



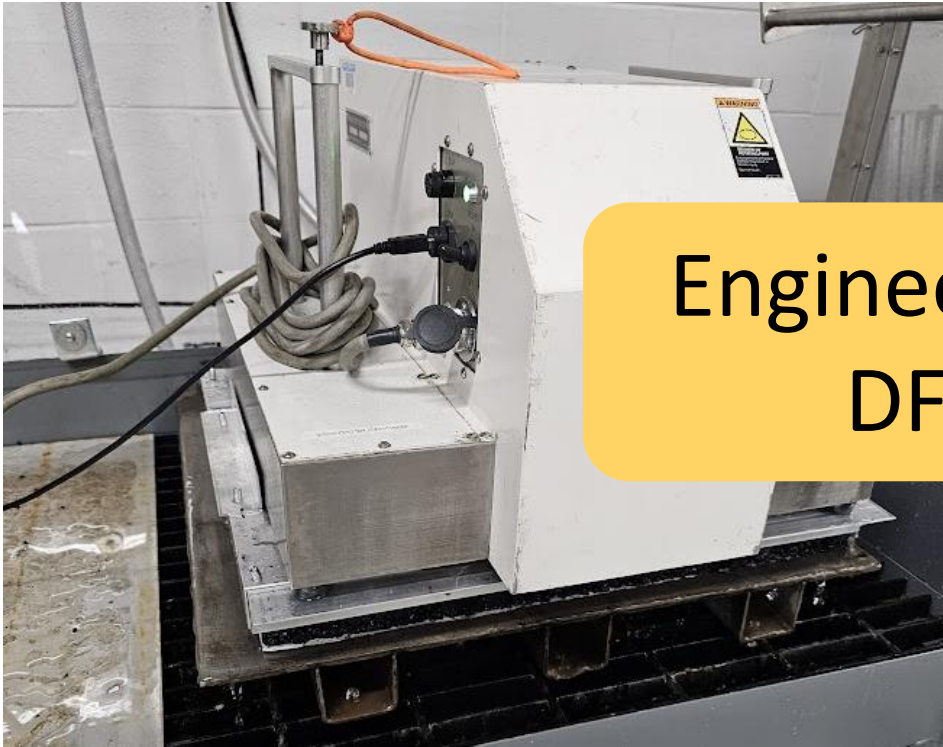
HONORING THE PAST. PAVING THE FUTURE.

ACCOUNTING FOR DEVICE VARIABILITY IN LAB-FIELD FRICTION CORRELATIONS

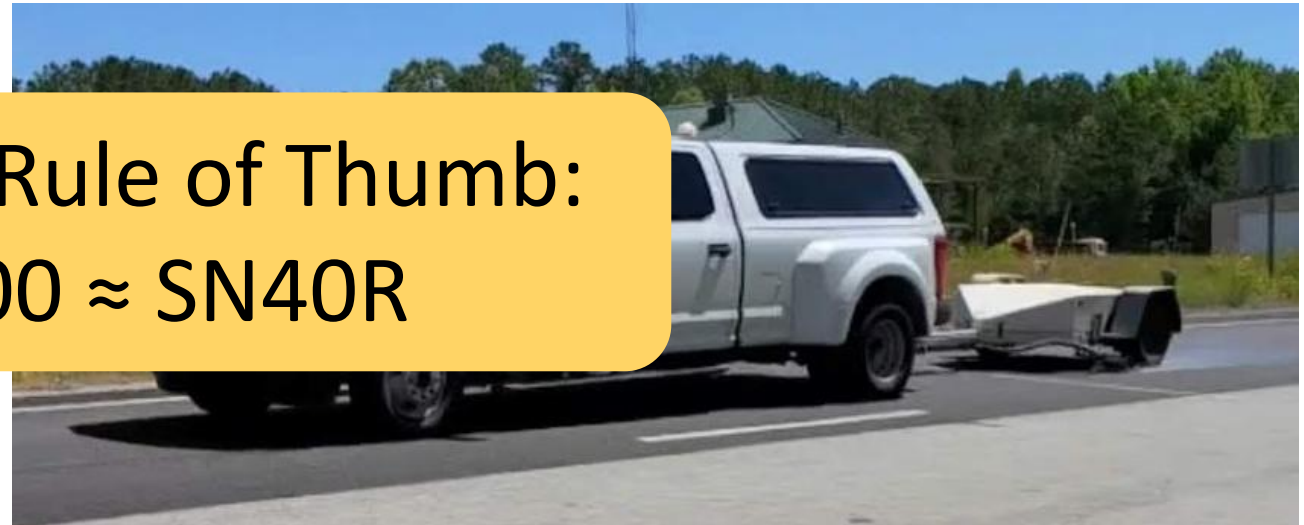
NATHAN MOORE, P.E. | NCAT | APRIL 30, 2026



BACKGROUND - DFT VS. LWFT CORRELATION



Engineering Rule of Thumb:
 $DFT \times 100 \approx SN40R$

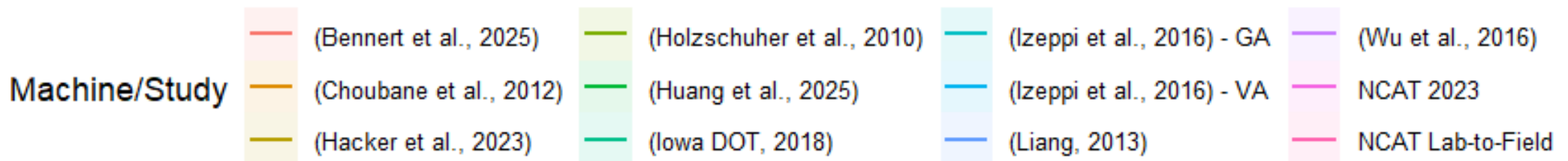
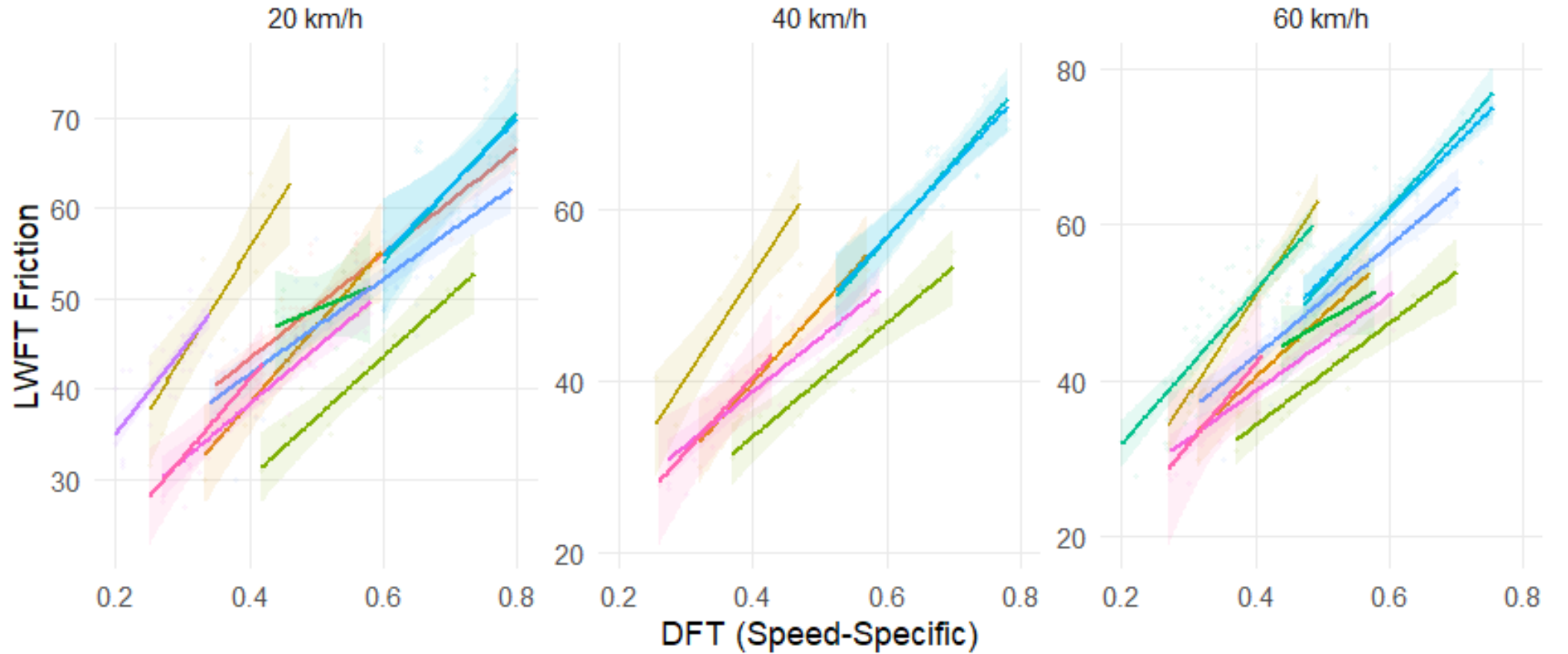




