

Building Weigh-In-Motion Systems Cheap

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Weigh-In-Motion (WIM) System

- Measures static weights of moving vehicles
- Data consists of vehicle records, comprising axle spacing, axle weights, speed, and classification
- Provides most accurate vehicle classification among present technologies
- Provides higher quality, detailed traffic data
- Primary input for MEPDG (Mechanical-Empirical Pavement Design Guide) and traditional pavement design
- Primary input for freight analysis

Needs for WIM (1)

- Heavy truck volumes on rural roads are increased due to higher demands on agricultural/mining commodities
- Do the posted weight-limit signs work?



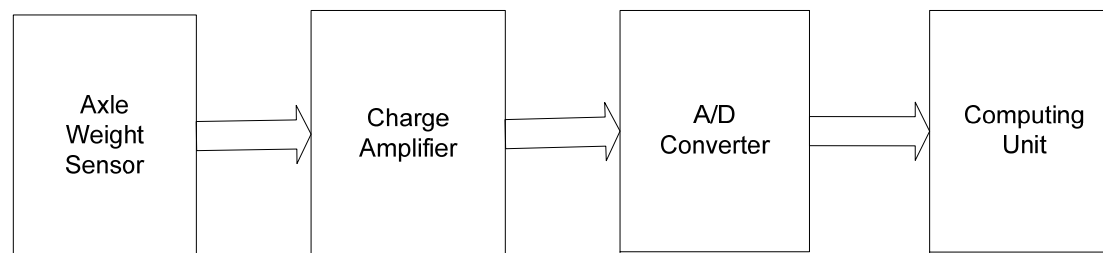
Needs for WIM (2)

- Needs to know truck loads and overweight violations, i.e., needs in weight monitoring
- Axle load data is critical for pavement redesign
- **Installing permanent WIM stations is expensive (over \$250K for 4-lane roads) → Needs are in low-cost WIM systems**

Portable WIM system (developed by Dr. Taek Kwon) can provide a low-cost alternative, but only for short duration data



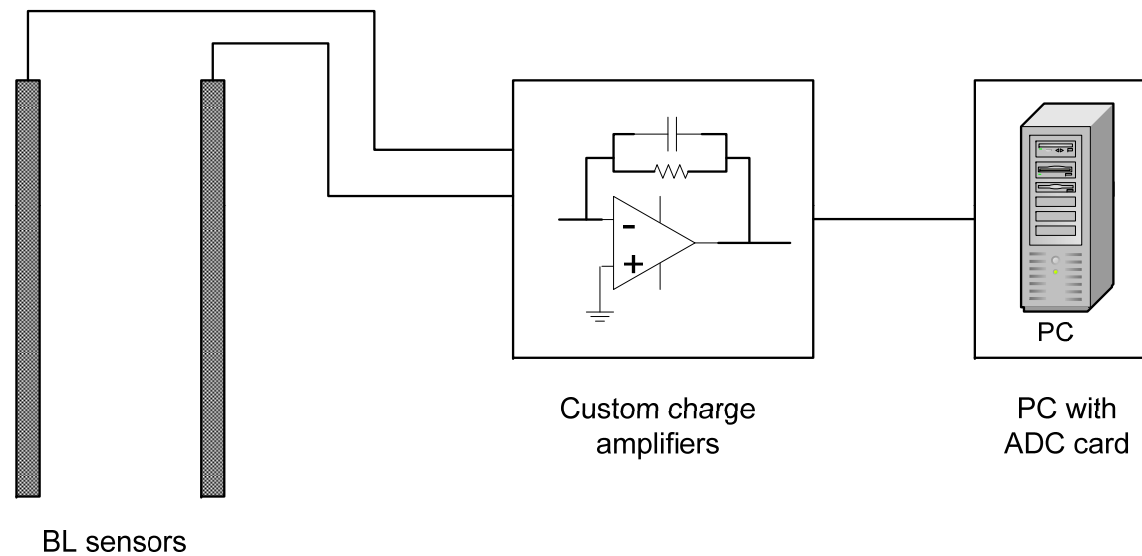
Typical In-Pavement, Permanent Roadside WIM System and Cost Consideration



WIM Axle Load Sensor Costs

Description	Company	Unit Cost	Quantity per Lane	Per Lane Cost	4-Lane Cost
Quartz Lineas 1.75m sensor with 100m lead cable	Kistler	\$6,200	4	\$24,800	\$99,200
Roadtrax BL 10 ft sensor with 400 ft lead cable	Measurement Specialties	\$800	2	\$1,600	\$6,400
Cost Difference				\$23,200	\$92,800

Low-Cost WIM System



\$1,800

4-Lanes: \$6,400

Must solve temperature sensitivity problem

Custom Low-Cost WIM Controller

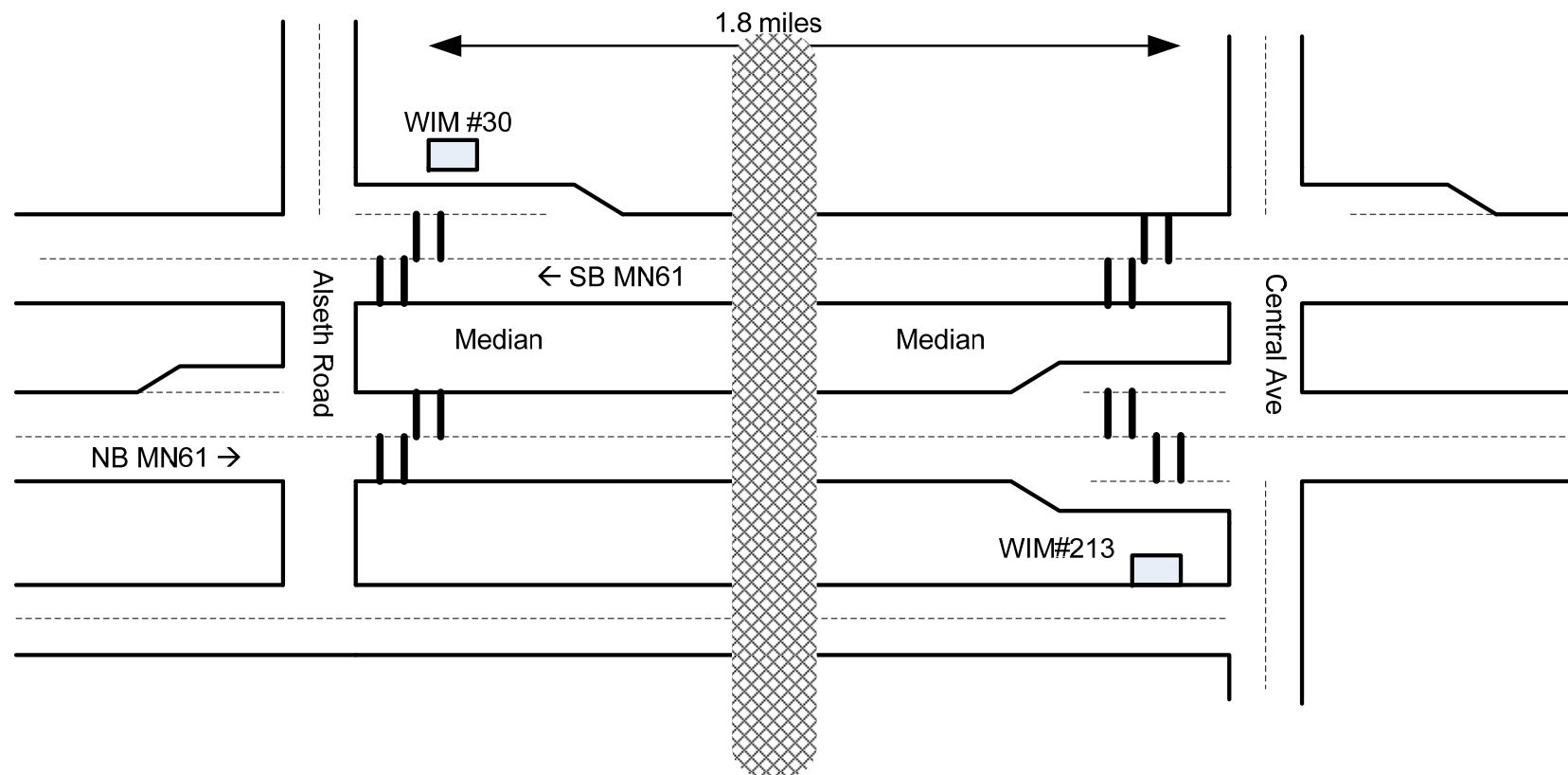
Description	Unit Price	Qty	Extension
Micro Tower PC, 8G RAM, Intel i-5, Win-7	\$804.88	1	\$804.88
16bit ADC, 200 Samples/Sec	\$419.00	1	\$419.00
USB Thermocouple	\$99.00	1	\$99.00
50-pin Screw Terminal	\$89.00	1	\$89.00
50-Conductor Ribbon Cable	\$68.00	1	\$68.00
2-Channel Charge Amplifier	\$35.79	4	\$143.16
Charge Amp Enclosure	\$105.75	1	\$105.75
Total			\$1,728.79



