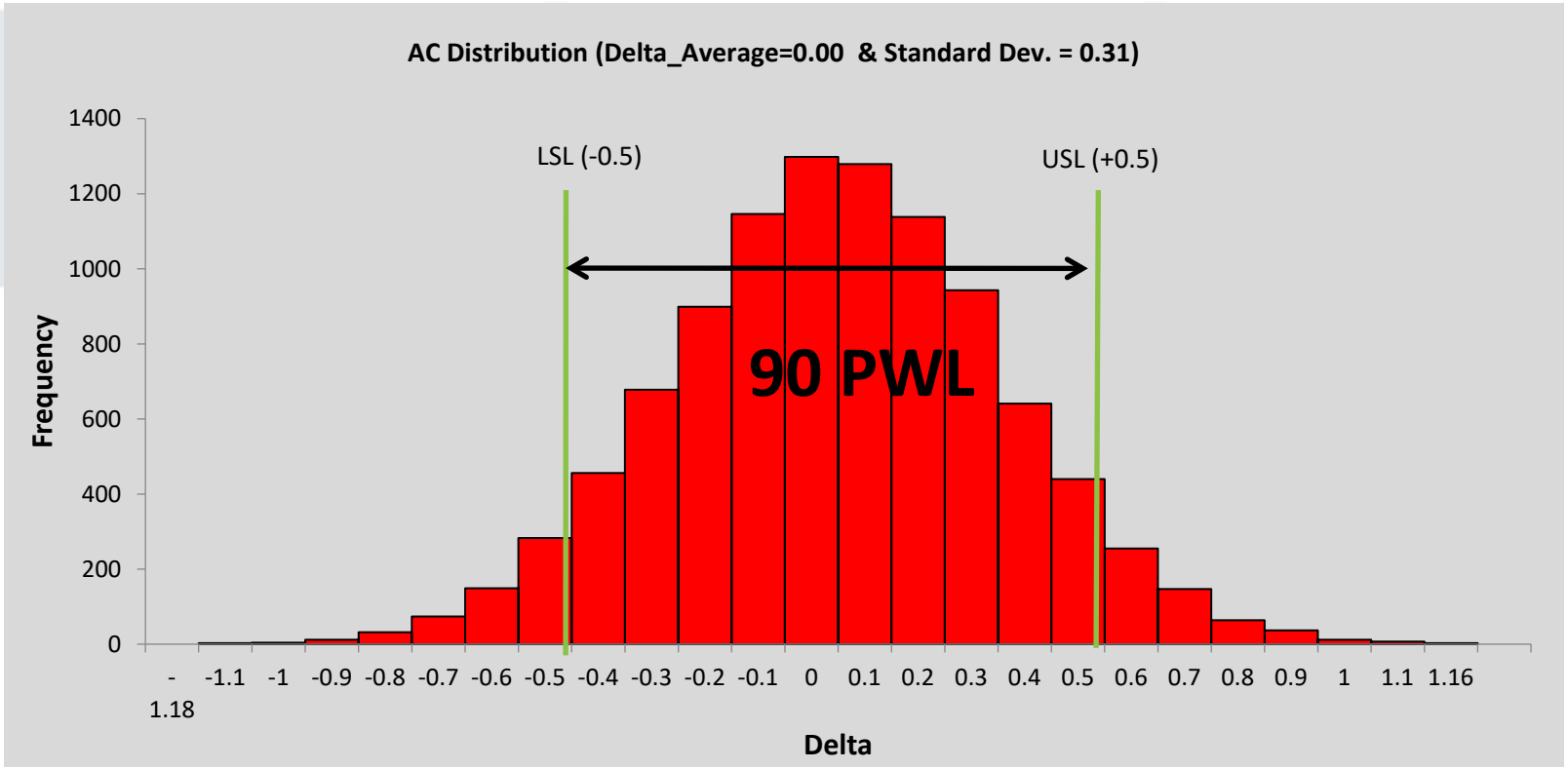
Quality Assurance of Transportation Materials and Construction—Part II

PWL Acceptance Specifications

- Examples
  - PWL on material & mixture properties (BC%, #4, #8, #200)
  - Composite CMPWSL on mixture
  - Dynamic modulus (E)
  - Field density
  - Strength, Smoothness, Thickness

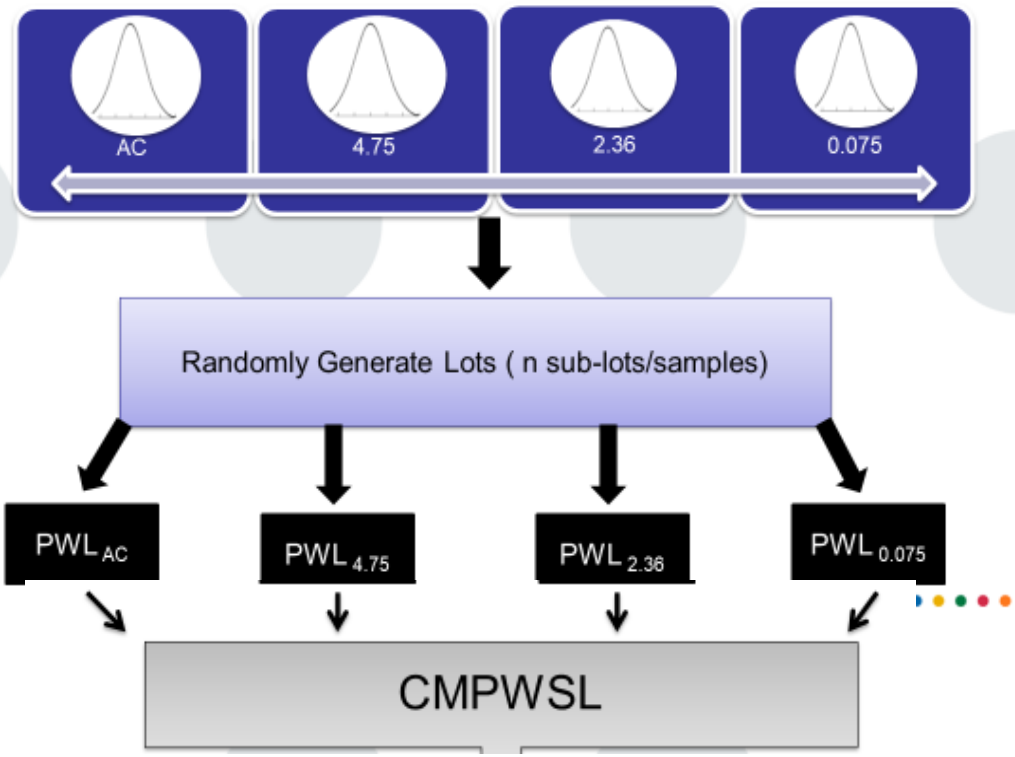
Example Specification (Dense Graded HMA)

- Specification tolerances
- AC Distribution



Acceptance Risks

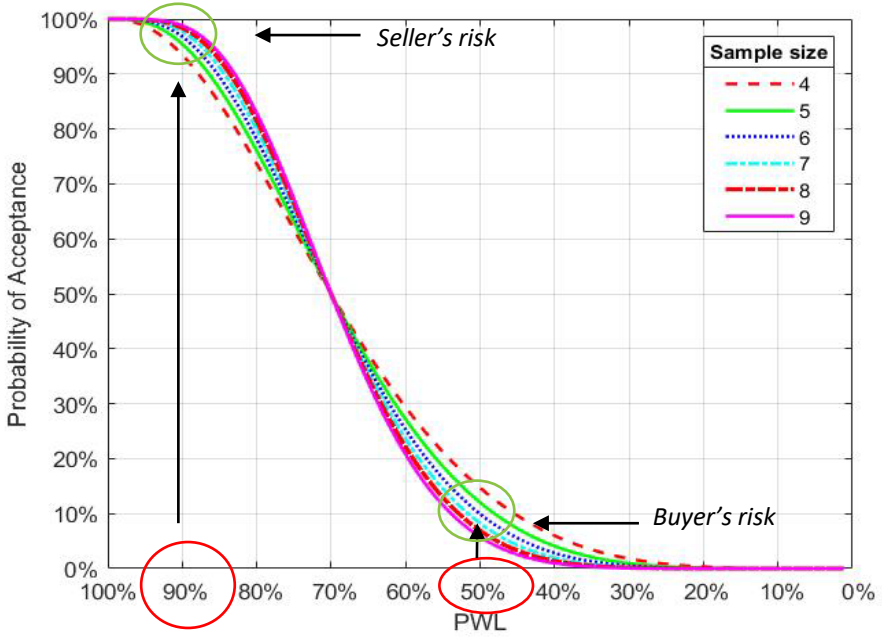
- Distributions of Material Properties
  - Historical data
  - Simulation & OC Development



