ERROR REDUCTION IN HS-WIM SYSTEMS VIA STATISTICAL REGRESSION OF PAVEMENT TEMPERATURE AND VEHICLE SPEED

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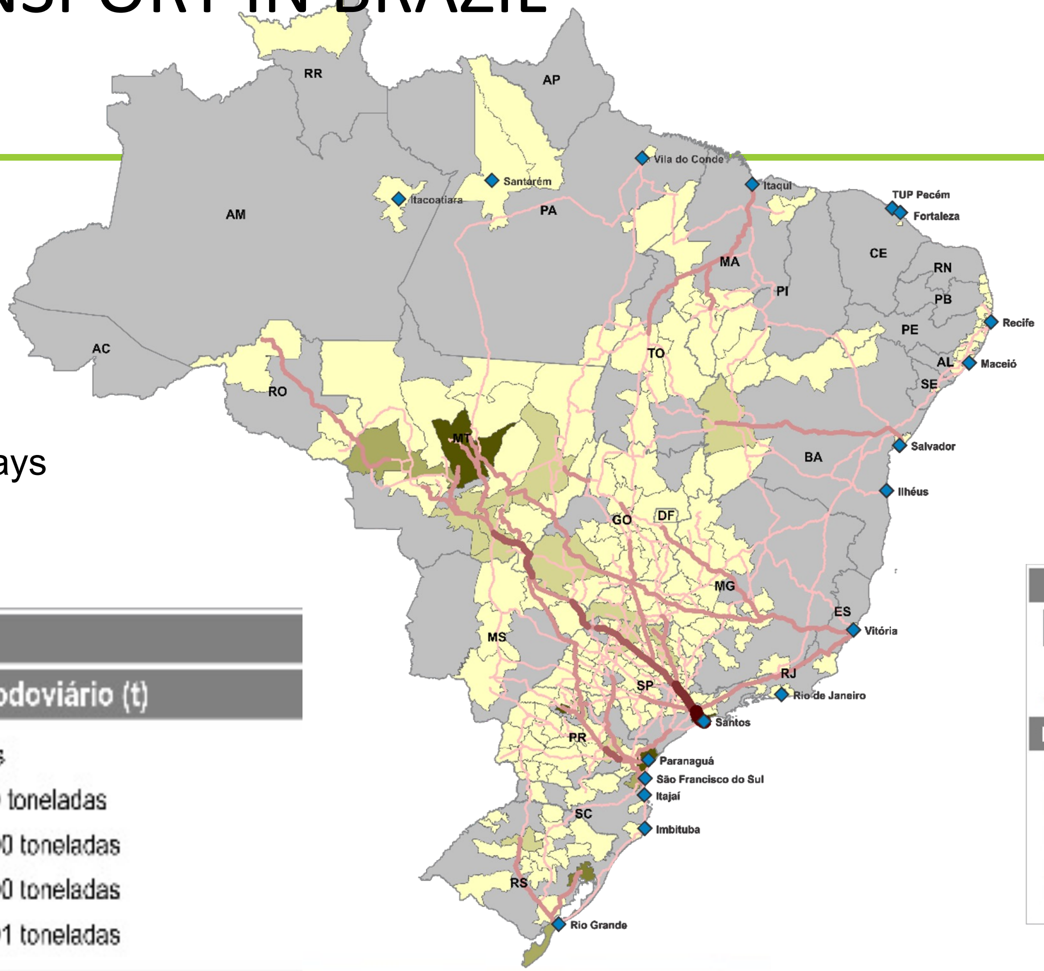
We Travel Together

presented by

INLAND TRANSPORT IN BRAZIL

Input - o exportation flux, ref. year 2014
Products: Sugar, Corn and Been, by grouped in microregions.
source: AliceWeb.