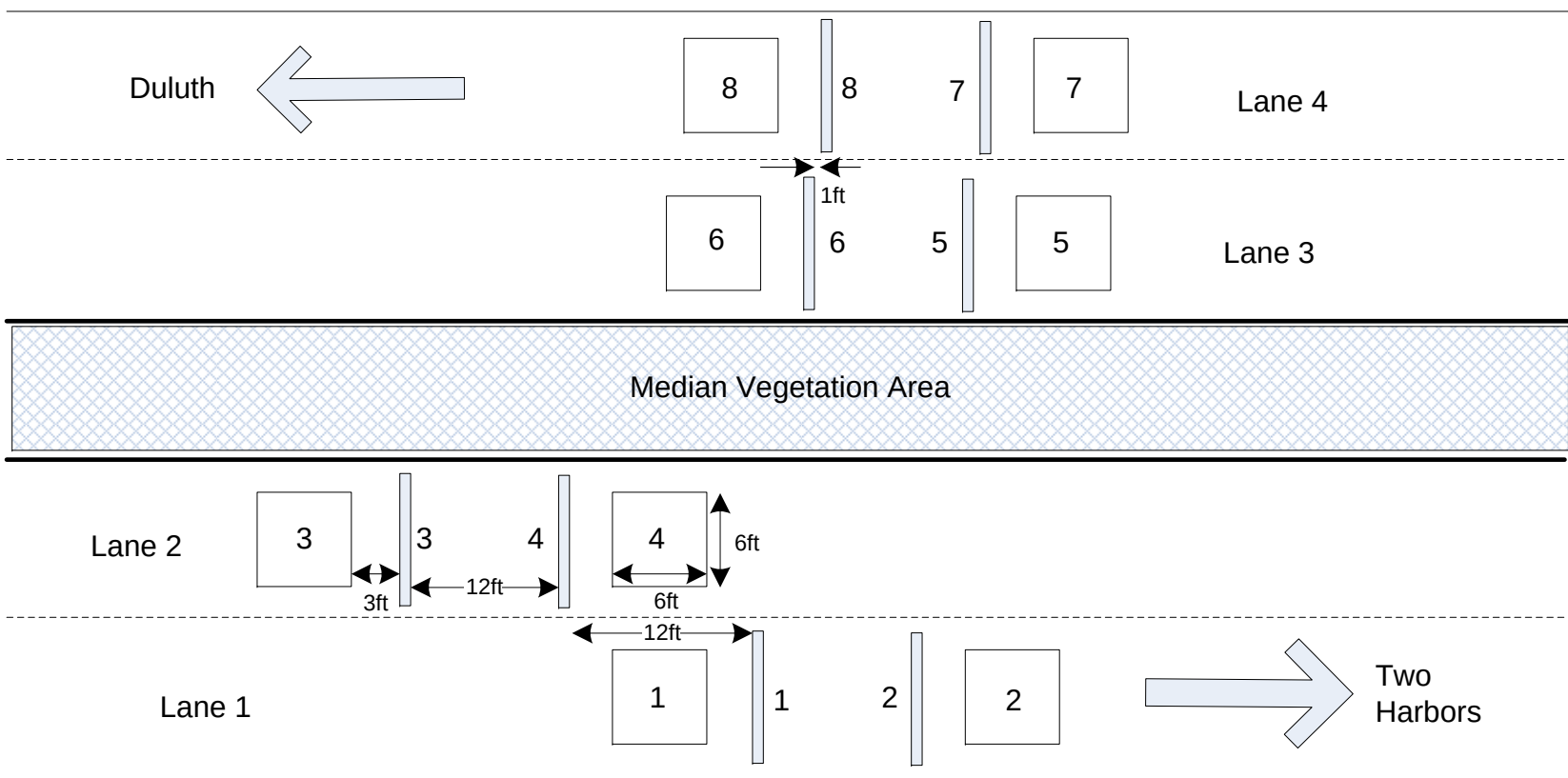
Cost Comparison for 4-Lane Highway

	Lineas-Sensor Based WIM System	BL-Sensor Based Low-Cost System
Sensor Total	\$99,200	\$6,400
Controller	\$26,000	\$1,729
Grouts	\$6,300	\$756
Installation	\$50,000	\$50,000
Total	\$181,500	\$58,885

Evaluation Plan: Study Sites



Low-Cost WIM Sensor Installation at Knife River, Highway 61 (WIM#213)



Low-Cost WIM System (WIM #213, BL Sensors)



