Illinois Department of Transportation

PFP Quality Level Analysis
Appendix E.1

Effective: December 12, 2003
Revised: June 28, 2017

This stand-alone document explains the statistical analysis and procedure used to determine the pay factor for a hot-mix asphalt (HMA) mixture on Pay for Performance (PFP) project. HMA materials specified to be sampled and tested for percent within limits payment adjustment (voids, VMA, and in-place density) and dust/AC adjustments will be evaluated for acceptance in accordance with this document.

Pay parameters evaluated using percent within (PWL) limits will be analyzed collectively and statistically by the Quality Level Analysis method using the procedures listed to determine the total estimated percent of the lot that is within specification limits. Quality Level Analysis is a statistical procedure for estimating the percent compliance to a specification and is affected by shifts in the arithmetic mean and the sample standard deviation. Two measures of quality are required to establish the contract unit price adjustment. The first measure is the Acceptable Quality Level (AQL) which is the PWL at which the lot will receive 100 percent pay. The second measure of quality is the Rejectable Quality Level (RQL) at which the Department has determined the material may not perform as desired and may be rejected.

The pay factor on full-depth projects shall be determined by weighting each mixture equally. Material placed at the same gyrations values but with and without polymer will be evaluated as two separate mixtures. For example: one surface mix and one binder mix will be weighted 50/50 regardless of tonnage. Additionally, one surface mix, one polymer binder mix and one non-polymer mix will be evaluated as three equally (1/3) weighted mixtures even if the polymer binder is the only difference between binder lifts.

Pay adjustments for Dust/AC ratio will be applied using the Dust/AC Pay Adjustment Table found in the Hot Mix Asphalt Pay for Performance Using Percent within Limits special provision.

QUALITY LEVEL ANALYSIS

Note: Table 1: Pay Attributes and Price Adjustment Factors contain the UL, LL, and pay factor “f” weights.

Items 1 through 8 of the following procedure will be repeated for each lot of the various pay factor parameters.

(1) Determine the arithmetic mean ($\bar{x}$) of the test results:

$$\bar{x} = \frac{\sum x}{n}$$

Where:

$\sum$ = summation of
x = individual test value
n = total number of test values

(2) Calculate the sample standard deviation (s):

$$s = \sqrt{\frac{n \cdot \Sigma (x)^2 - (\Sigma x)^2}{n(n-1)}}$$

Where:

$\sum (x^2)$ = summation of the squares of individual test values

$(\sum x)^2$ = summation of the individual test values squared

(3) Calculate the upper quality index (Q_U):

$$Q_U = \frac{UL - \bar{x}}{s}$$

Where:

UL = upper specification limit (target value (TV) plus allowable deviation)

(4) Calculate the lower quality index (Q_L):

$$Q_L = \frac{\bar{x} - LL}{s}$$

Where:

LL = lower specification limit(target value (TV) minus allowable deviation)

(5) Determine P_U (percent within the upper specification limit which corresponds to a given Q_U) from Table 2. (Note: Round up to nearest Q_U in table 2.)

Note: If a UL is not specified, P_U will be 100.

(6) Determine P_L (percent within the lower specification limit which corresponds to a given Q_L) from Table 2. (Note: Round up to nearest Q_L in table 2.)

Note: If a LL is not specified, P_L will be 100.

(7) Determine the Quality Level or *PWL* (the total percent within specification limits).

$$PWL = (P_U + P_L) - 100$$

(8) To determine the pay factor for each individual parameter lot:

Pay Factor (PF) = 55 + 0.5 (PWL)

PFP Quality Level Analysis
Appendix E.1
(continued)

Effective: December 12, 2003
Revised: June 28, 2017

(9) Once the project is complete determine the Total Pay Factor (*TPF*) for each parameter by using a weighted lot average by tons (mix) or distance (density) of all lots for a given parameter.

$$TPF = W1PFlot1 + W2PFlot(n+1) + etc.$$

Where:
W1,W2… = weighted percentage of material evaluated
PF = Pay factor for the various lots
TPF = Total pay factor for the given parameter

(10) Determine the Composite Pay Factor (*CPF*) for each mixture. The *CPF* shall be rounded to 3 decimal places.

$$CPF = \left[f_{VMA}\left(TPF_{VMA}\right) + f_{voids}\left(TPF_{voids}\right) + f_{density}\left(TPF_{density}\right)\right] / 100$$

Substituting from Table 1:

$$CPF = \left[0.3\left(TPF_{VMA}\right) + 0.3\left(TPF_{voids}\right) + 0.4\left(TPF_{density}\right)\right] / 100$$

Where:
f_{VMA}, f_{voids}, and $f_{density}$ = Price Adjustment Factor listed in Table 1

TPF_{VMA}, TPF_{voids}, and $TPF_{density}$ = *Total Pay Factor for the designated measured attribute from (9)*

(11) Determine the final pay for a given mixture.