BACKGROUND - DFT VS. LWFT CORRELATION

- What about different surfaces, equipment models, operators, temperatures, weather, etc?
- Plenty of correlation studies have already been completed
 - (Holzschuher et al., 2010) - Florida
 - (Choubane et al., 2012) - Florida
 - (Hacker et al., 2023) - Kentucky
 - (Iowa DOT, 2018) - Iowa
 - (Liang, 2013) - Ohio
 - (Izeppi et al., 2016) - Smart Road, VTTI
 - (Wu et al., 2016) - Louisiana
 - (Huang et al., 2025) - Tennessee
 - (Bennert et al., 2025) - New Jersey
 - Plus unpublished data from NCAT

BACKGROUND - DFT VS. LWFT CORRELATION





OBJECTIVE

- Determine an overall “global” average relationship between DFT and LWFT (SN40R).
 - Calculate the 95% prediction interval for any DFT-LWFT testing pair
-
- Purpose:
 - Forensic tool
 - Design tool
 - Research tool

SUMMARY STATISTICS FROM INDIVIDUAL STUDIES

Study	DFT Speed	N	Root Mean Square Error	R ²	Intercept	Slope
(Izeppi et al., 2016) - GA	20	14	5.5	54%	9.0	76.2
(Izeppi et al., 2016) - VA	20	16	5.1	54%	11.0	73.4
(Choubane et al., 2012)	20	10	3.4	78%	4.3	85.6
(Holzschuher et al., 2010)	20	10	3.0	86%	3.1	67.7
(Hacker et al., 2023)	20	13	5.8	71%	7.9	119.6
NCAT Lab-to-Field 2021	20	4	1.3	97%	6.3	87.1
(Wu et al., 2016)	20	51	2.9	69%	20.6	78.9
NCAT 2023	20	29	3.3	78%	13.3	62.6
(Liang, 2013)	20	49	3.9	82%	19.3	55.4
(Bennert et al., 2025)	20	67	3.2	79%	20.6	57.2
(Huang et al., 2025)	20	8	4.2	15%	33.5	30.6

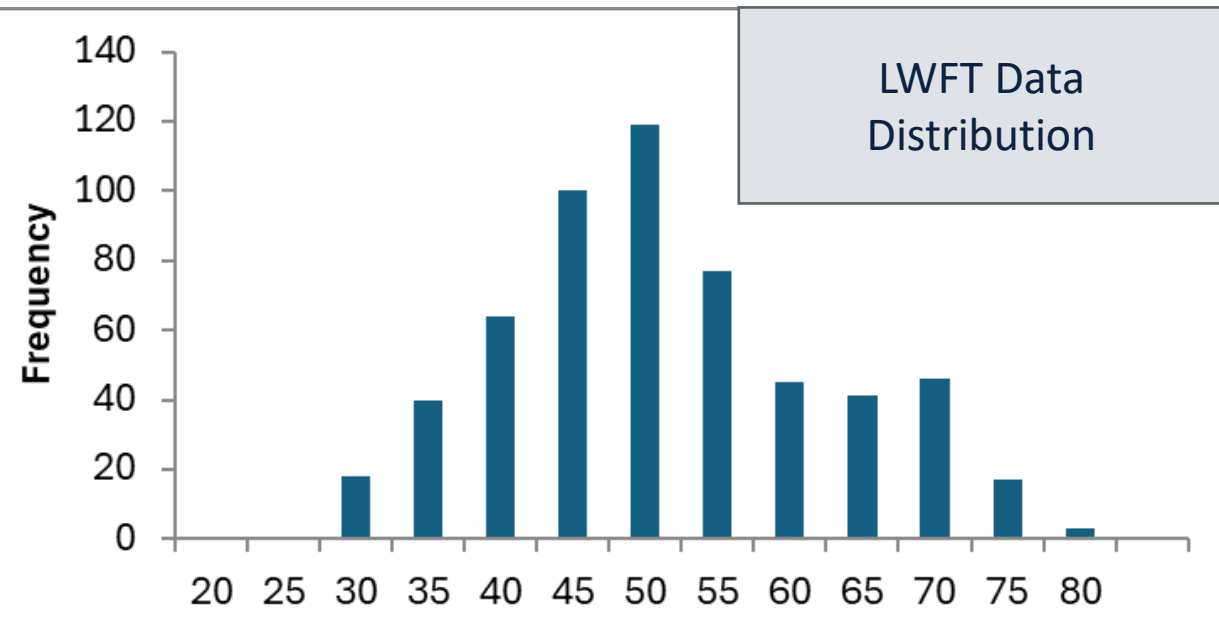
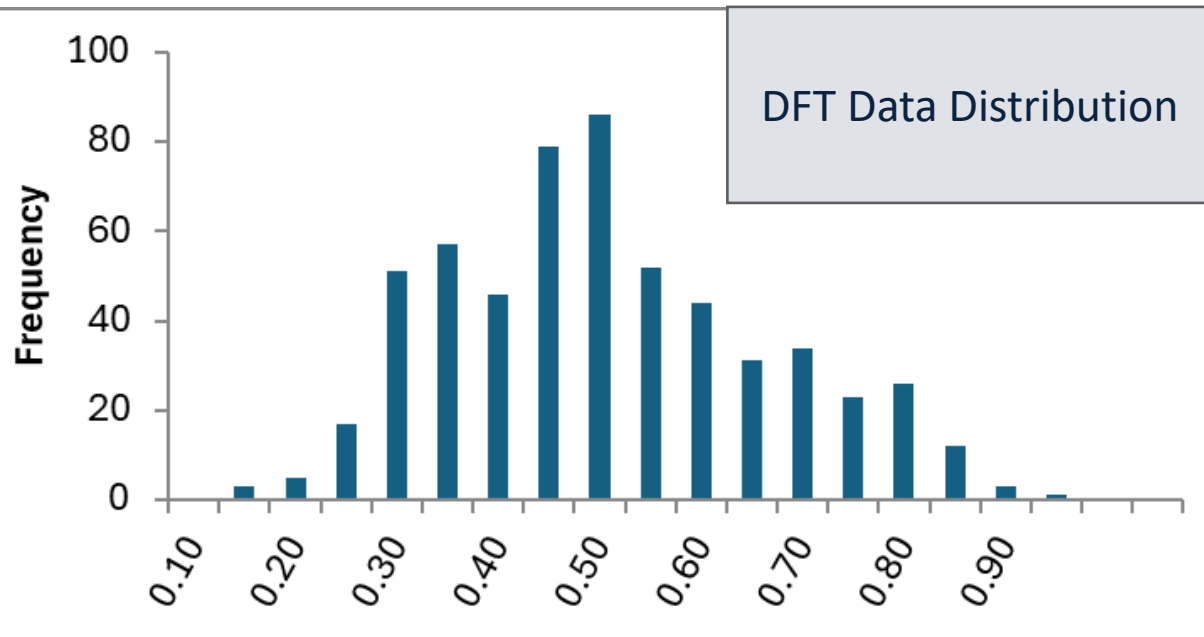
Study	DFT Speed	N	Root Mean Square Error	R ²	Intercept	Slope
(Izeppi et al., 2016) - GA	60	14	2.8	88%	4.3	96.2
(Izeppi et al., 2016) - VA	60	16	2.1	92%	9.8	86.5
(Choubane et al., 2012)	60	10	3.2	80%	9.0	78.8
(Holzschuher et al., 2010)	60	10	2.7	89%	8.2	65.4
(Iowa DOT, 2018)	60	47	4.6	74%	12.4	97.9
(Hacker et al., 2023)	60	13	3.3	90%	0.0	127.6
NCAT Lab-to-Field 2021	60	4	2.5	90%	0.8	103.6
NCAT 2023	60	29	3.4	77%	14.3	61.2
(Liang, 2013)	60	49	3.7	84%	18.6	62.9
(Huang et al., 2025)	60	11	4.0	24%	22.8	49.2