Acceptance Risks

- Development of Operating Characteristics (OC) curves
  - Individual PWL or CMPWSL

- Acceptance Risks
  - AQL (acceptable quality level) – 90%
  - RQL (rejectable quality level) - 50%
  - Type I, risk (α seller's => AQL rejected)
  - Type II risks (β buyer's => RQL accepted)



Zhao & Goulias TRR 2021

Criticality	Recommended α	Recommended β
Critical	0.050	0.005
Major	0.010	0.050
Minor	0.005	0.100
Contractual	0.001	0.200

AASHTO R9

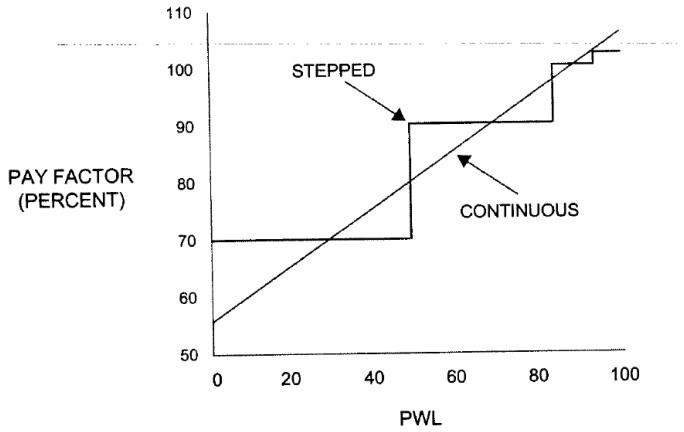
Specification Pay Factors (examples)

PF variable versus stepped functions

- $MF = 0.55 + 0.5\ CMPWSL$
  - $\text{if} CMPWSL < 40\%\ MF = 0$
  - $\text{if} CMPWSL \geq 90\%\ MF = 1$ (**no bonus provision**)

- $CMPWSL = \frac{w1\ PWSL1 + w2\ PWSL2 + w3\ PWSL3 + w4\ PWSL4}{\sum wi}$

- **Bonus provision** when CMPWSL>90%, with max of 5% incentive



AASHTO R9-36

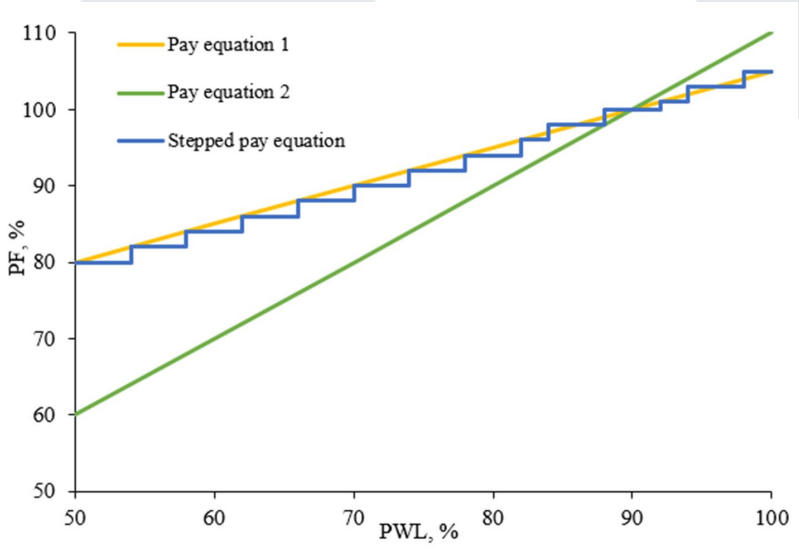
Specification Pay Factors (examples)

PF variable versus stepped functions

- $CMPF = 0.55 + 0.5\ CMPWL$

$$CMPWL = 0.25 \times PWL_{strength} + 0.35 \times PWL_{thickness} + 0.4 \times PWL_{roughness}$$

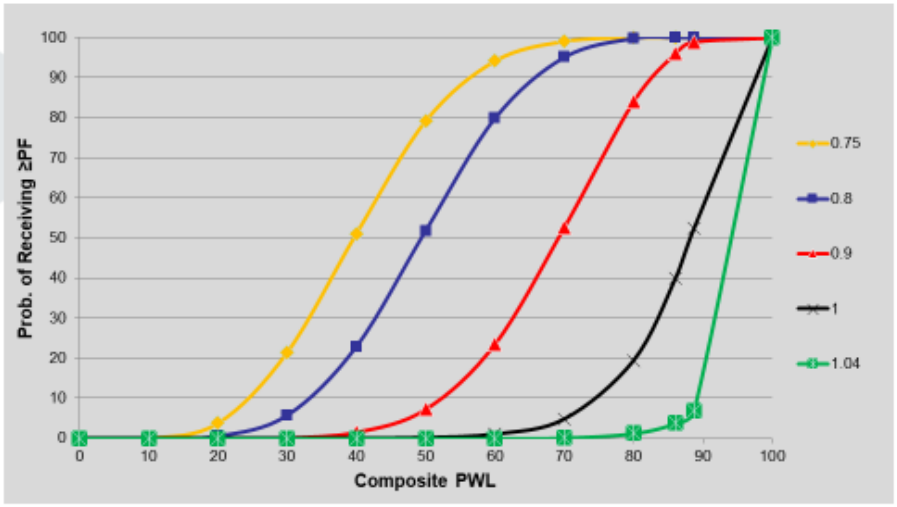
$$CPF = 0.25 \times PF_{strength} + 0.35 \times PF_{thickness} + 0.4 \times PF_{roughness}$$

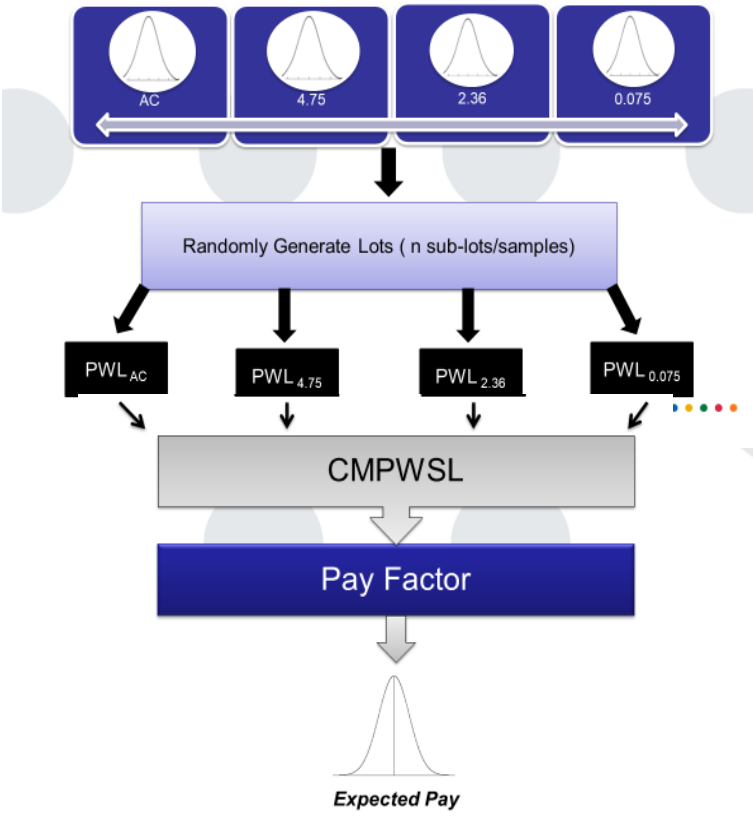


Zhao & Goulias TRB 2021

Acceptance Risks & PF Assessment

- Risks Analysis & Expected Pay
  - Historical data
  - Simulation & OC Development
  - Probability of EP





Karimi & Goulias IJCER 2018

Acceptance Risks & PF Assessment

- Balancing Risks with Pay Factors
  - PF variable versus stepped functions
  - Bonus provisions
  - Integrating performance in PF

FHWA-RD-02-095, Optimal Procedures for Quality Assurance Specifications

Acceptance Risks & PF Assessment

- Integrating performance in PF
  - Example ΔY with E*

- Relating E* values to performance (i.e. predicted service life):

$$Y = \frac{\log\left(\left(\frac{RUT}{RUTc} * \frac{E^*}{E^*c}\right)^{2.08662} \left((1+r)^{Yc} - 1\right) + 1\right)}{\log(1+r)}$$