Main road transport - highways



LEGENDA

Volumes acumulados - modal rodoviário (t)

- de 1 até 1.000.000 toneladas
- de 1.000.000 até 10.000.000 toneladas
- de 10.000.000 até 20.000.000 toneladas
- de 20.000.000 até 30.000.000 toneladas
- de 30.000.000 até 37.146.801 toneladas

Production in tons

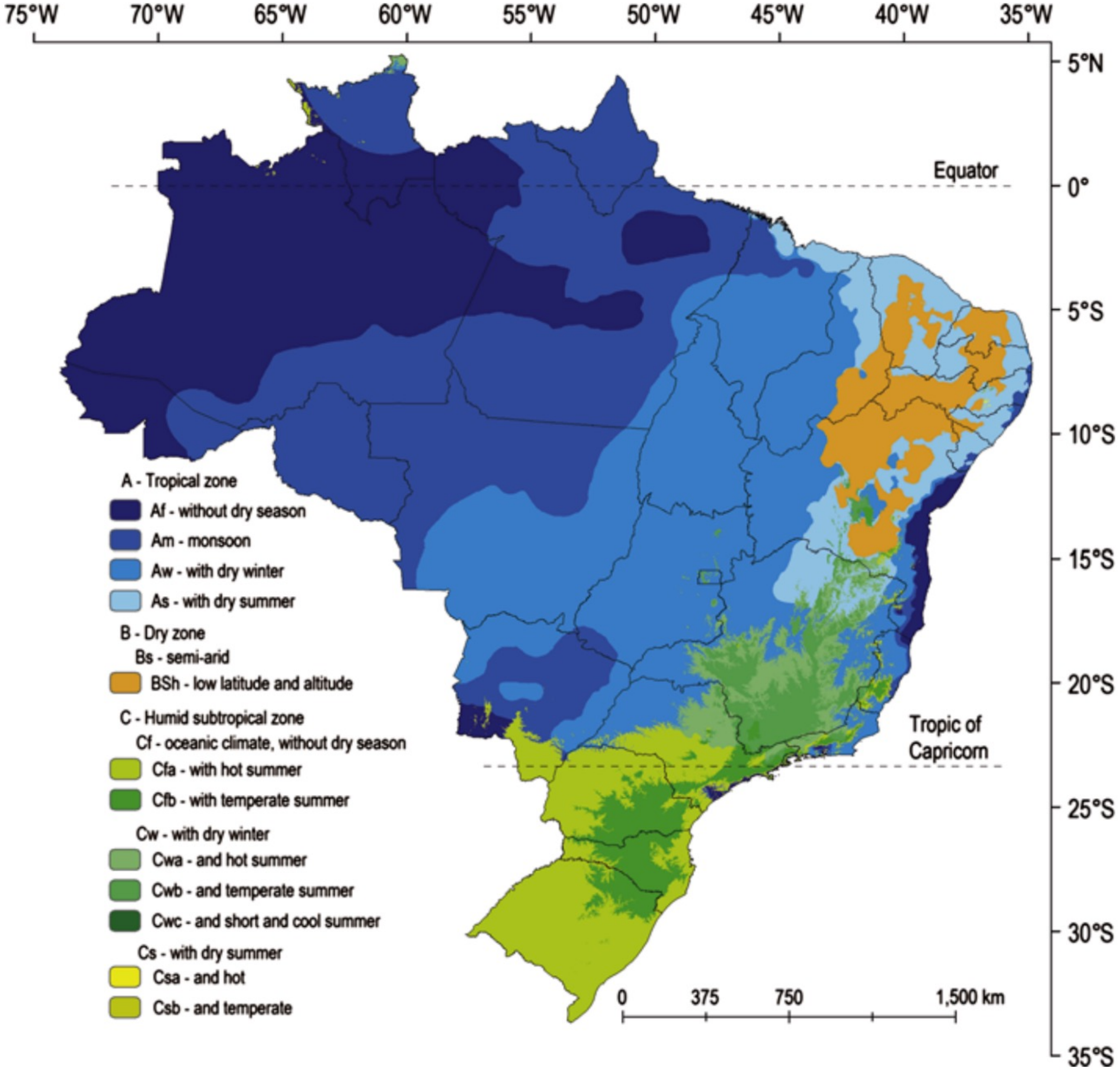
LEGENDA

- Estados
- Instalações Portuárias
- Malha Rodoviária

Exportação de Açúcar, Milho e Soja - Microrregiões - 2014 (t)