Study	DFT Speed	N	Root Mean Square Error	R ²	Intercept	Slope
(Izeppi et al., 2016) - GA	40	14	3.4	82%	5.6	85.4
(Izeppi et al., 2016) - VA	40	16	3.0	84%	11.2	76.5
(Choubane et al., 2012)	40	10	3.1	82%	5.0	87.1
(Holzschuher et al., 2010)	40	10	2.9	87%	7.2	65.9
(Hacker et al., 2023)	40	13	5.2	77%	4.5	119.8
NCAT Lab-to-Field 2021	40	4	1.8	95%	5.7	86.8
NCAT 2023	40	29	3.3	77%	13.9	62.3

Note:
Tables provided for further review after slides are published.

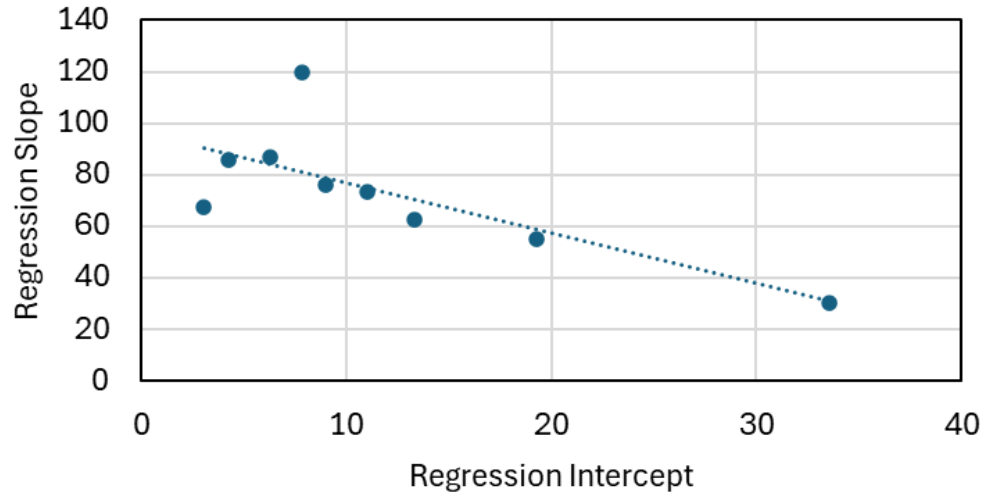
Average R²
20 km/hr – 68%
40 km/hr – 83%
60 km/hr – 79%