  - RUT = rut depth = 1.1421 $E^{-0.71}$ = 0.521 in
  - RUT_C = rut depth criterion value, deterministically predicted = 0.446 in
  - E^* = dynamic modulus = 302.2 ksi
  - E^*_c = dynamic modulus criterion value = 374.1 ksi
  - r = growth rate (rate of traffic increase per year) =4%
  - Y_c = design life =19.766 years
  - Y = predicted service life

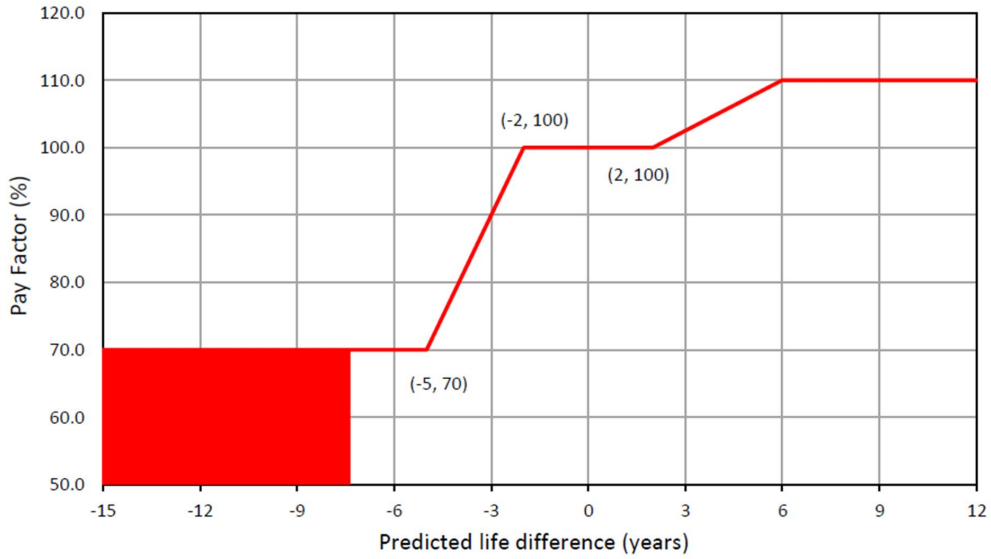
NCHRP 704 A Performance-Related Specification for Hot-Mixed Asphalt

Acceptance Risks & PF Assessment

- Integrating performance in PF
  - Example ΔY with E*

- Example HMA Pay Factor Schedule:

$$\begin{cases} \Delta Y \leq -7\ years \Rightarrow PF = 0\% \\ -7 < \Delta Y \leq -5 \Rightarrow PF = 70\% \\ -5 < \Delta Y \leq -2 \Rightarrow PF = 10\Delta Y + 120 \\ -2 < \Delta Y \leq +2 \Rightarrow PF = 100\% \\ +2 < \Delta Y \leq +6 \Rightarrow PF = 2.5\Delta Y + 95 \\ \Delta Y \geq +6 \Rightarrow PF = 110\% \end{cases}$$



NCHRP 704 A Performance-Related Specification for Hot-Mixed Asphalt

Example Analysis: Zhao, Goulias, Karimi, TRB 2023 & TRR 2025

Balancing Risks and Pay Factors

- Improve production quality and uniformity
- Assess Alternatives
  - Risk Analysis: Type I, II risks
  - AQL & RQL to balance risks
  - Revised Specification Tolerances
  - Sample size (n) effects

A. JAMES CLARK
SCHOOL OF ENGINEERING

Dr. Dimitrios Goulias

University of Maryland

dgoulias@umd.edu

Thank You !

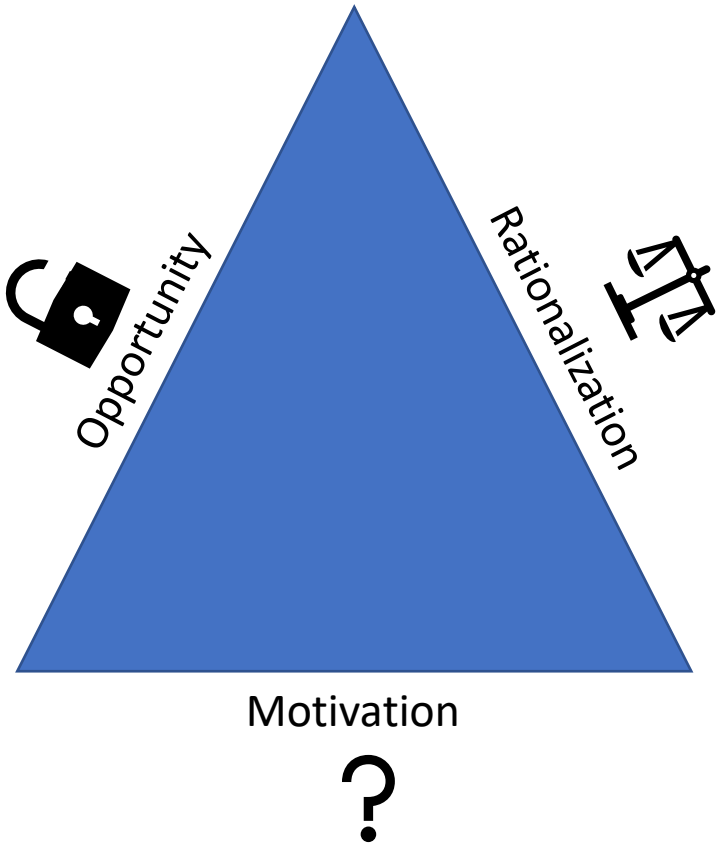
Monitoring Quality Assurance Specifications