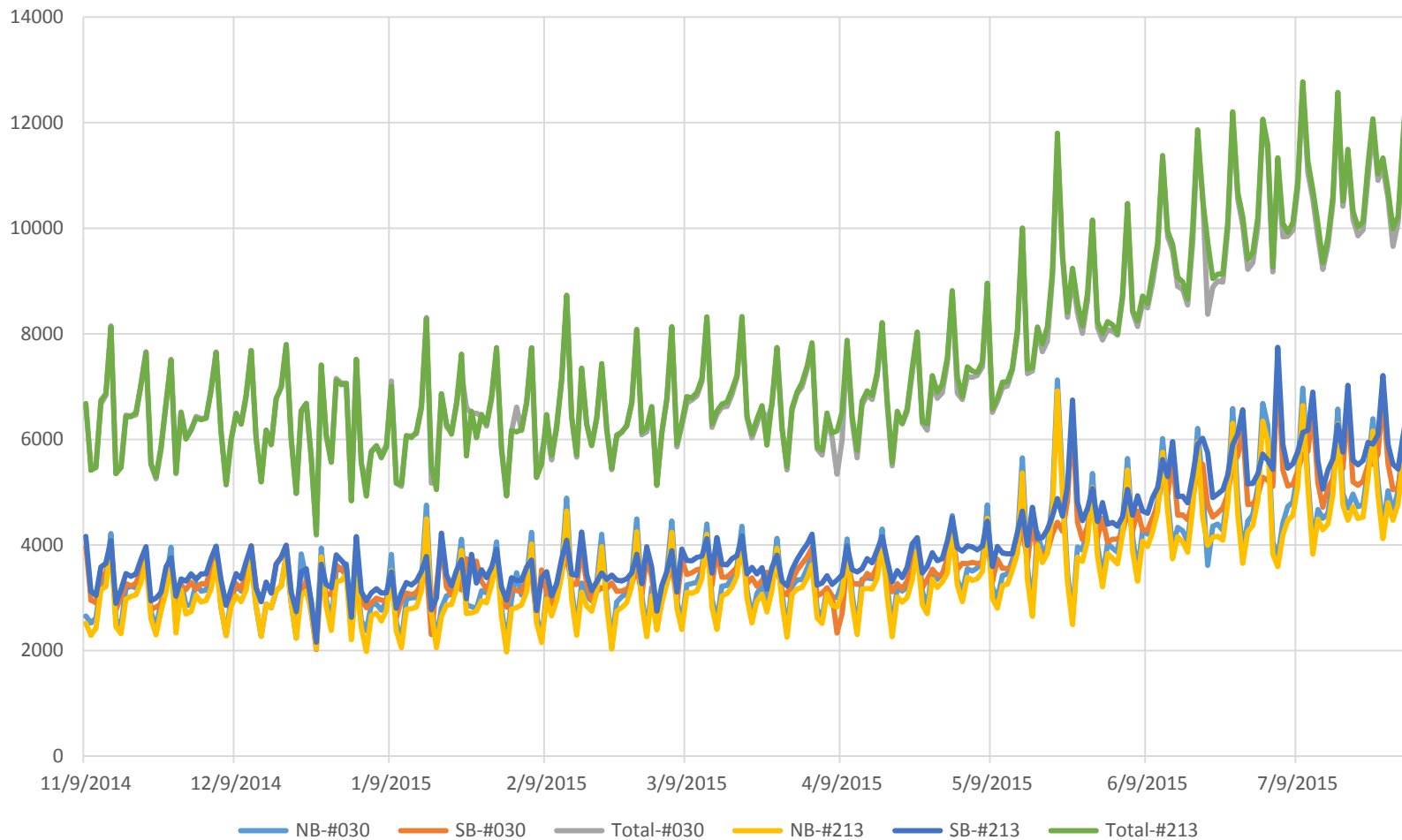
WIM #30 Site (Two Harbors): Kistler Lineas Sensors