DATA DISTRIBUTION

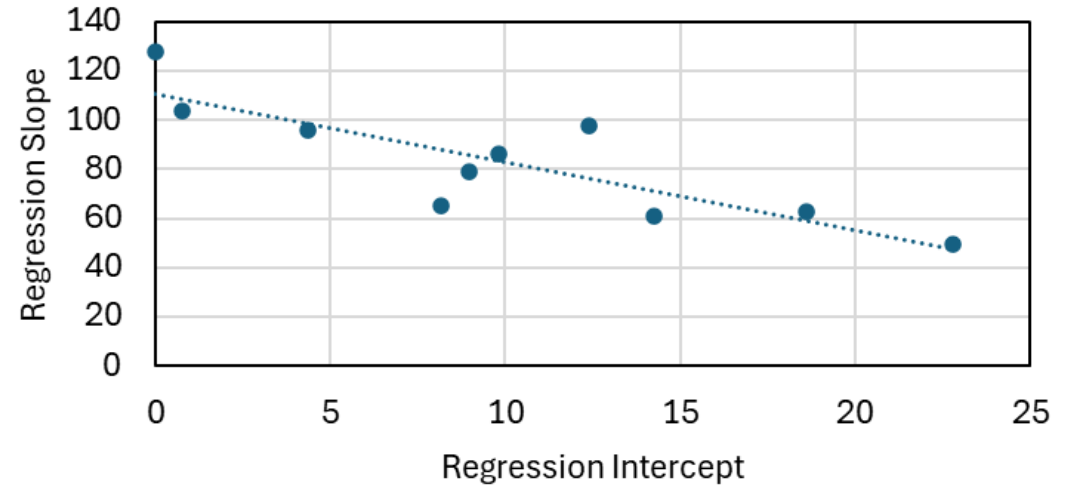


COMPARISON OF DIFFERENT STUDY COEFFICIENTS

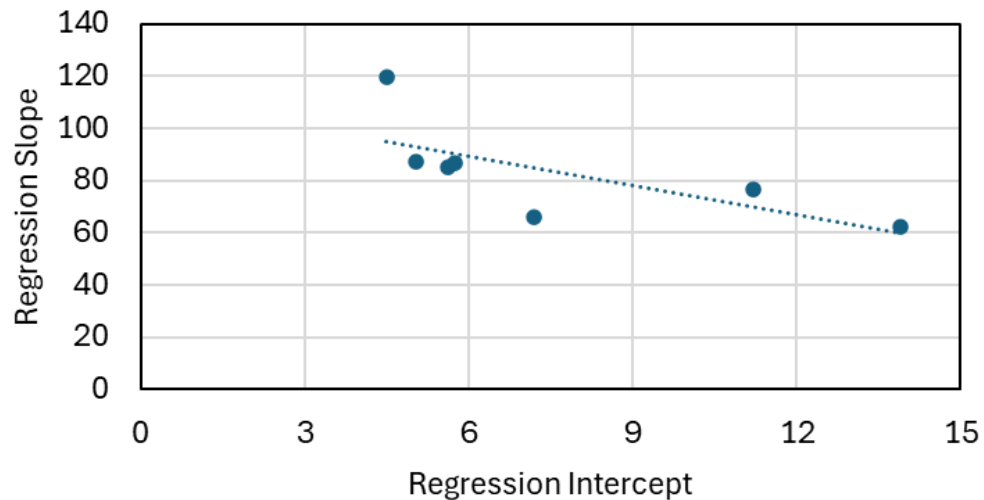
20 km/hr



60 km/hr



40 km/hr

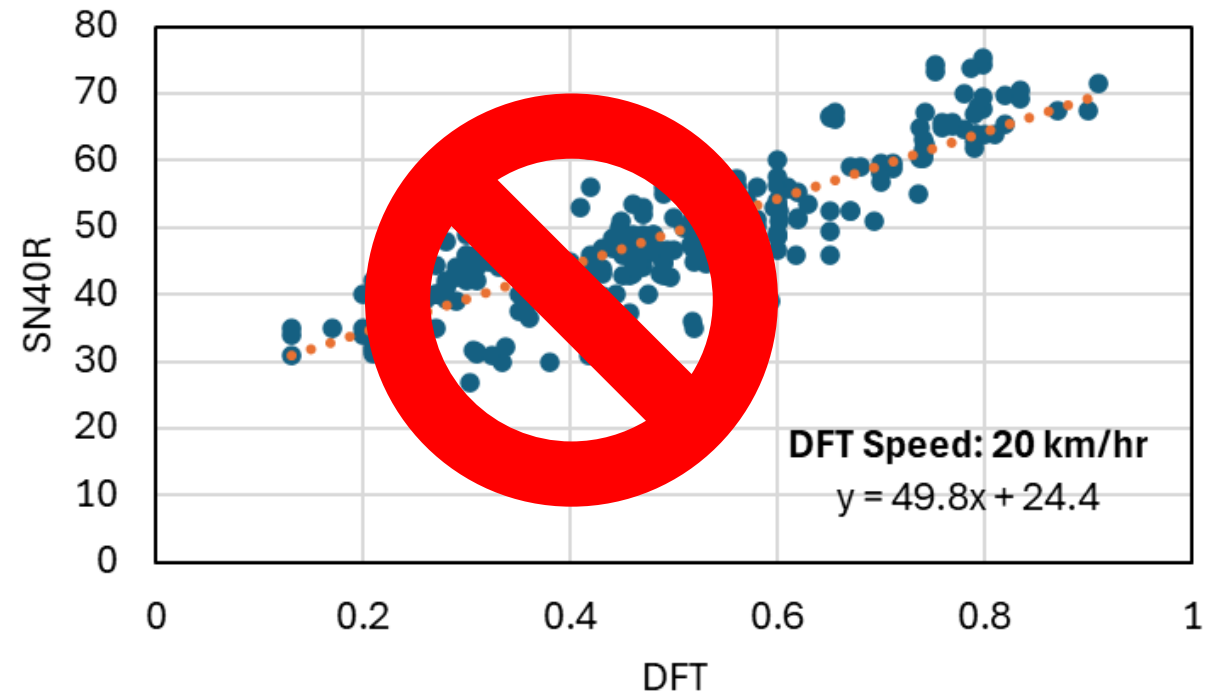


Summary:

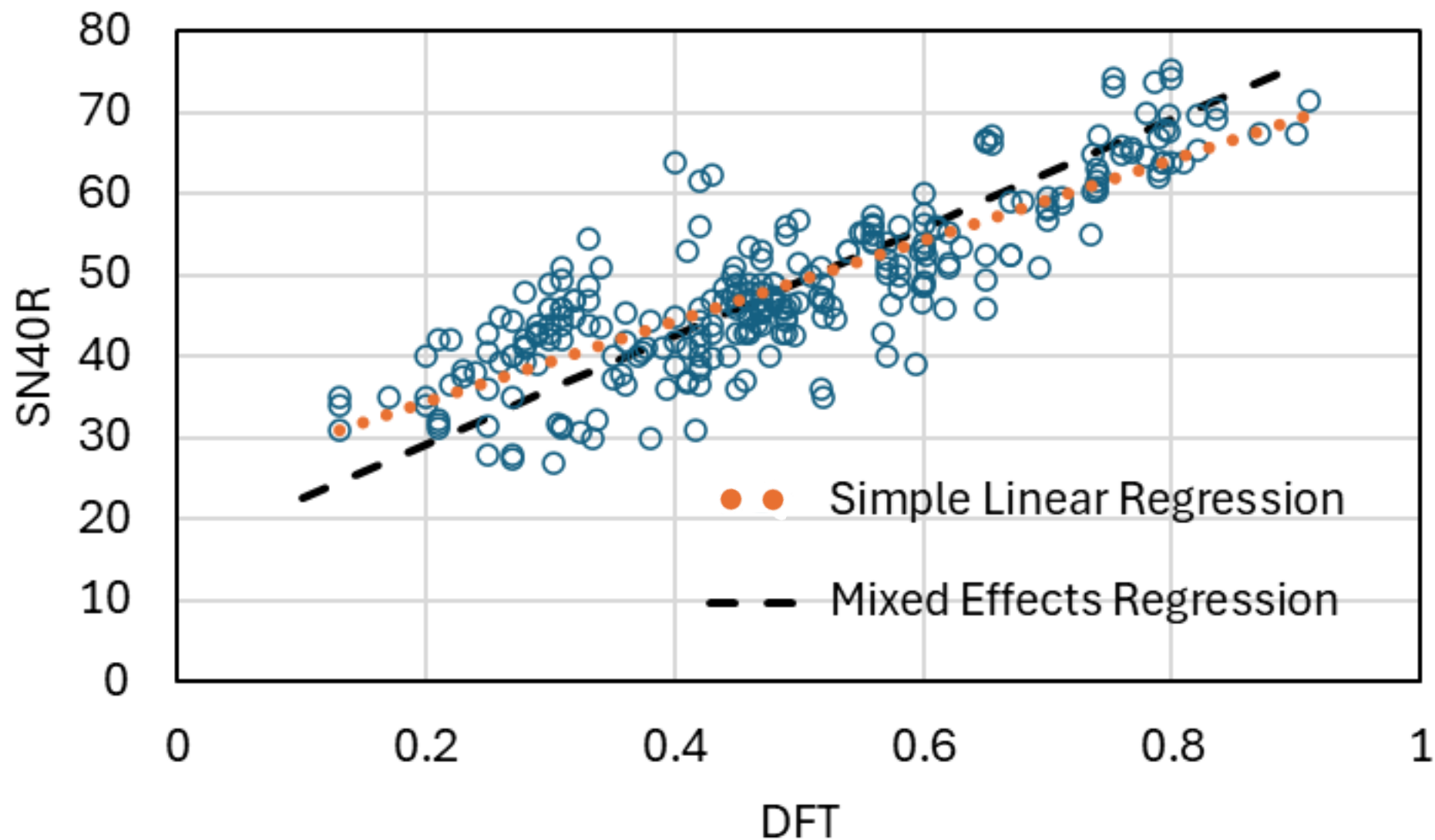
1. The regression coefficients for random device pairings are **highly correlated**.
2. When combining these studies, “good” studies should be assigned **larger weights** than “poor” studies.
3. A **single study should not dominate** the overall average relationship.

RANDOM EFFECTS VS. FIXED EFFECTS

- Simple Linear Regression (SLR) assumes every datapoint has an equal vote
- Large differences in sample size within individual studies
- Treat the published studies as "random effects."
- Overall average slope should be influenced most by "good" studies.

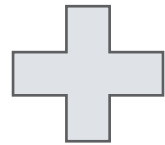
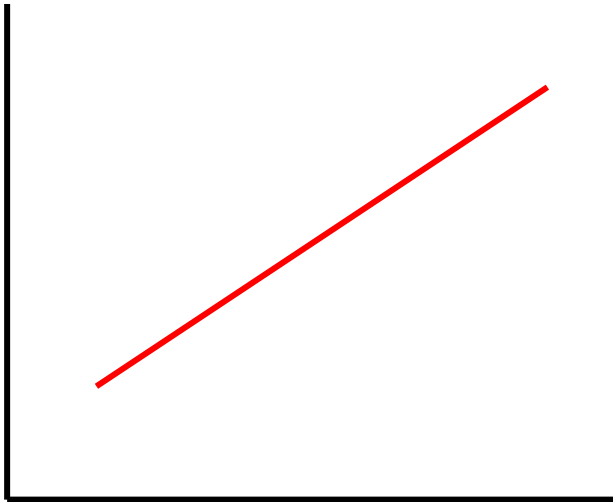


EXAMPLE AT 20 KM/HR DFT SPEED

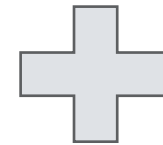
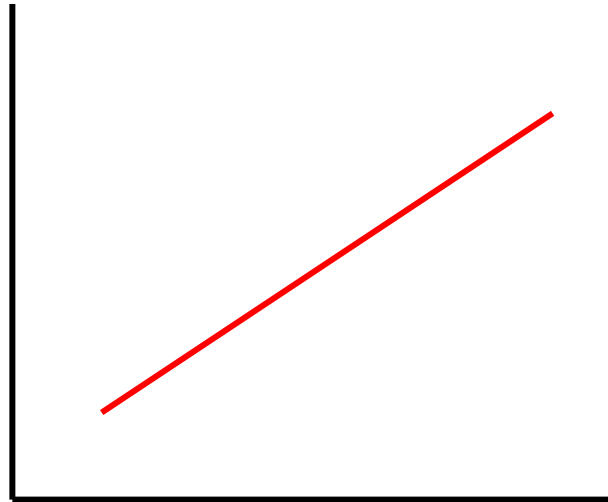