Mike Copeland

Construction & Materials Quality Program Manager

Idaho Transportation Department

Where We Left Off: Fraud Risks in Quality Assurance

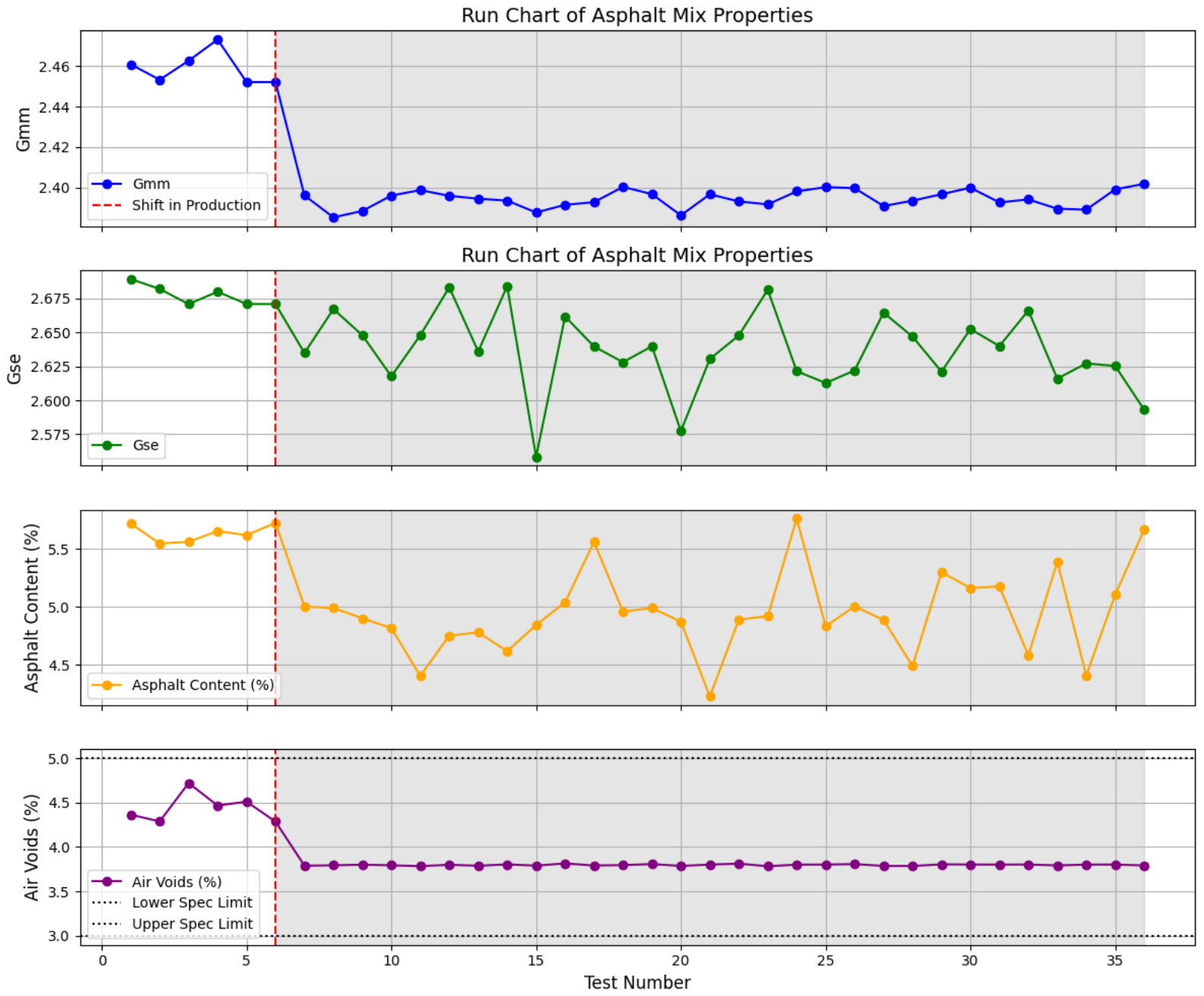


Why QA Monitoring is Critical

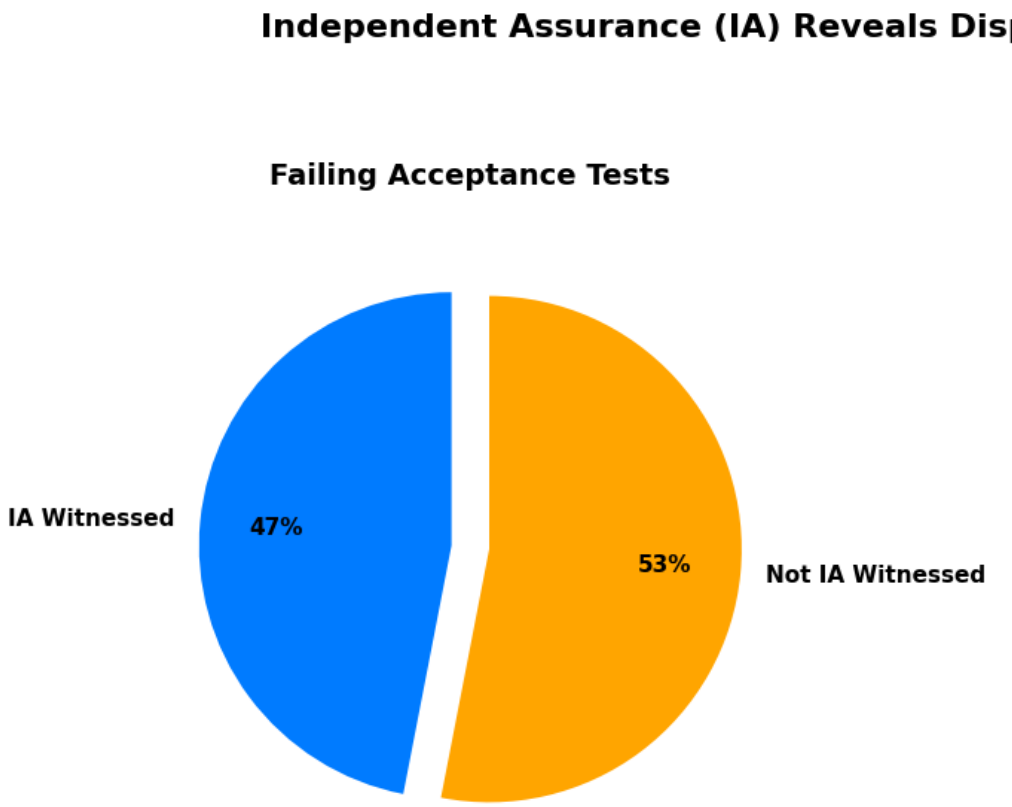
Evolution of Quality

Case Study: Unintended Consequences of Static QA Specifications in Idaho

Look Out For Red Flags

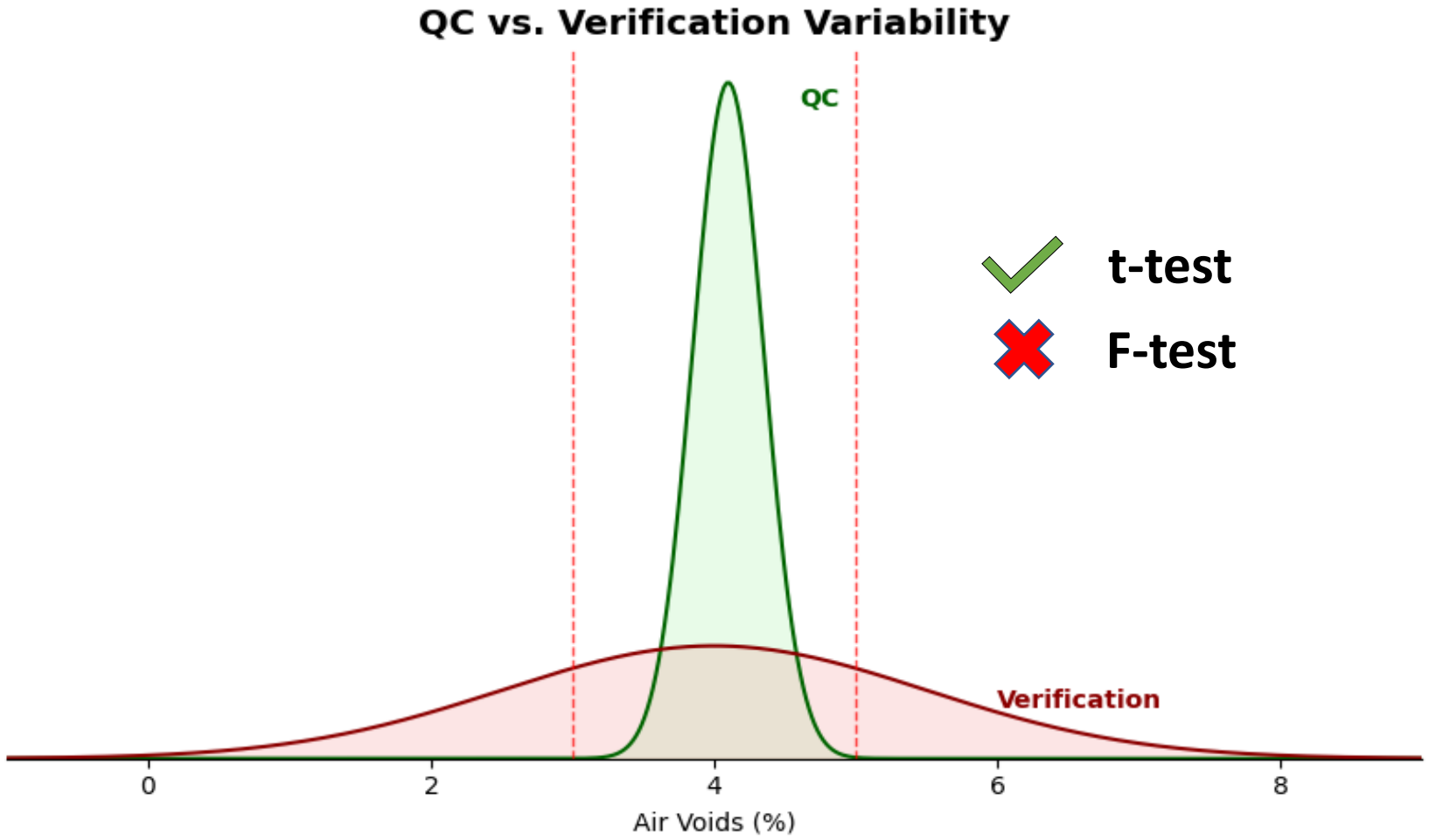


The Oversight Effect: When Do Tests Fail?