Data Collection

- November 9, 2014 to present
- Data analysis: 11/9/2014 – 7/31/2015

Volume Comparison

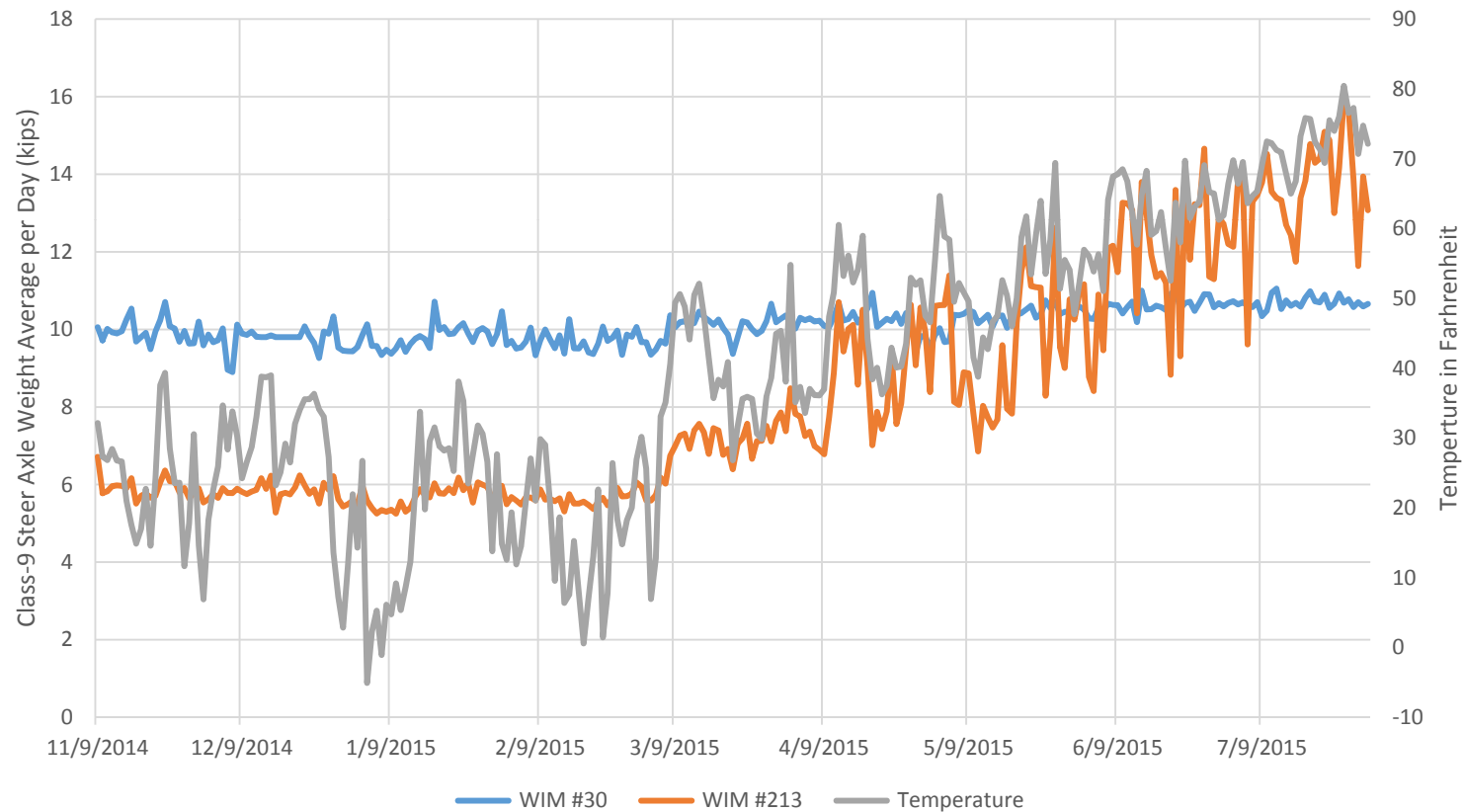


RMSE was 1.2% or 95 veh/day

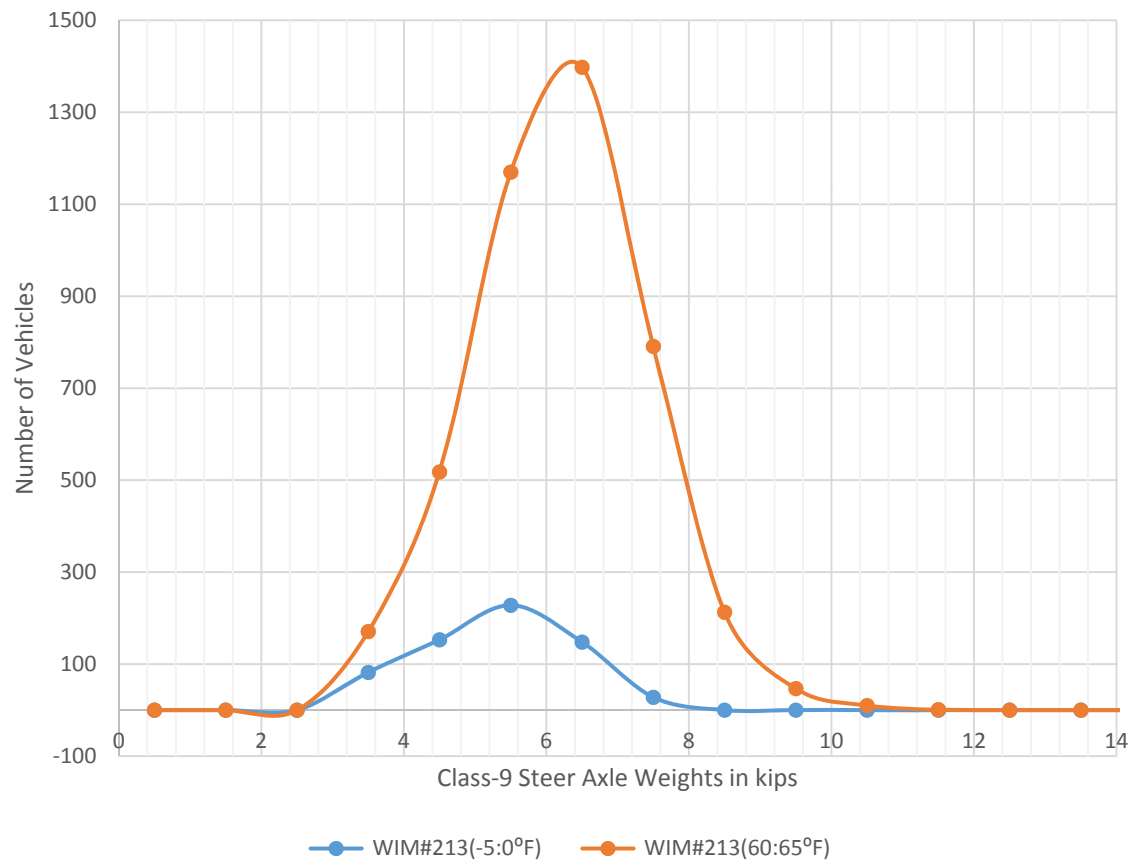
Sample Directional Volume Table

Date	NB-#030	SB-#030	Total-#030	NB-#213	SB-#213	Total-#213
11/9/2014	2654	3973	6627	2517	4164	6681
11/10/2014	2527	2957	5484	2295	3126	5421
11/11/2014	2615	2902	5517	2422	3047	5469
11/12/2014	3277	3396	6673	3156	3583	6739
11/13/2014	3366	3469	6835	3211	3654	6865
11/14/2014	4217	3934	8151	4042	4084	8126
11/15/2014	2593	2773	5366	2455	2895	5350
11/16/2014	2457	3009	5466	2321	3152	5473
11/17/2014	3189	3270	6459	2974	3459	6433
11/18/2014	3217	3229	6446	3027	3406	6433
11/19/2014	3196	3267	6463	3057	3453	6510
11/20/2014	3512	3541	7053	3286	3729	7015
11/21/2014	3863	3799	7662	3677	3966	7643
11/22/2014	2741	2780	5521	2603	2944	5547
11/23/2014	2428	2825	5253	2300	2994	5294

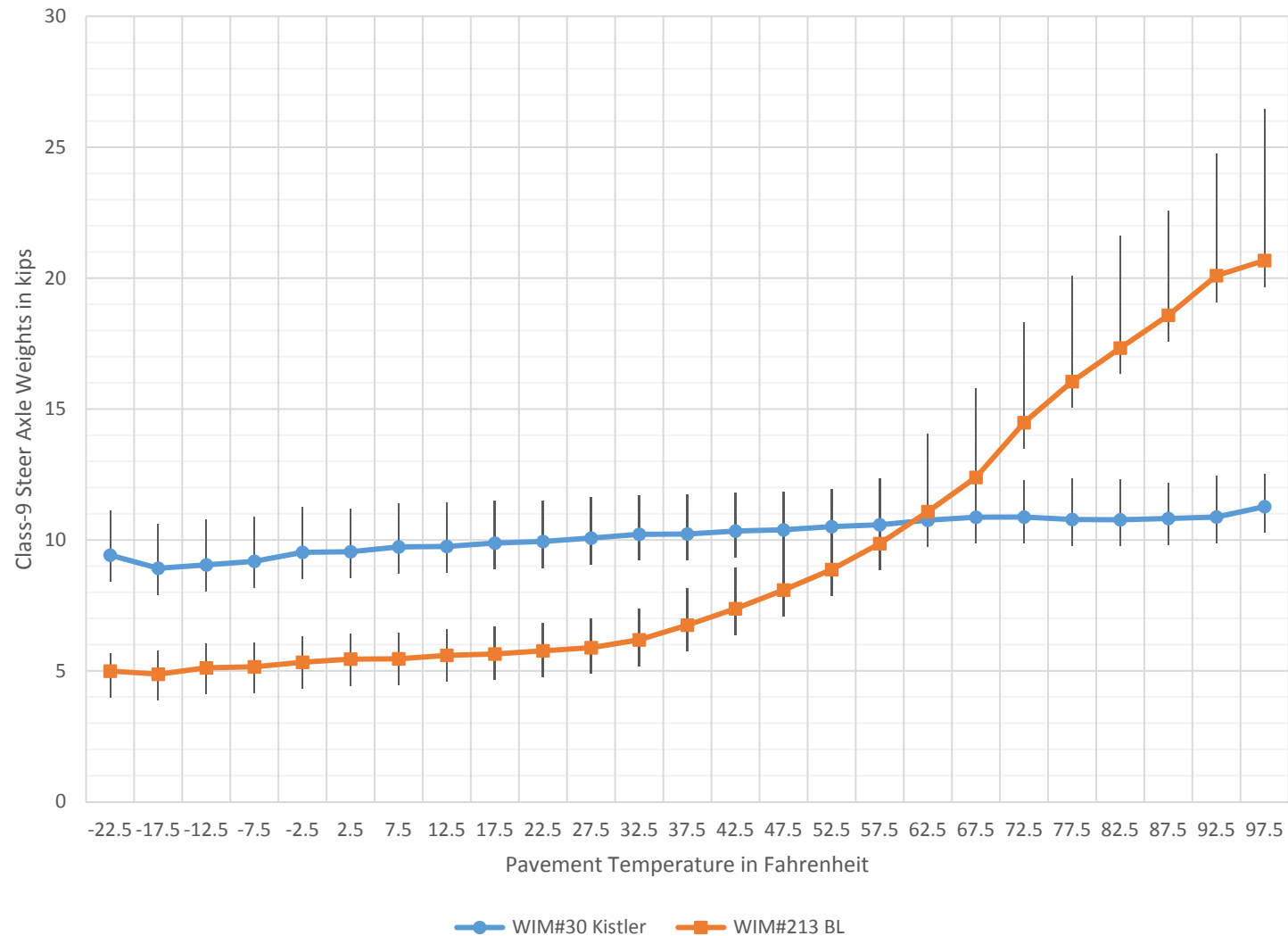
Class-9 Steer Axle Daily Weight Averages and Pavement Temperature Relation