*Final Pay = Mixture Unit Price * Quantity * CPF*

PFP Quality Level Analysis
Appendix E.1
(continued)

Effective: December 12, 2003
Revised: June 28, 2017

Table 1: Pay Attributes and Price Adjustment Factors			
Measured Attribute	Factor *"f"*	*UL*	*LL*
VMA	0.3	MDR/1 + 3.0	MDR/1 – 0.7
Plant Voids	0.3	Design Voids + 1.35	Design Voids – 1.35
In-Place Density	0.4	97.0/2	91.5/2
IL 9.5 FG Level Binder3/	0.4	97.0	90.5
IL 19.0	0.4	97.0	92.2
SMA	0.4	98.0	93.0

1. MDR = Minimum Design Requirement
2. Applies to all HMA mixes other than IL-4.75, IL-19.0, SMA and IL 9.5 FG Level Binder placed ≤ 1.25 in. (32 mm) thick
3. Placed at a thickness ≤ 1.25 in. (32 mm)

PFP Quality Level Analysis
Appendix E.1
(continued)

Effective: December 12, 2003
Revised: June 28, 2017

Example:

Determine the Pay factor for the given lot of a N90 HMA surface being placed at 1.5 inches thick as an overlay. The project consists of 10,000 tons over 17 miles.

Note that mix sample and density lots are independent of each other.

In this example the mix sample lot represents 10,000 tons while the density lot represents 6 miles (N=30). The project would have two additional density lots following the same calculations as the first lot. All three lots are combined as per item (9).

Mix sample: Each sublot represents 1000 tons

Lot #	Sublot #	Voids TV = 4.0	VMA Design Min = 14.5
1	1	4.2	14.4
	2	4.5	14.7
	3	3.3	13.9
	4	5.0	15.0
	5	5.4	15.2
	6	2.5	13.5
	7	3.8	14.2
	8	4.1	14.3
	9	4.3	14.4
	10	4.5	14.6
	Average:	4.16	14.42
	Standard Deviation:	0.825	0.498

Density: Each density test interval represents 0.2 mile thus N=30 in which 5 cores are taken per mile would represent 6 miles of paving.

Lot #	Density Test Interval	Density
1	1	91.5
	2	93.0
	3	92.9
	4	93.5
	5	93.0
	6	94.0
	7	92.8
	8	93.5
	9	91.0
	⋮	⋮
	30	92.7
	Average:	92.79
	Standard Deviation:	0.910

Determine the pay factor for each parameter.

Voids:

Lot: Average = 4.16
Standard Deviation = 0.825

$$Q_U = \frac{(4.0 + 1.35) - 4.16}{0.825} = 1.44$$

$$Q_L = \frac{4.16 - (4.0 - 1.35)}{0.825} = 1.83$$

N = 10 sublots (from table)

$P_U = 94$

$P_L = 98$

PWL = (94 + 98) - 100

PWL = 92

PF = 55 + 0.5 (92)

PF = 101.0

Determine the pay factor for Voids.

$PF_{Voids} = 101.0$

VMA:

Lot : Average = 14.42
Standard Deviation = 0.498

$$Q_U = \frac{(14.5 + 3.0) - 14.42}{0.498} = 6.18$$

$$Q_L = \frac{14.42 - (14.5 - 0.7)}{0.498} = 1.24$$

N = 10 sublots (from table)

P_U = 100

P_L = 90

PWL = (100 + 90) - 100

PWL = 90

PF = 55 + 0.5 (90)

PF = 100.0

Determine the pay factor for VMA.