MIXED EFFECTS MODEL VARIANCE SOURCES

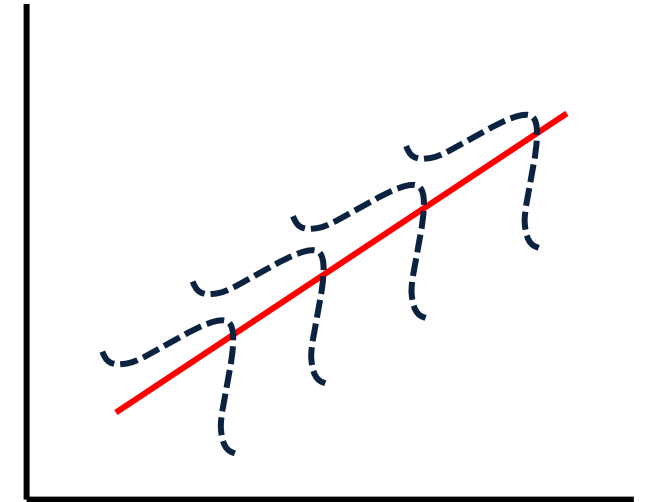
Fixed Effect:
Global Mean Estimate



Random Effect:
LWFT-DFT Pairing

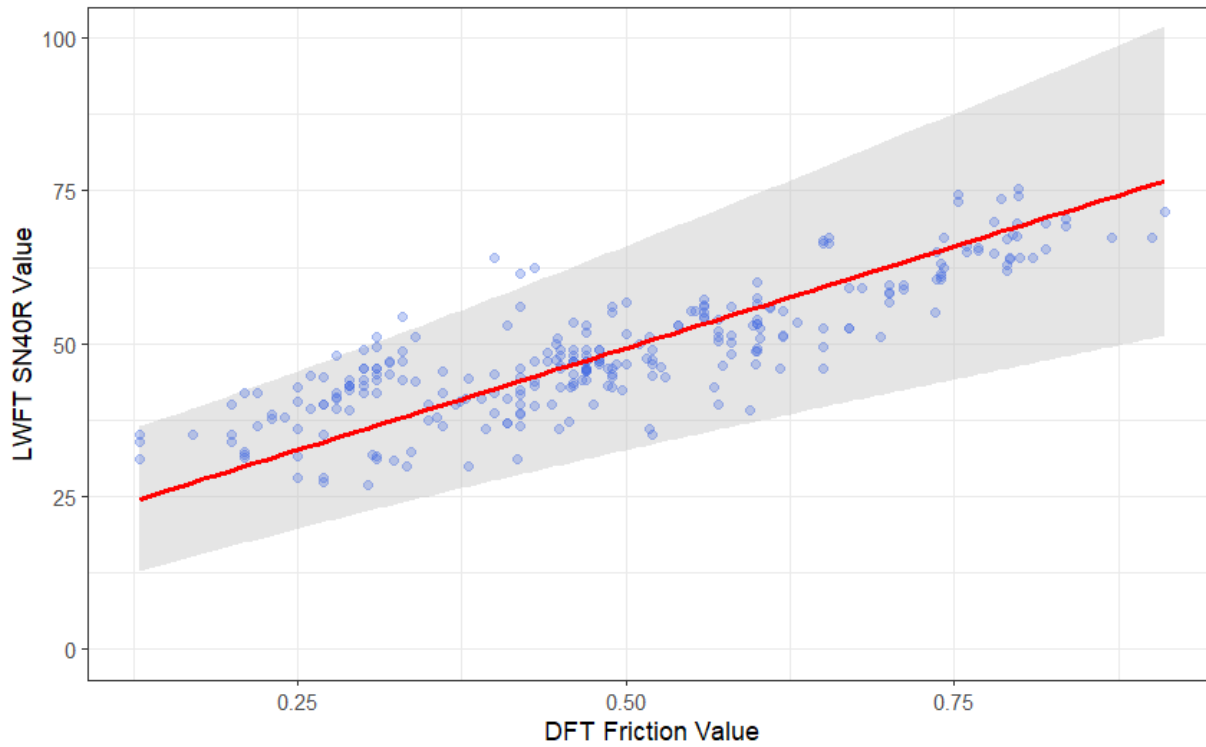


Residual Error:
Normal Testing
Variability

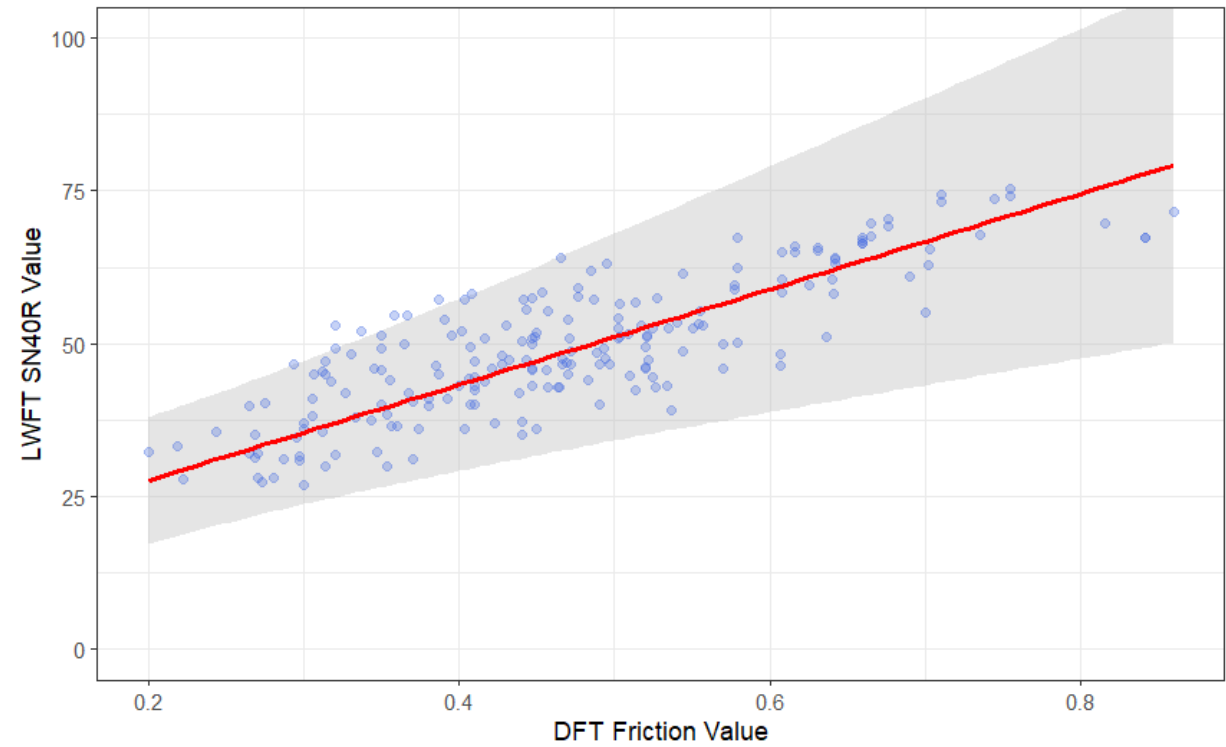