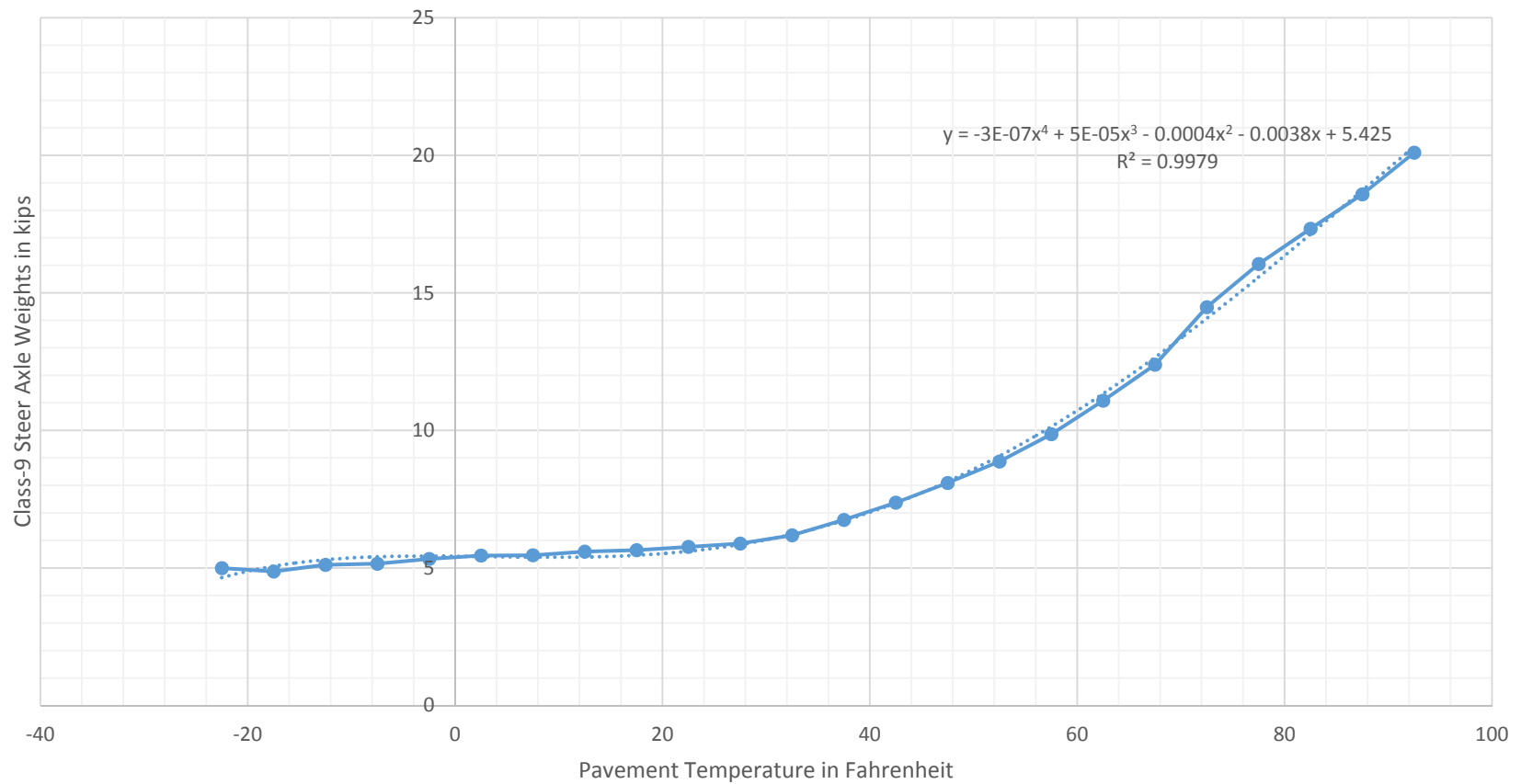
WIM#213 Class-9 Steer Axle Weight Histogram at Different Temperature Ranges