PF_{VMA} = 100.0

Density:

Lot: Average = 92.79
Standard Deviation = 0.910

$$Q_U = \frac{97.0 - 92.79}{0.910} = 4.63$$

$$Q_L = \frac{92.79 - 91.5}{0.910} = 1.42$$

N = 30 Density measurements (from table)

$P_U = 100$

$P_L = 93$

$PWL = (100 + 93) - 100$

$PWL = 93$

$PF = 55 + 0.5\ (93)$

$PF = 100.5$

Determine the pay factor for Density.

$PF_{Density} = 101.5$

PFP Quality Level Analysis
Appendix E.1
(continued)

Effective: December 12, 2003
Revised: June 28, 2017

Determine the total pay factors for each parameter. In this example 10,000 tons of mix represents the entire project so only one lot exists for VMA and voids. If more mix lots occurred on a project they would be combined just like density as shown.

Lot #	Mix Tons	Void PF	VMA PF	Density Distance	Density PF
1	10,000	101.0	100.0	31680 ft	101.5
2				31680 ft	101.4
3				24640 ft	97.3
TPF		**101.0**	**100.0**	88000 ft	**100.3**

$TPF_{Density} = W1PF_{lot1} + W2PF_{lot2} + W3PF_{lot3}$

$TPF_{Density} = (31680/88000)(101.5)+(31680/88000)(101.4)+(24640/88000)(97.3)$

$TPF_{Density} = 100.3$

Combine the three Total Pay Factors to determine the Composite Pay Factor for the mix.

$CPF = [0.3(101.0) + 0.3(100.0) + 0.4(100.3)] / 100$

$CPF = 1.004$

Determine the price paid for the given mixture.

Given that the mixture bid price per ton = $65.00 and 10,000 tons were placed.

Plan Unit Pay = $65.00/ton * 10,000 tons = $650,000

Adjusted Pay = $65.00/ ton * 10,000 tons * 1.004 = $652,600

Determine the difference between the adjusted pay and the plan unit pay.

Adjusted pay – Plan Unit Pay = $652,600 – $650,000 = $2,600

If the difference is a positive value this will be the incentive paid. If the difference is a negative value this will be the disincentive paid. In this case a $2,600 incentive would be paid as per policy memorandum 9-4.

Full Depth Examples:

Given a full-depth project with two mixtures whose combined pay factors were determined to be 101.5% and 99.2%. The full-depth pay factor shall be calculated as follows:

101.5(1/2) + 99.2(1/2) = 100.4%

Determine the adjusted pay for the full-depth pay factor.

Given that the bid price per square yard = $25.00 and 1400 yd^2 were placed.

Plan Unit Pay = $25.00/ yd^2 * 1400 yd^2 = $35,000

Adjusted Pay = $25.00/ yd^2 * 1400 yd^2 * 1.004 = $35,140

Difference = $35,140 – $35,000 = $140 (Positive value = Incentive)

Given a full-depth project with three mixtures whose pay factors were determined to be 98.9%, 101.5% and 99.2%. The full depth pay factor shall be calculated as follows:

98.9(1/3) + 101.5(1/3) + 99.2(1/3) = 99.9%

Determine the adjusted pay for the full-depth pay factor.

Given that the bid price per square yard = $25.00 and 1400 yd^2 were placed.

Plan Unit Pay = $25.00/ yd^2 * 1400 yd^2 = $35,000

Adjusted Pay = $25.00/ yd^2 * 1400 yd^2 * 0.999 = $34,965

Difference = $34,965 – $35,000 = -$35 (Negative = Disincentive)

PFP Quality Level Analysis
Appendix E.1
(continued)