95% PREDICTION INTERVAL FOR 20 & 60 KM/HR

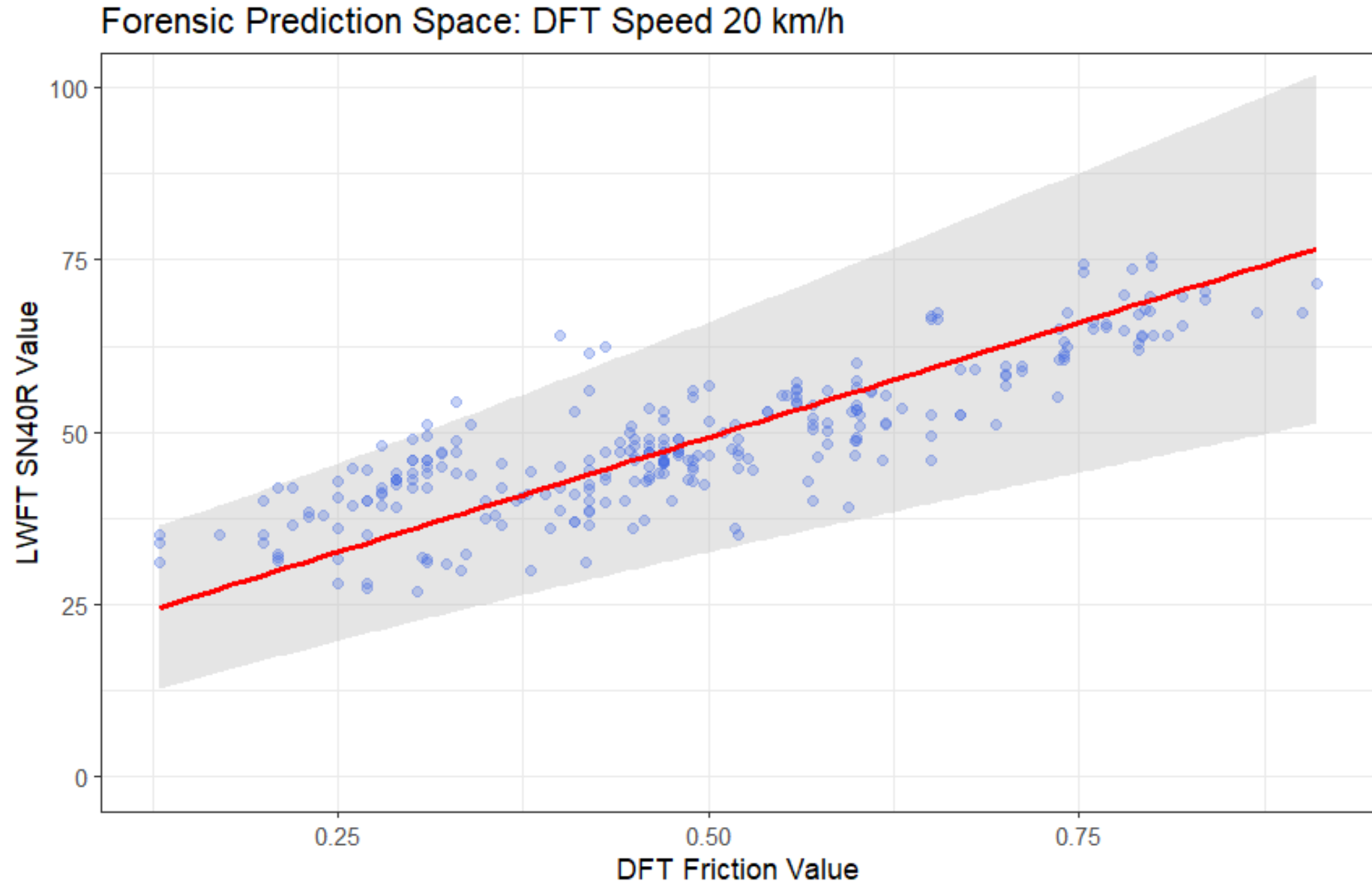
Forensic Prediction Space: DFT Speed 20 km/h



Forensic Prediction Space: DFT Speed 60 km/h

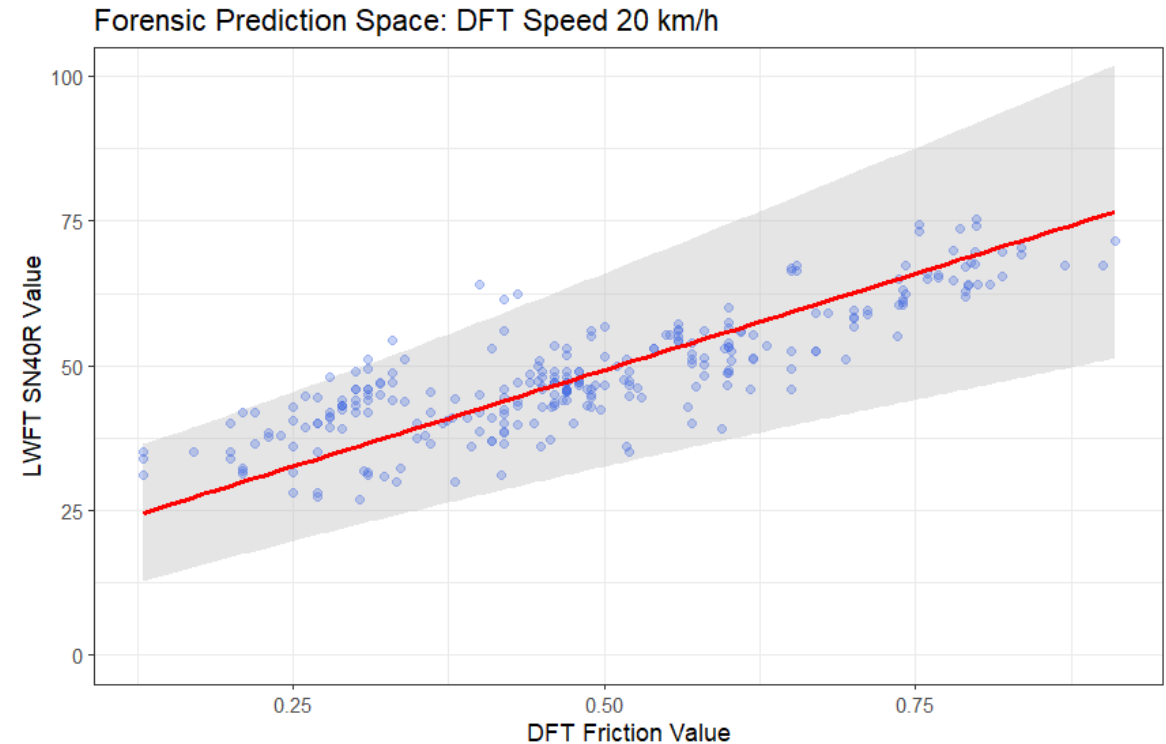


WHY DOES THIS MATTER?



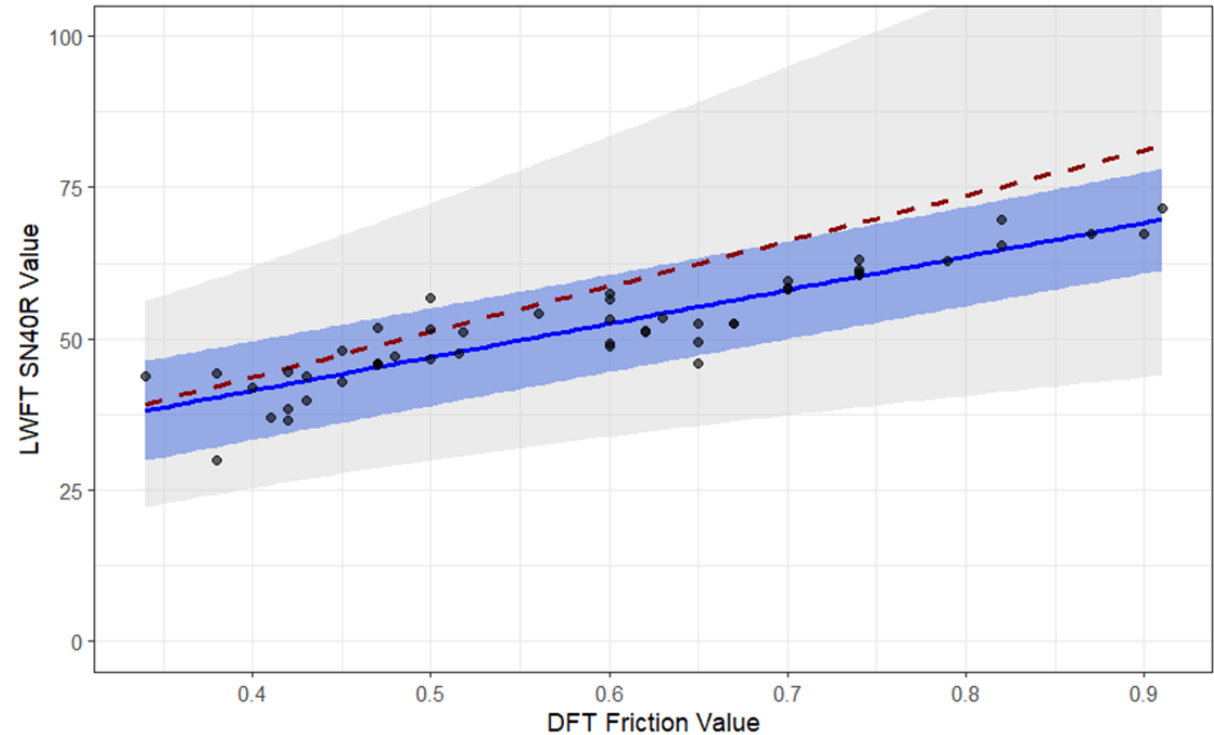
WHY DOES THIS MATTER?