Average Class-9 Steer Axle Weight per 5° Fahrenheit Bins Over 9 Months



BL Sensor Temperature Effect Modeling



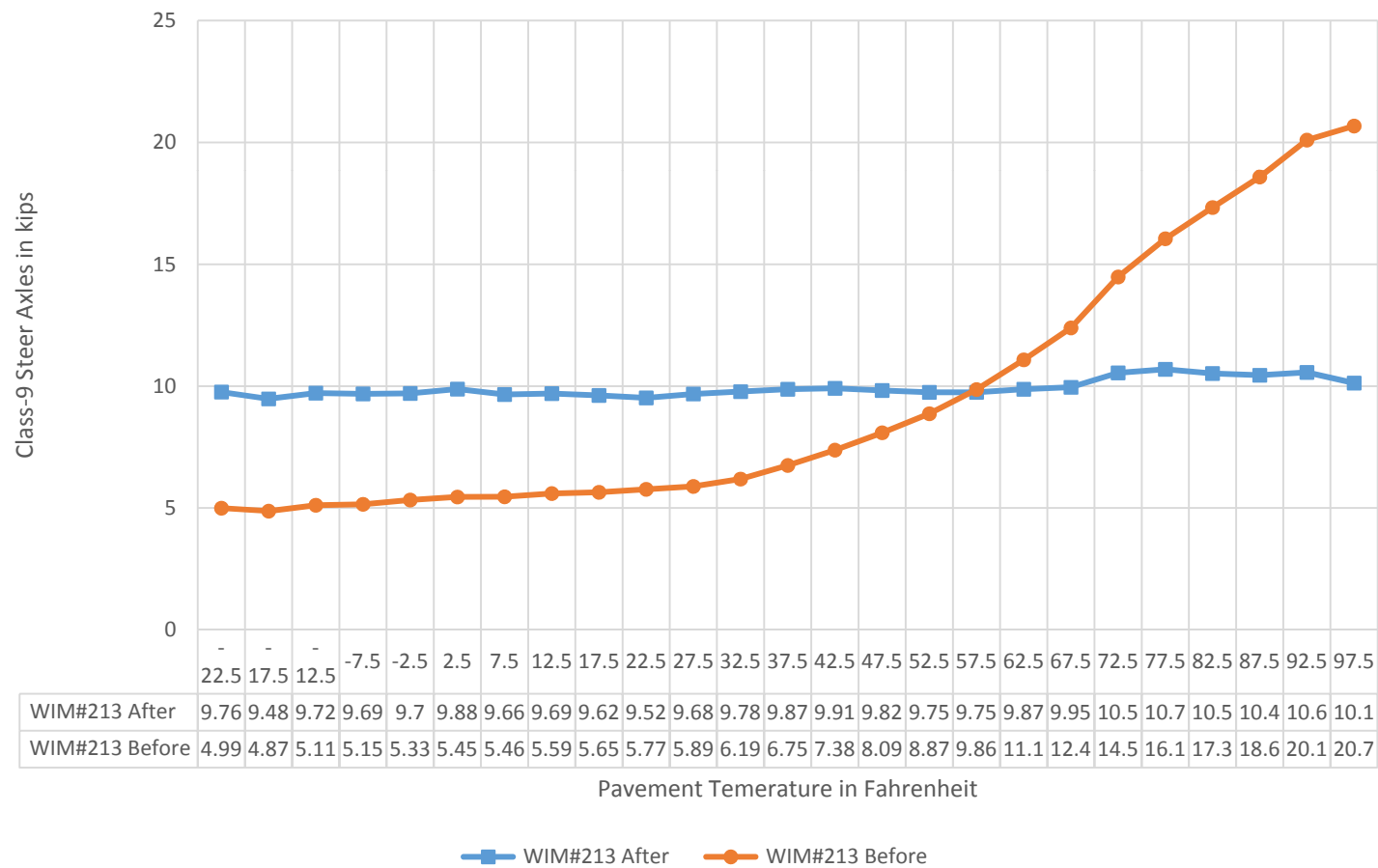
Weight Calibration Based Temperature Modeling and Class-9 Steer Axle Weight

$$y = f(T)$$

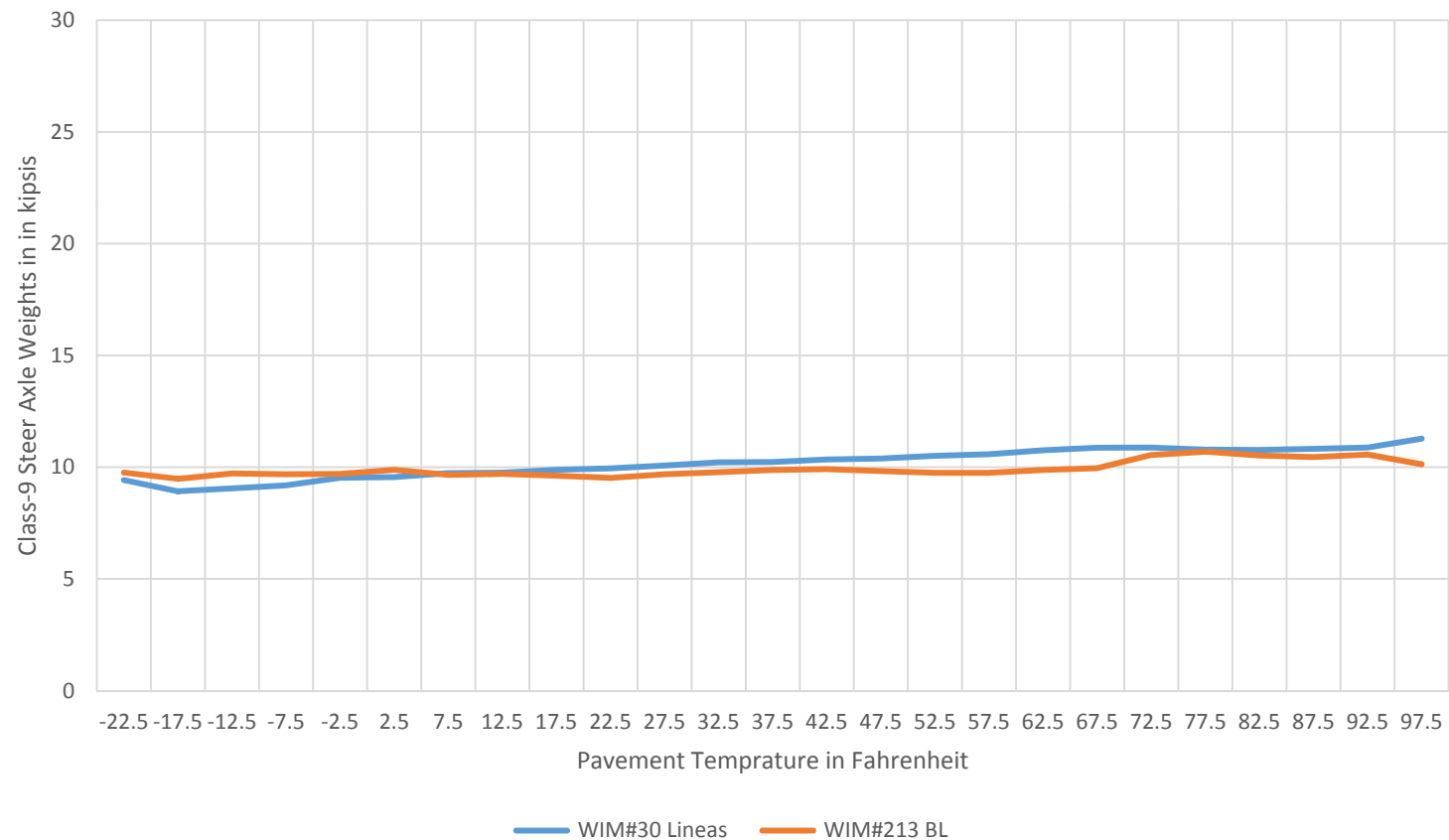
$$\text{Calibration_Factor} = 10/y$$

$$\text{Adjusted_Axle_Weight} = \text{Measured_Axle_Weight} * \text{Calibration_Factor}$$