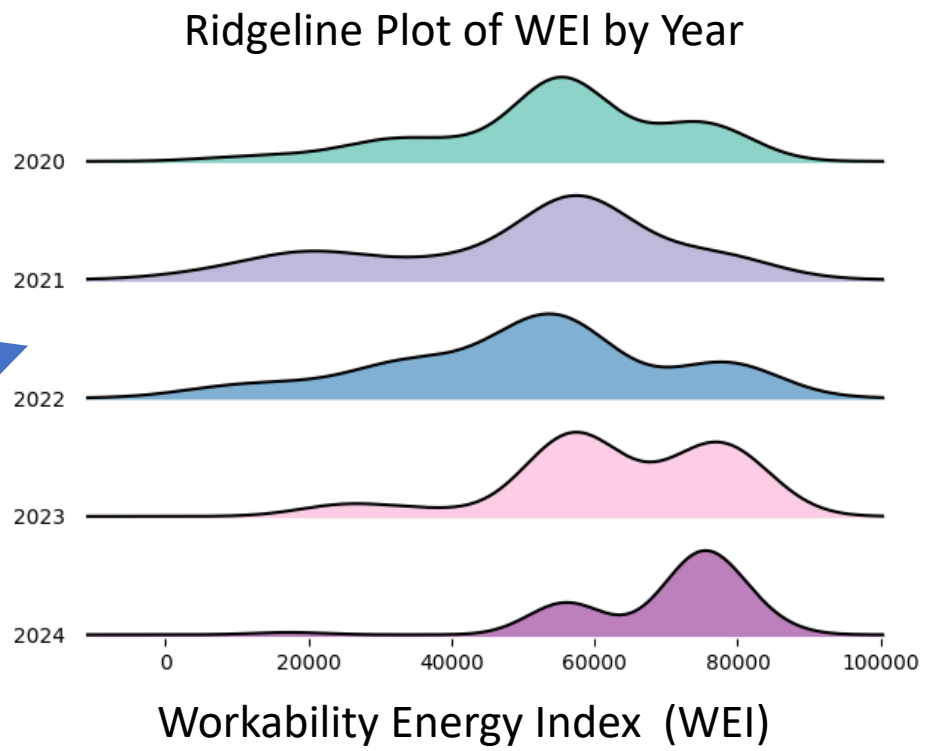
- **IA Witnessed 4% of all testing**

Identify Loopholes and Weaknesses

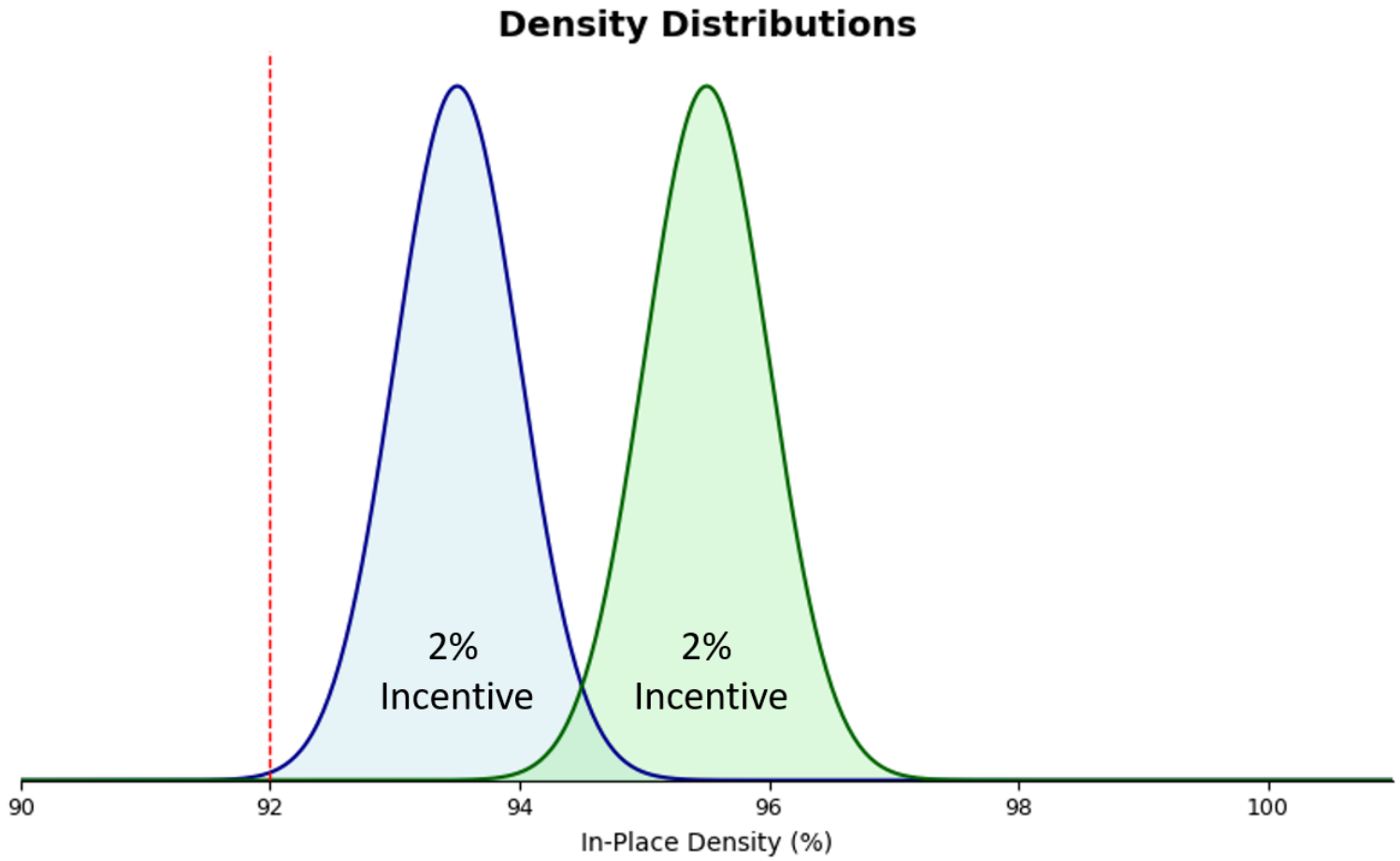


War Gaming in Action: Plant Sampling

How Do We Monitor Specifications?