- Too much variability between devices to trust as a design tool.
- Every unique DFT-to-LWFT pairing will need its own calibration.



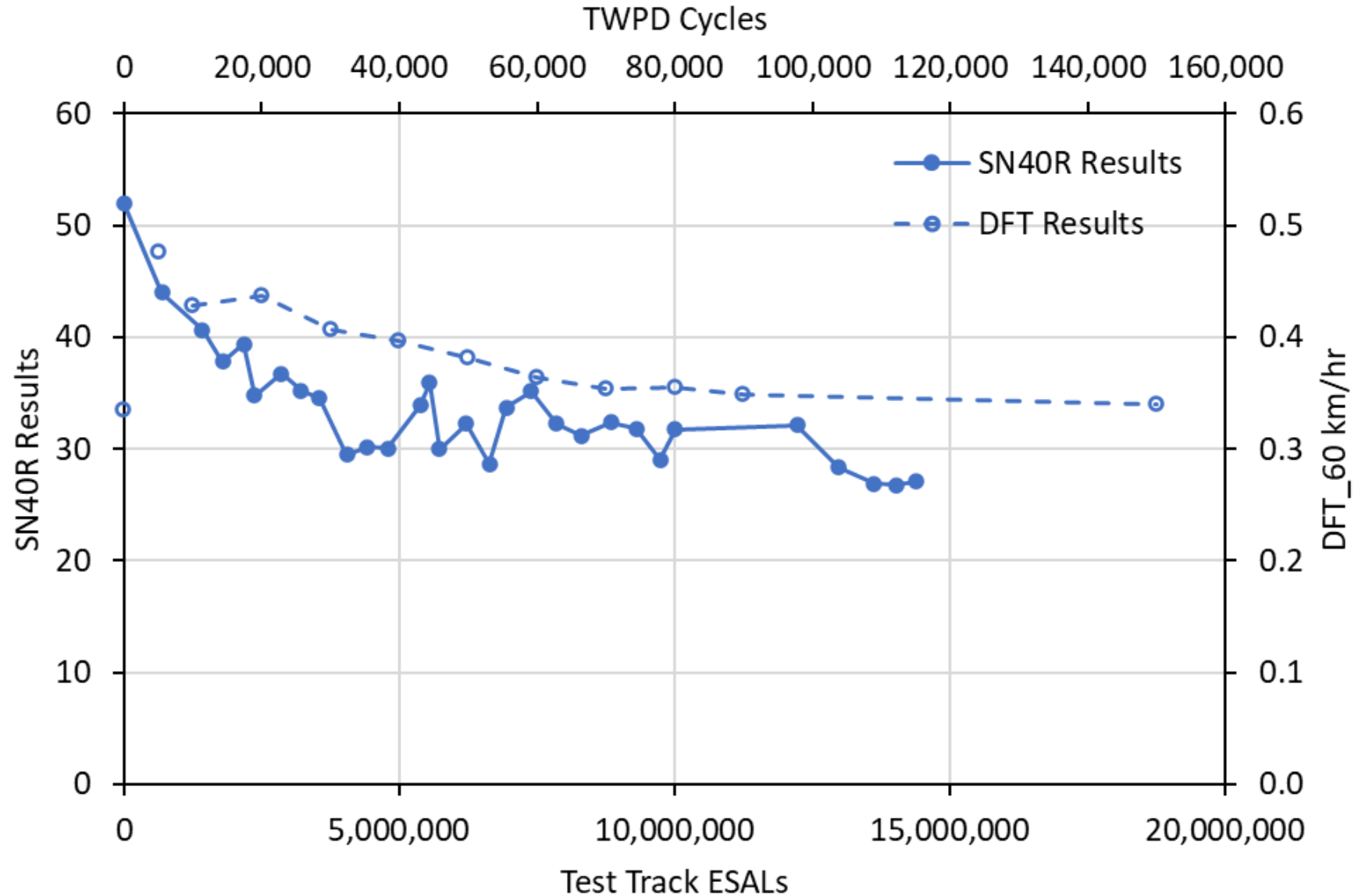
EXAMPLE: LOCAL PREDICTION INTERVAL

- No variance from device uncertainty
- Significantly more useful for forensics & design
- “Smell check” the data

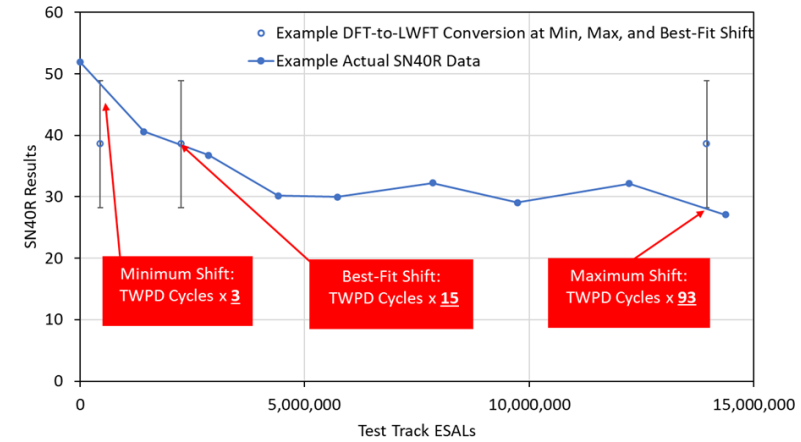
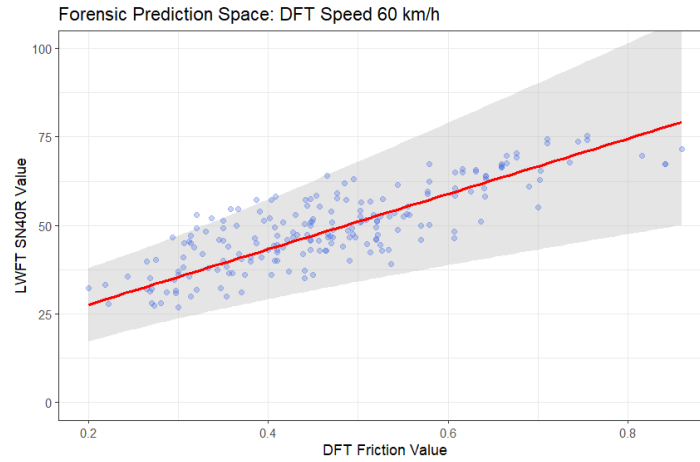
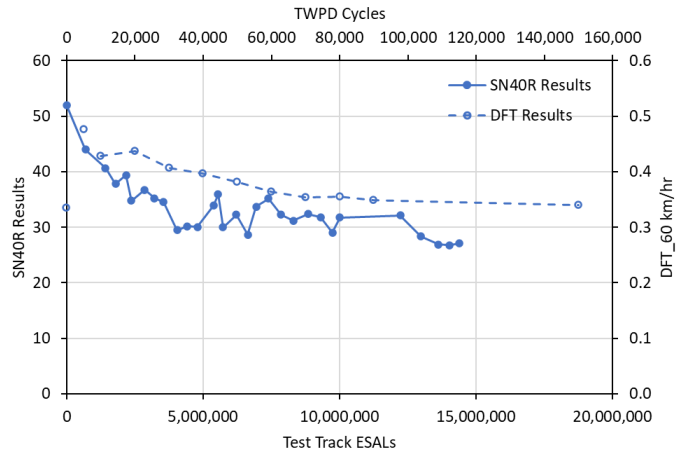


BONUS APPLICATION!