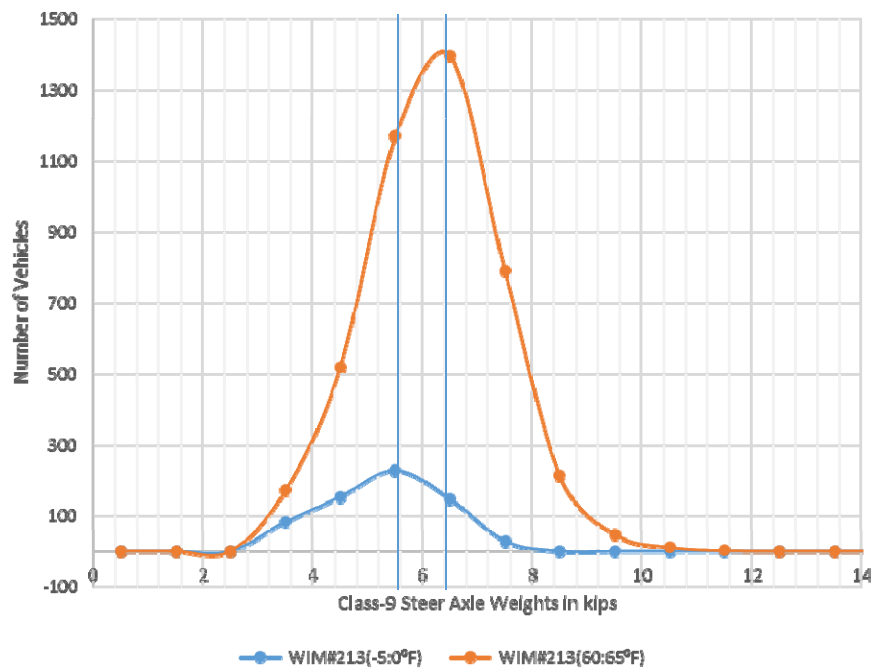
WIM#213 Average Class-9 Steer Axle Weight per 5° Fahrenheit Bins Over 9 Months: Before and After Calibration



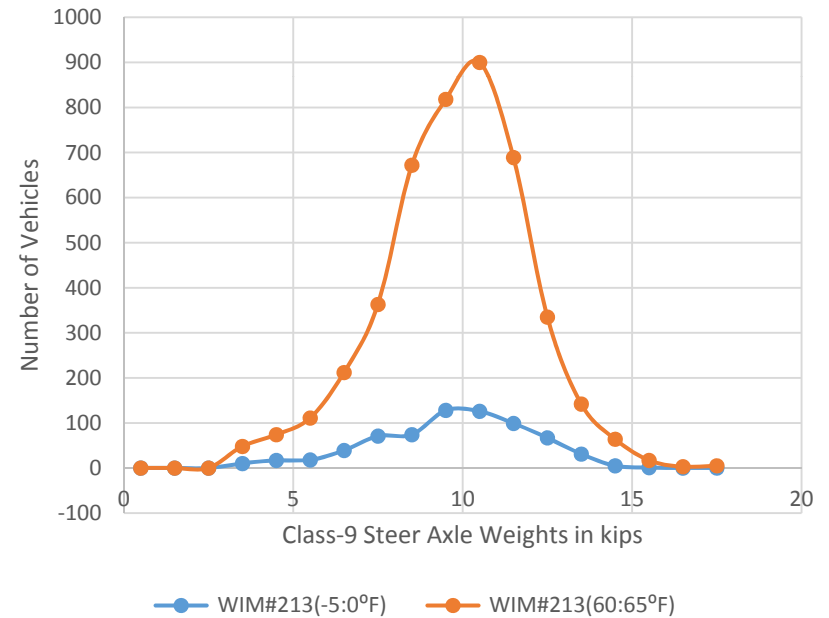
Average Class-9 Steer Axle Weight per 5° Fahrenheit Bins Over 9 Months after Calibration



WIM#213 Class-9 Steer Axle Weight Histogram at Different Temperature Ranges: Before and After