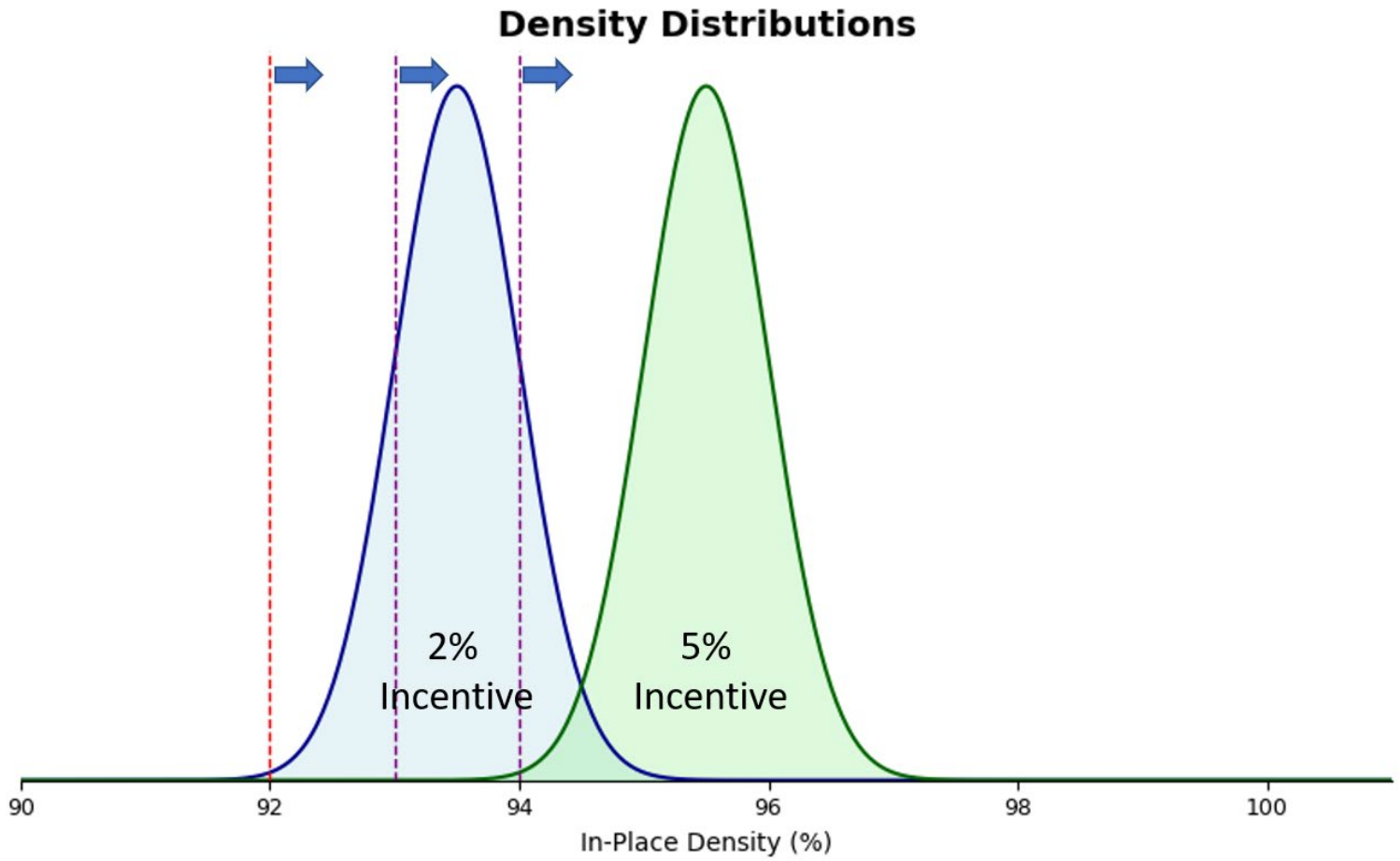


Conventional Incentives



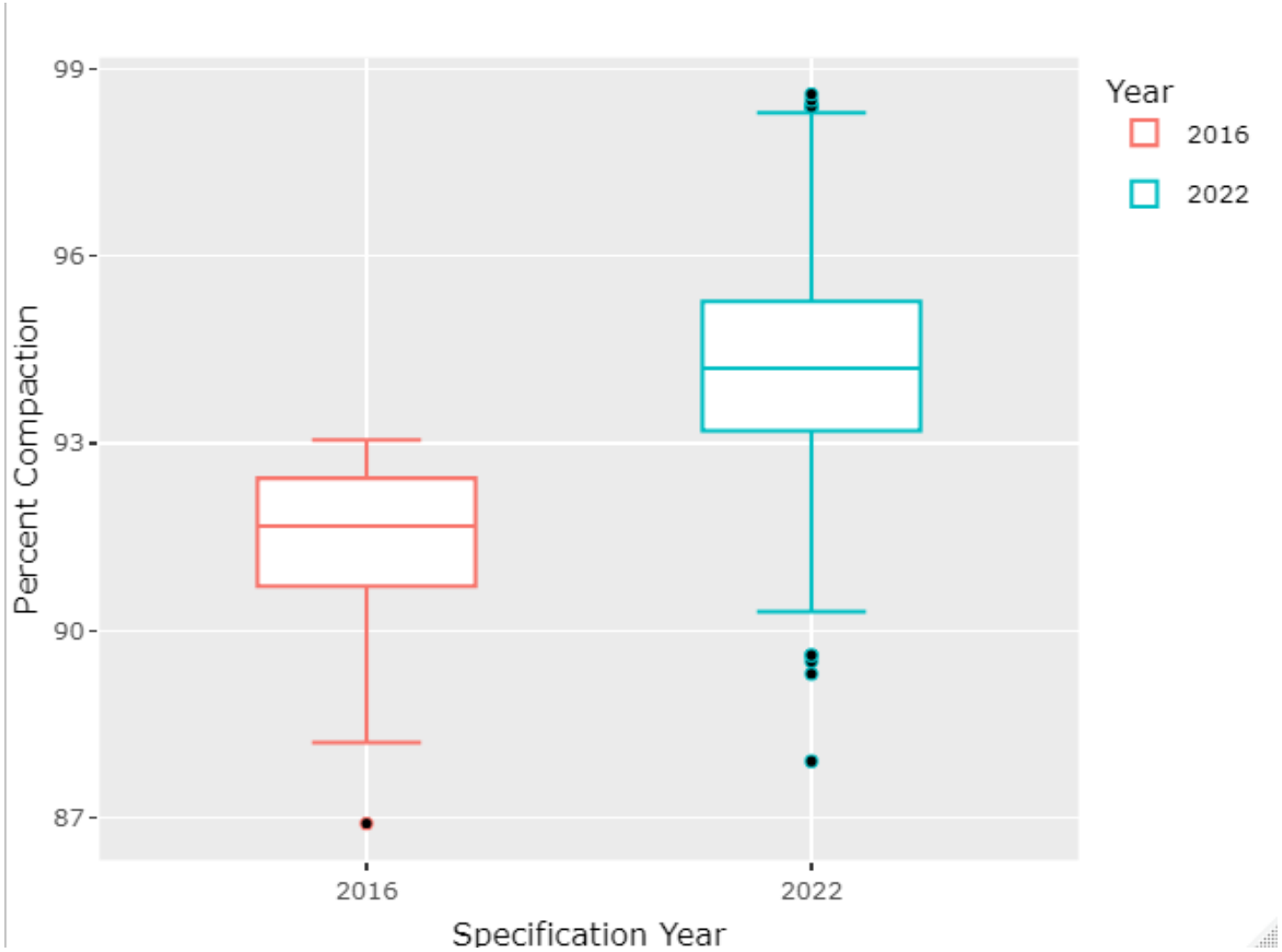
$$PF_{MLD} = \frac{55 + 0.5 \times PWL_{92}}{100}$$