Effective: December 12, 2003
Revised: June 28, 2017

TABLE 2: QUALITY LEVELS
QUALITY LEVEL ANALYSIS BY STANDARD DEVIATION METHOD

P_U OR P_L PERCENT WITHIN LIMITS FOR POSITIVE VALUES OF Q_U OR Q_L	UPPER QUALITY INDEX Q_U OR LOWER QUALITY INDEX Q_L														
	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=18	n=19 to n=25	n=26 to n=37	n=38 to n=69	n=70 to n=200	n=201 to infinity
100	1.16	1.50	1.79	2.03	2.23	2.39	2.53	2.65	2.83	3.03	3.20	3.38	3.54	3.70	3.83
99		1.47	1.67	1.80	1.89	1.95	2.00	2.04	2.09	2.14	2.18	2.22	2.26	2.29	2.31
98	1.15	1.44	1.60	1.70	1.76	1.81	1.84	1.86	1.91	1.93	1.96	1.99	2.01	2.03	2.05
97		1.41	1.54	1.62	1.67	1.70	1.72	1.74	1.77	1.79	1.81	1.83	1.85	1.86	1.87
96	1.14	1.38	1.49	1.55	1.59	1.61	1.63	1.65	1.67	1.68	1.70	1.71	1.73	1.74	1.75
95		1.35	1.44	1.49	1.52	1.54	1.55	1.56	1.58	1.59	1.61	1.62	1.63	1.63	1.64
94	1.13	1.32	1.39	1.43	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.55
93		1.29	1.35	1.38	1.40	1.41	1.42	1.43	1.44	1.44	1.45	1.46	1.46	1.47	1.47
92	1.12	1.26	1.31	1.33	1.35	1.36	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.40	1.40
91	1.11	1.23	1.27	1.29	1.30	1.30	1.31	1.31	1.32	1.32	1.33	1.33	1.33	1.34	1.34
90	1.10	1.20	1.23	1.24	1.25	1.25	1.26	1.26	1.26	1.27	1.27	1.27	1.28	1.28	1.28
89	1.09	1.17	1.19	1.20	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.23
88	1.07	1.14	1.15	1.16	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.06	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13
86	1.04	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
84	1.01	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99
83	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95
82	0.97	0.96	0.95	0.94	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
81	0.96	0.93	0.91	0.90	0.90	0.89	0.89	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88
80	0.93	0.90	0.88	0.87	0.86	0.86	0.86	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.84
79	0.91	0.87	0.85	0.84	0.83	0.82	0.82	0.82	0.82	0.81	0.81	0.81	0.81	0.81	0.81
78	0.89	0.84	0.82	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.77	0.77	0.77
77	0.87	0.81	0.78	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.74	0.74	0.74	0.74
76	0.84	0.78	0.75	0.74	0.73	0.73	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.71
75	0.82	0.75	0.72	0.71	0.70	0.70	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.67
74	0.79	0.72	0.69	0.68	0.67	0.66	0.66	0.66	0.66	0.65	0.65	0.65	0.65	0.64	0.64
73	0.76	0.69	0.66	0.65	0.64	0.63	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.61	0.61
72	0.74	0.66	0.63	0.62	0.61	0.60	0.60	0.60	0.59	0.59	0.59	0.59	0.59	0.58	0.58

PFP Quality Level Analysis
Appendix E.1
(continued)

Effective: December 12, 2003
Revised: June 28, 2017

TABLE 2: QUALITY LEVELS
QUALITY LEVEL ANALYSIS BY STANDARD DEVIATION METHOD

P_U OR P_L PERCENT WITHIN LIMITS FOR POSITIVE VALUES OF Q_U OR Q_L	UPPER QUALITY INDEX Q_U OR LOWER QUALITY INDEX Q_L														
	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=18	n=19 to n=25	n=26 to n=37	n=38 to n=69	n=70 to n=200	n=201 to infinity
71	0.71	0.63	0.60	0.59	0.58	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.55	0.55
70	0.68	0.60	0.57	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.53	0.53	0.53	0.53
69	0.65	0.57	0.54	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50
68	0.62	0.54	0.51	0.50	0.49	0.49	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.47
67	0.59	0.51	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44
66	0.56	0.48	0.45	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.41	0.41	0.41
65	0.52	0.45	0.43	0.41	0.41	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39
64	0.49	0.42	0.40	0.39	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.36
63	0.46	0.39	0.37	0.36	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.33	0.33	0.33
62	0.43	0.36	0.34	0.33	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31
61	0.39	0.33	0.31	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28
60	0.36	0.30	0.28	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25
59	0.32	0.27	0.25	0.25	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23
58	0.29	0.24	0.23	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.20
57	0.25	0.21	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
56	0.22	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
55	0.18	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
54	0.14	0.12	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
53	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
52	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
51	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: For negative values of Q_U or Q_L, P_U or P_L is equal to 100 minus the table P_U or P_L. If the value of Q_U or Q_L does not correspond exactly to a figure in the table, use the next higher value.