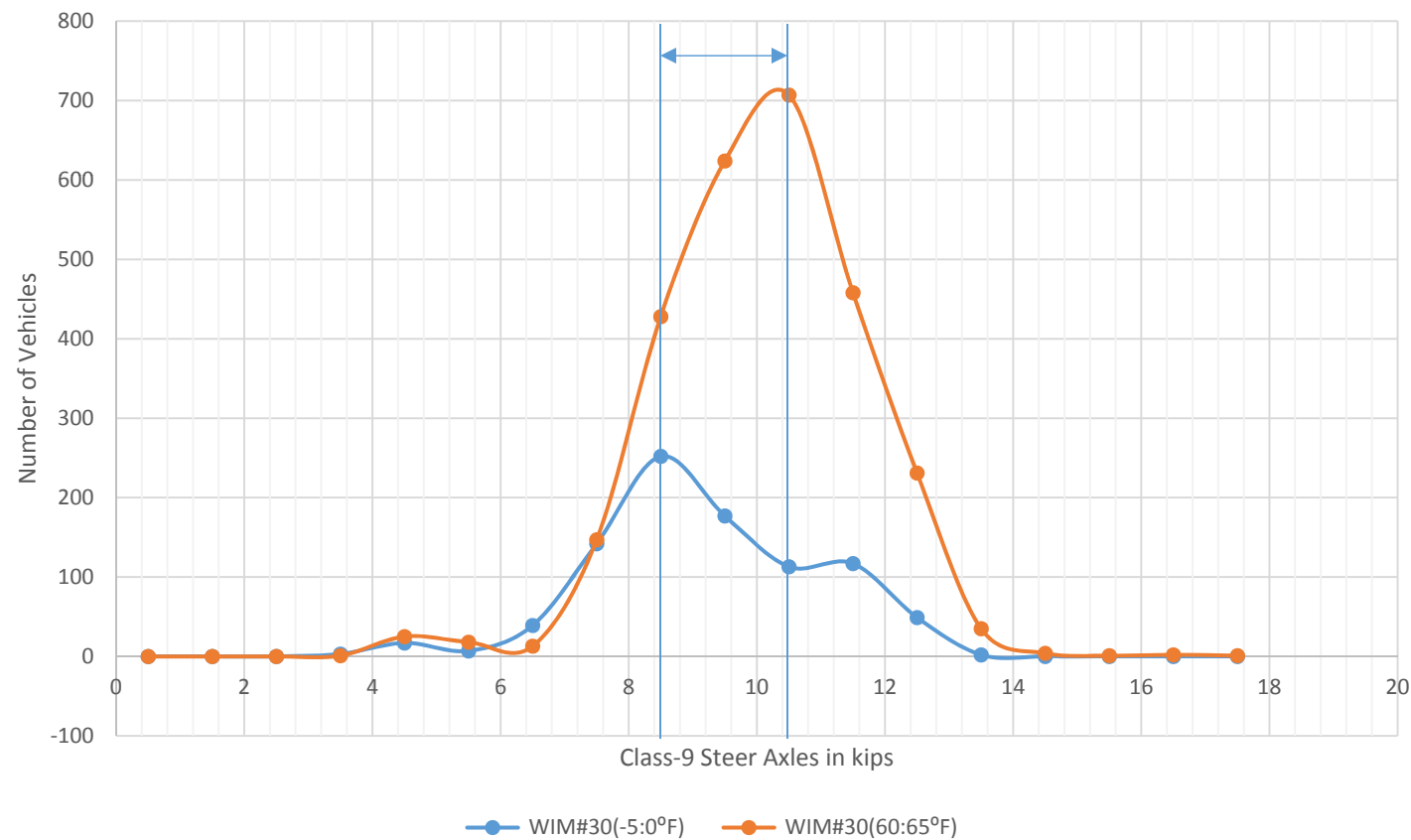


Before Calibration

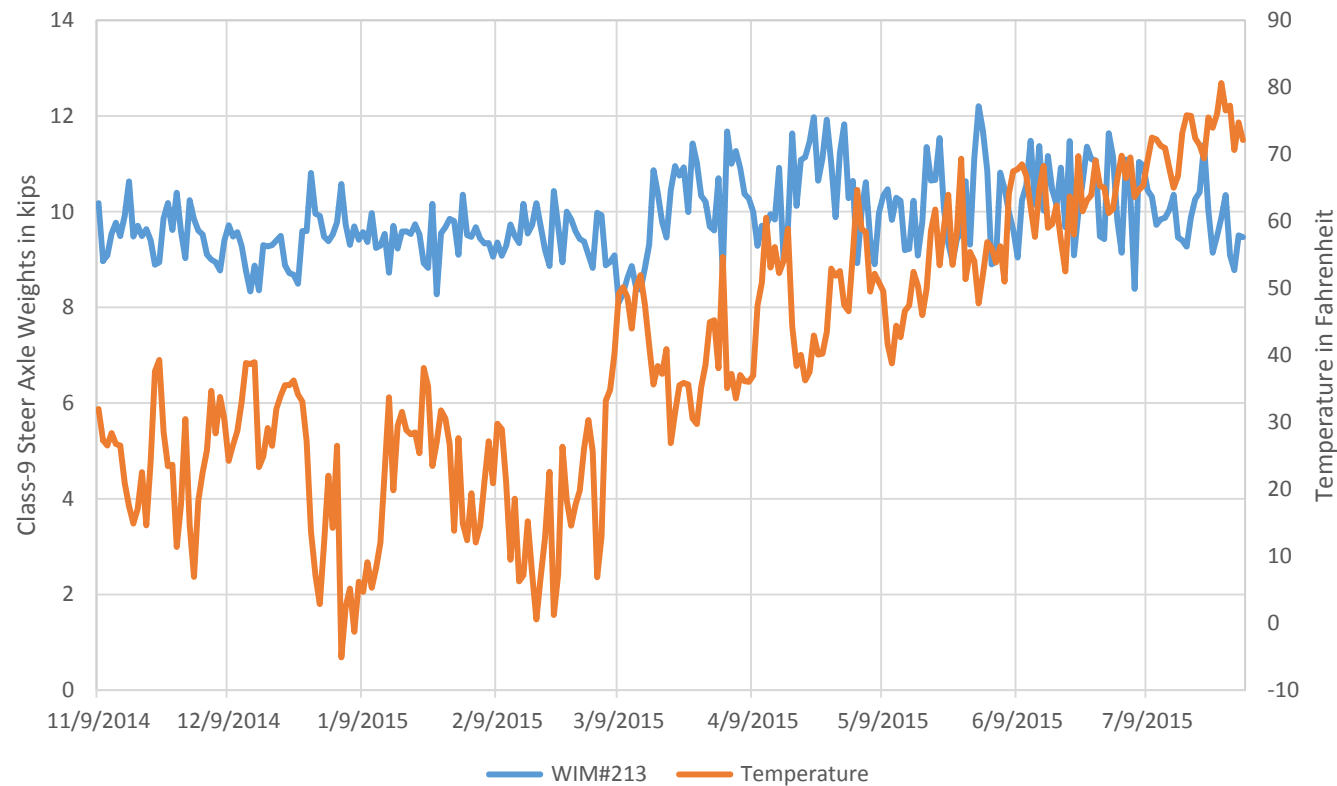


After Calibration

WIM#30 Class-9 Steer Axle Weight Histogram at Different Temperature Ranges: Lineas Sensor Without Calibration



Class-9 Steer Axle Daily Weight Averages and Pavement Temperature Relation: After Calibration



Vehicle Classification

WIM #30

Date	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	Total-30
7/10/2015	7906	3887	49	230	48	21	87	197	41	8	3	0	68	136	12685
7/11/2015	7274	3265	41	122	15	11	35	48	9	3	0	1	71	145	11047
7/12/2015	6860	3235	38	115	4	21	57	72	10	3	1	0	62	75	10558
7/13/2015	6078	3016	38	243	29	11	48	222	34	1	3	8	65	42	9841
7/14/2015	5864	2673	30	197	46	12	47	208	41	1	0	3	52	47	9222
7/15/2015	6001	2954	42	204	39	18	47	194	58	1	2	4	60	55	9680
7/16/2015	6402	3230	28	221	31	26	73	245	62	2	1	15	69	74	10479
7/17/2015	7612	3985	43	215	40	23	77	174	56	8	1	6	94	110	12447
7/18/2015	6913	3054	28	116	8	11	44	51	18	3	0	1	56	109	10419
7/19/2015	7421	3482	36	104	2	4	31	74	13	5	0	1	53	141	11375
7/20/2015	6238	3143	32	217	35	12	47	233	50	1	1	5	60	89	10164

WIM #213

Date	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	Total-213
7/10/2015	7614	3670	49	222	45	5	51	204	42	4	2	0	314	545	12774
7/11/2015	7018	3165	37	115	18	0	17	59	10	3	0	3	280	532	11270
7/12/2015	6441	3215	41	111	2	1	22	79	14	3	0	0	263	524	10722
7/13/2015	5718	2909	49	221	20	3	57	240	34	1	2	7	266	547	10081
7/14/2015	5412	2551	50	212	46	4	49	235	36	1	0	3	231	514	9348
7/15/2015	5556	2833	59	224	36	3	47	219	57	0	0	3	256	524	9823
7/16/2015	5992	3118	39	184	29	10	51	262	60	2	2	14	276	559	10601
7/17/2015	7185	3896	59	189	36	5	62	189	61	5	0	5	315	556	12572
7/18/2015	6633	2949	35	111	8	1	18	59	17	2	0	0	219	453	10516
7/19/2015	7094	3295	47	109	1	1	22	75	15	3	0	1	269	543	11495
7/20/2015	5826	2979	64	215	31	1	45	245	49	2	0	4	278	580	10329

Portable WIM



Portable WIM System

BL WIM weigh-pad	\$3,314	2	\$6,628
Controller	\$7,894	1	\$7,894
Ext. battery pack	\$1,300	2	\$2,600
Productions labor	\$12,500	1	\$12,500
Spare parts	\$1,000	1	\$1,000
Shipping and handling of parts	\$500	1	\$500
Total			\$31,122

Concluding Remarks

- BL-Sensor Based WIM systems can be three times cheaper than Lineas- sensor based, i.e., **\$181,500 vs \$58,885** for a 4-lane road
- Lineas sensors have temperature sensitivity but not as severe as BL sensors
- If Lineas sensors are not temperature calibrated, its accuracy is below temperature calibrated BL sensors.
- BL-Sensor Based WIM systems can achieve a similar or better accuracy with much cheaper price if axle weights are temperature calibrated

Contact Information

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