Optimizing Incentives

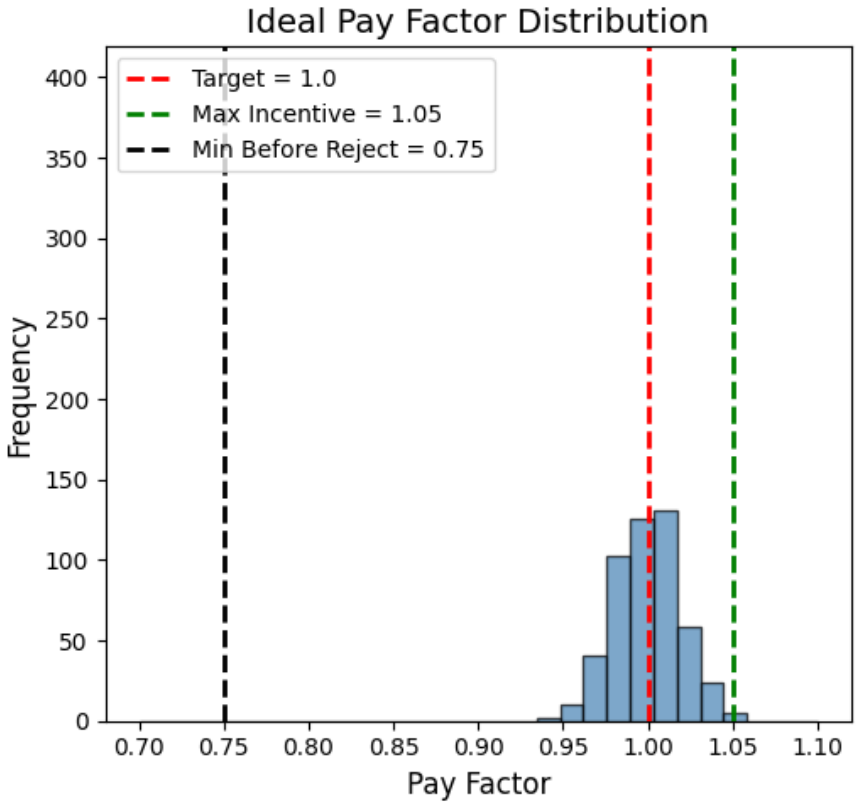


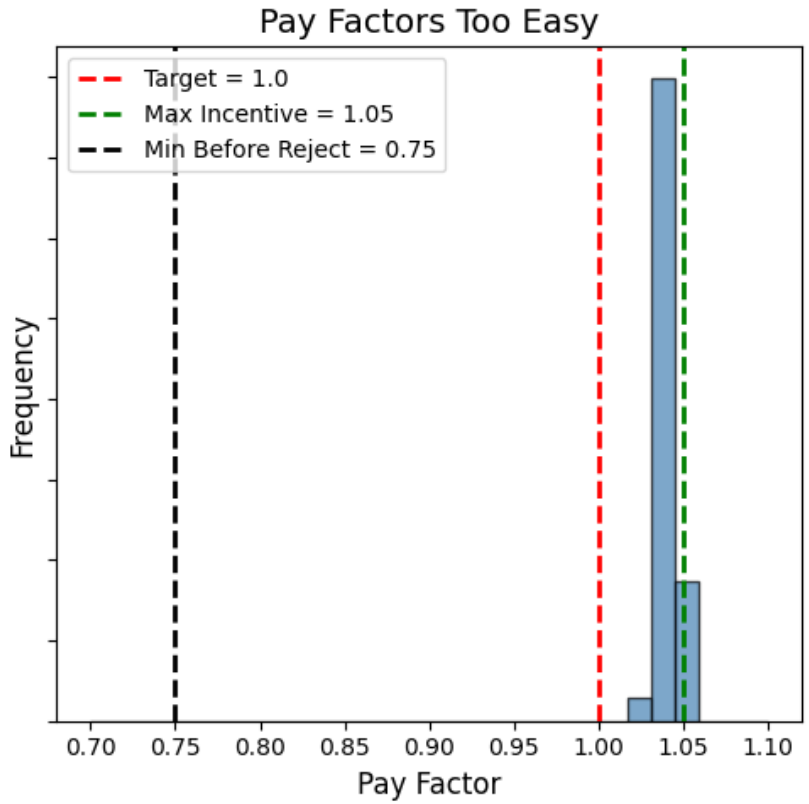
$$PF_{MLD} = \frac{55+0.5\times\left(PWL_{92}-\frac{(PWL_{92}-90)+|PWL_{92}-90|}{2}\right)}{100} + \frac{(PWL_{92}-90)+|PWL_{92}-90|}{1000} + \frac{(PWL_{93}-90)+|PWL_{93}-90|}{1000} + \frac{(PWL_{94}-90)+|PWL_{94}-90|}{1000}$$

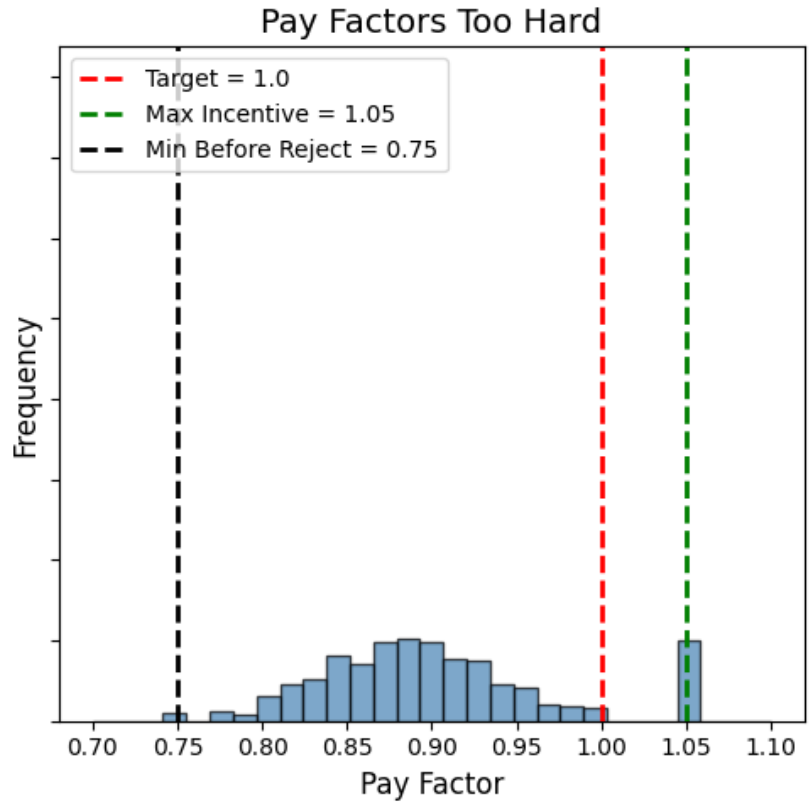
Proof in the Data: Incentives Drive Higher Density



When do I Adjust Specification Limits?

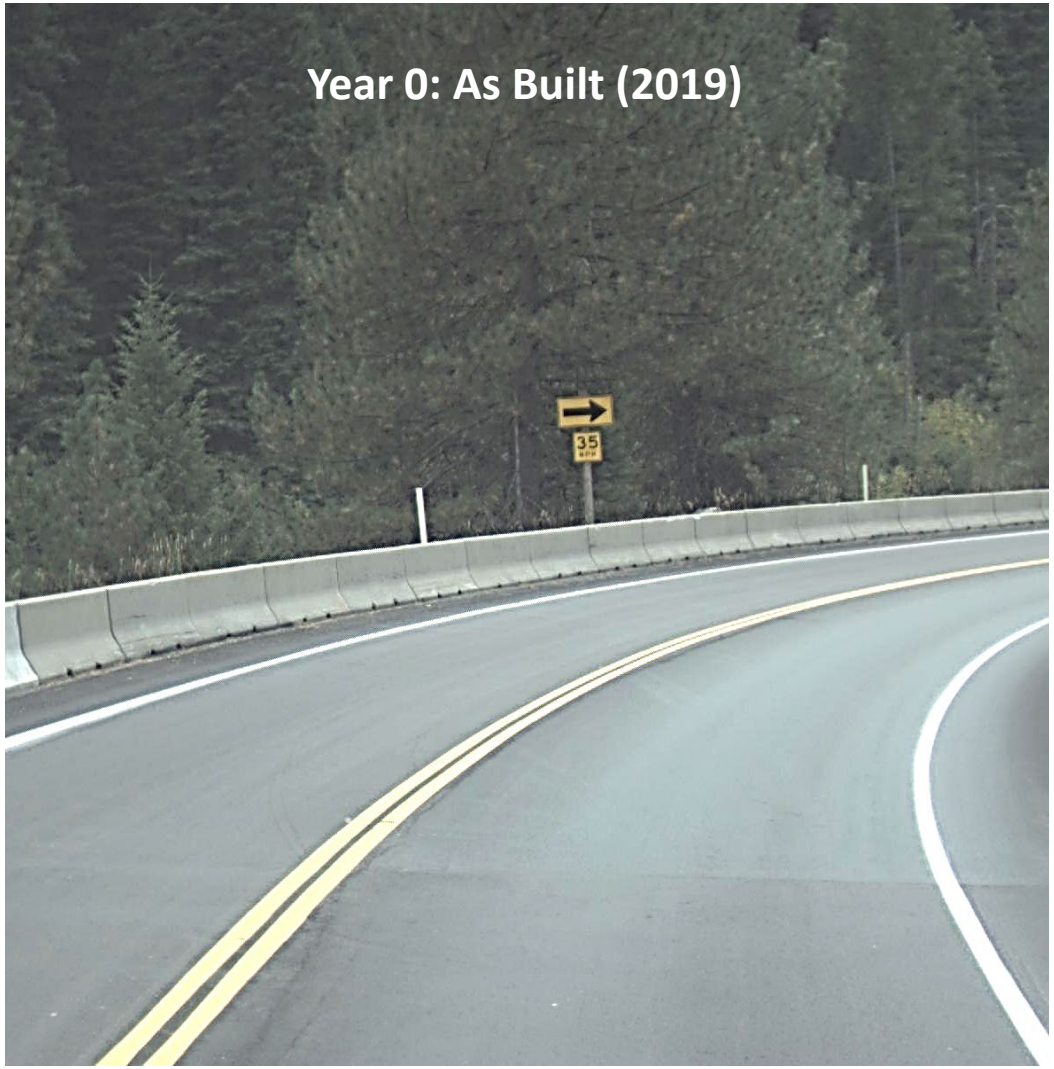




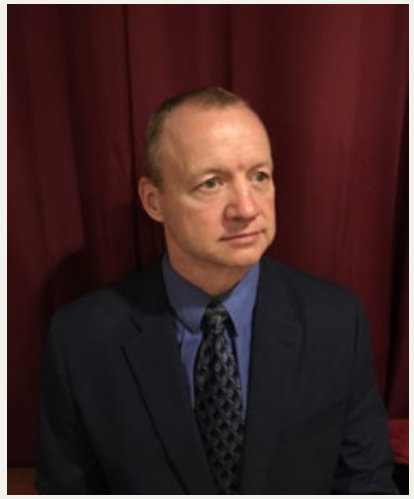


Conclusion

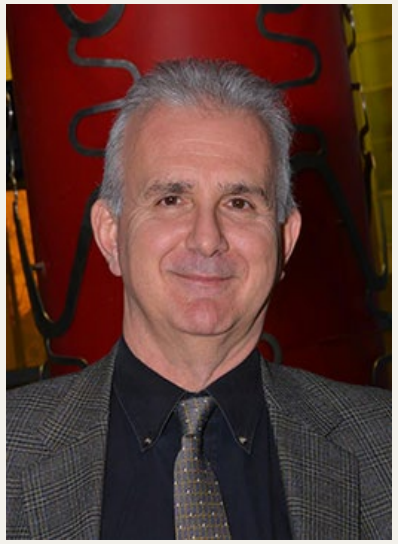
Monitor, Analyze, and Adapt.