HOW MANY AADT = 1 TWPD CYCLE?

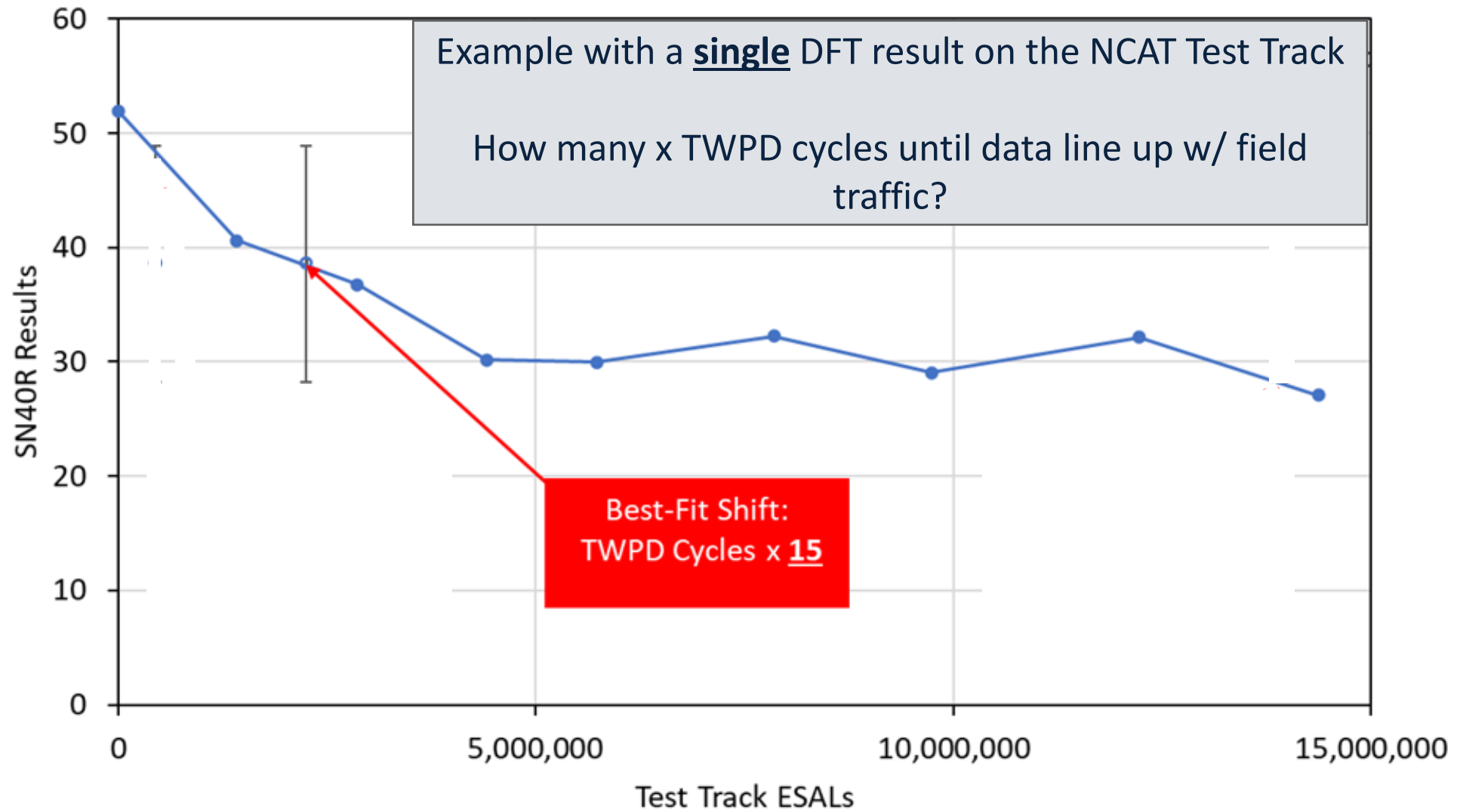


BONUS APPLICATION! HOW MANY AADT = 1 TWPD CYCLE?



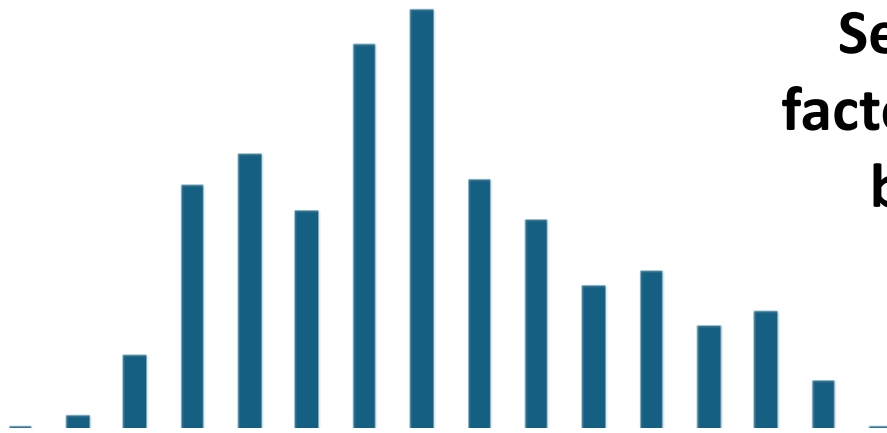
BONUS APPLICATION!

HOW MANY AADT = 1 TWPD CYCLE?

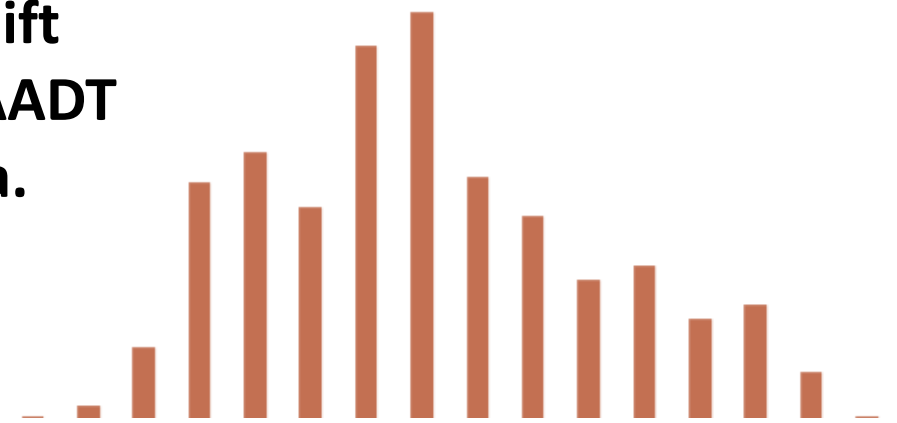


COMPARE DISTRIBUTION OF SHIFT FACTORS

Distribution of Minimum Shifts



Distribution of Maximum Shifts



Select a range of shift factors for TWPD to AADT based on real data.



SUMMARY

- The DFT and LWFT have a high degree of agreement between them.
- The specific values of the agreement of unique DFT/LWFT depend on many factors.
- Device-specific calibration is necessary to improve the relationship
- The “big picture” correlation still have value as a forensic, design, and research tool.



**THANK YOU!
QUESTIONS?**

Nathan Moore, P.E. | NCAT | April 30, 2026