Today's presenters

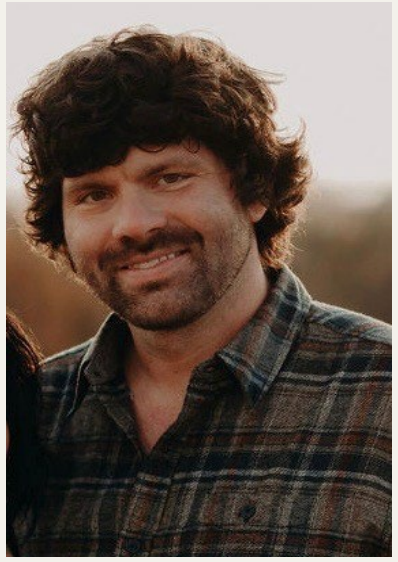


Mark Felag
mfelag@hotmail.com
Mark E. Felag, PE, LLC



Dimitrios Goulias
dgoulias@umd.edu
University of Maryland

Dennis Dvorak
Ddvorak59@gmail.com
Federal Highway Administration
Resource Center



Mike Copeland
Michael.Copeland@itd.idaho.gov
Idaho Transportation Department

NATIONAL ACADEMIES *Sciences Engineering Medicine*

Upcoming events for you

March 26, 2025

TRB Webinar: AI's Impact on Systems, Enterprise, and Cyber Resilience in Transportation

March 28, 2025

TRB Webinar: Innovations in Concrete Bridge Deck Design, Construction, and Materials

https://www.nationalacademies.org/trb/events

NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

Subscribe to *TRB Weekly*

If your agency, university, or organization perform transportation research, you and your colleagues need the *TRB Weekly* newsletter in your inboxes!

Each Tuesday, we announce the latest:

- RFPs
- TRB's many industry-focused webinars and events
- 3-5 new TRB reports each week
- Top research across the industry

Spread the word and subscribe!

https://bit.ly/ResubscribeTRBWeekly

Discover new TRB Webinars weekly

Set your preferred topics to get the latest listed webinars and those coming up soon every Wednesday, curated especially for you!

https://mailchi.mp/nas.edu/trbwebinars

And follow #TRBwebinar on social media

@NASEMTRB
@NASEMTRB
Transportation Research Board

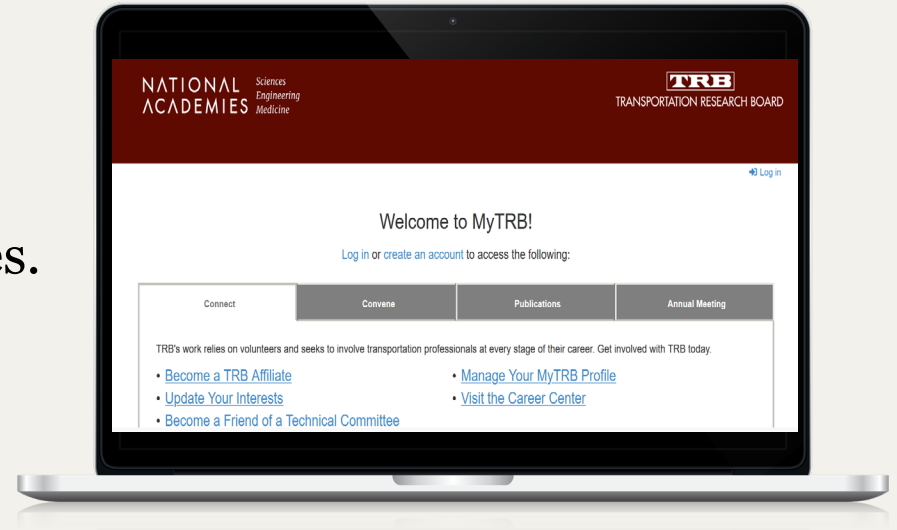
NATIONAL ACADEMIES Sciences Engineering Medicine
TRB TRANSPORTATION RESEARCH BOARD

Get involved

TRB mobilizes expertise, experience, and knowledge to anticipate and solve complex transportation-related challenges.

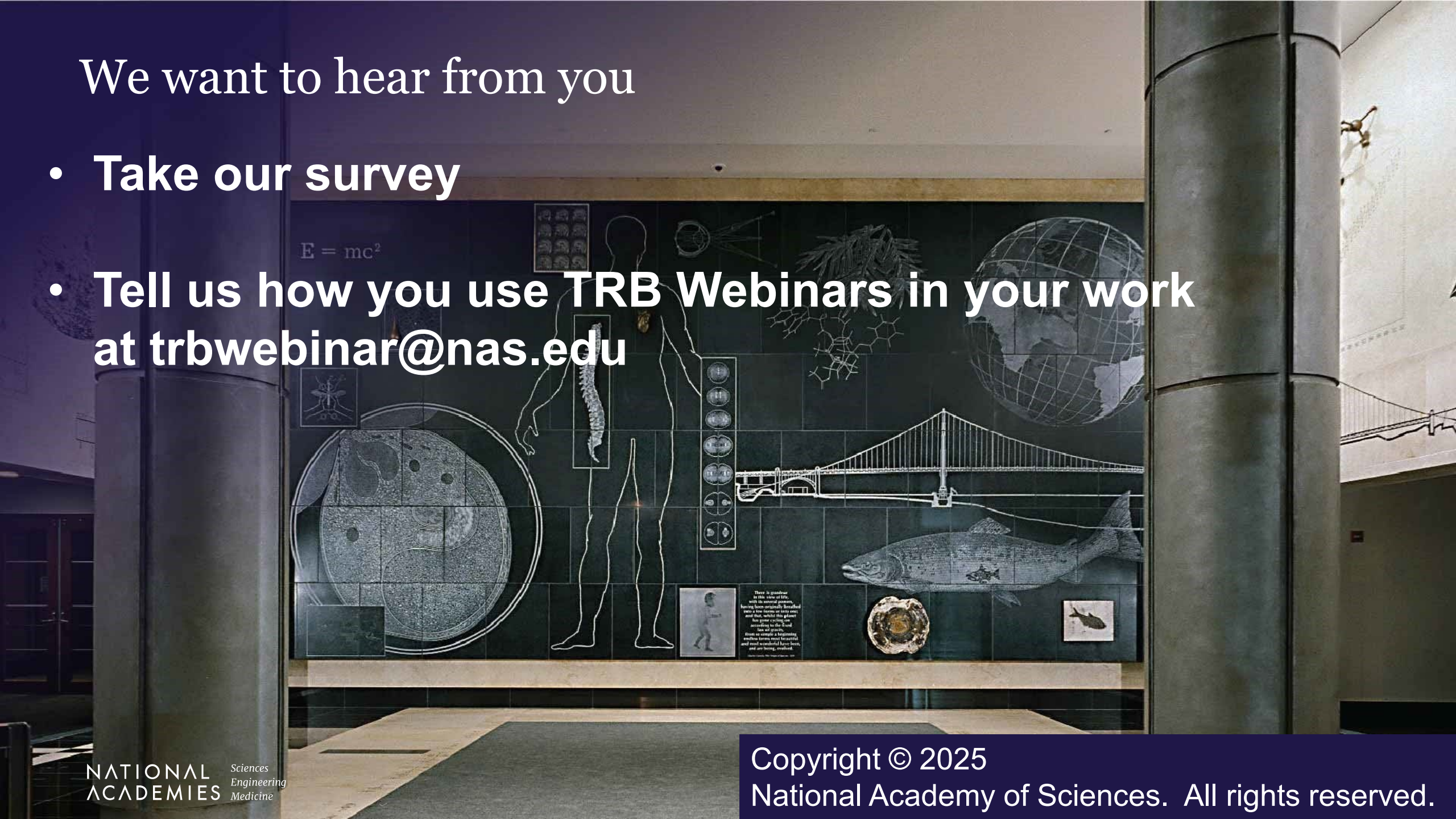
TRB's mission is accomplished through the hard work and dedication of more than **8,000 volunteers**.

https://www.nationalacademies.org/trb/get-involved



We want to hear from you

- **Take our survey**
- **Tell us how you use TRB Webinars in your work at trbwebinar@nas.edu**



NATIONAL ACADEMIES Sciences Engineering Medicine