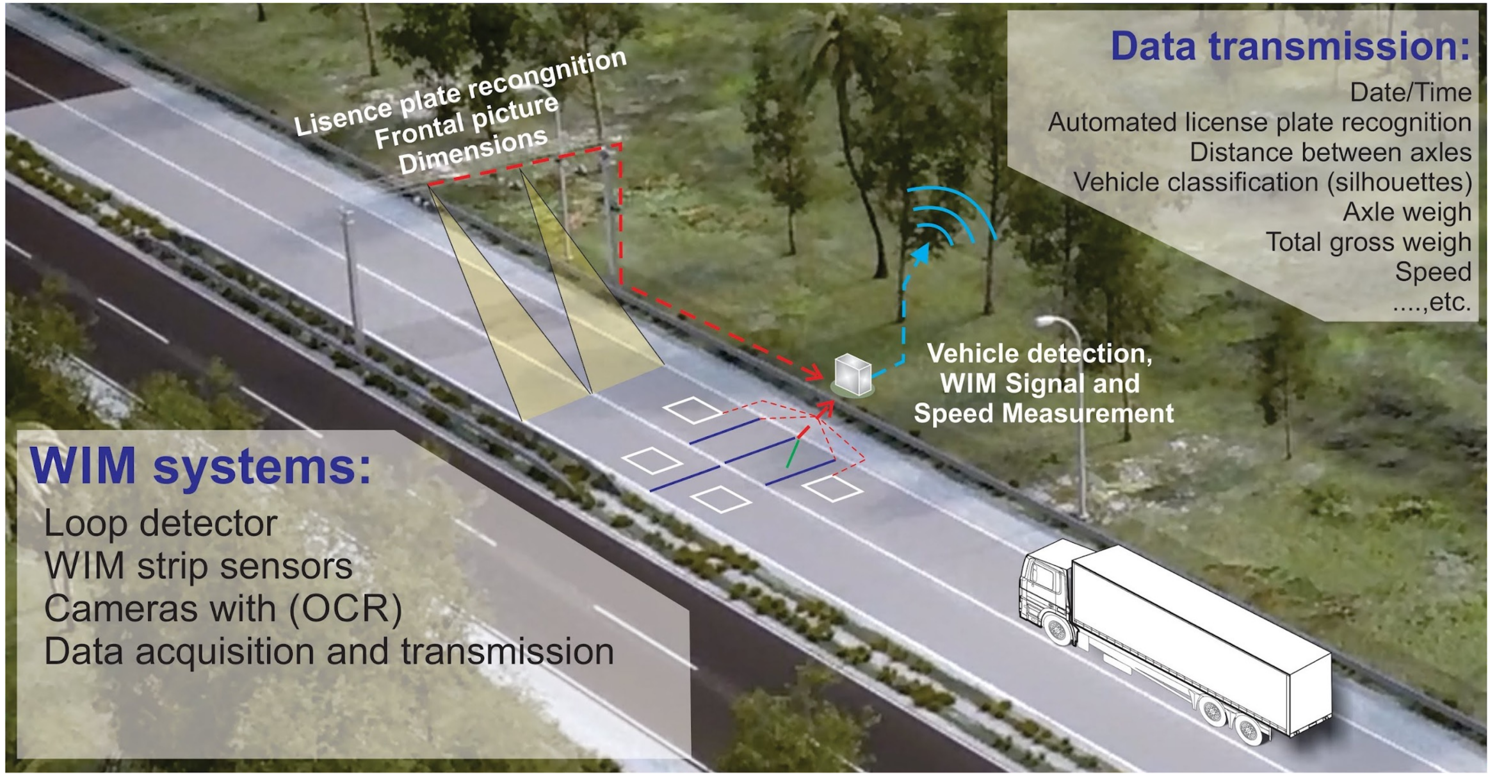
- de 1 até 1.000.000 toneladas
- de 1.000.000 até 2.000.000 toneladas
- de 2.000.000 até 3.000.000 toneladas
- de 3.000.000 até 5.000.000 toneladas
- de 5.000.000 até 8.376.435 toneladas

CLIMATE MAP OF BRAZIL



Alvares, C.A. et al. (2013). *Köppen's climate classification map for Brazil*.

HS-WIM SYSTEM



DESCRIPTION OF THE EXPERIMENTAL SITE

Araranguá - SC BR-101/Sul Sítio WIM	I - WIM Itegrated systems	II - WIM Direct enforcement	III - Weight station

Integrated Station

Thick Asphalt Pavement

CRCP

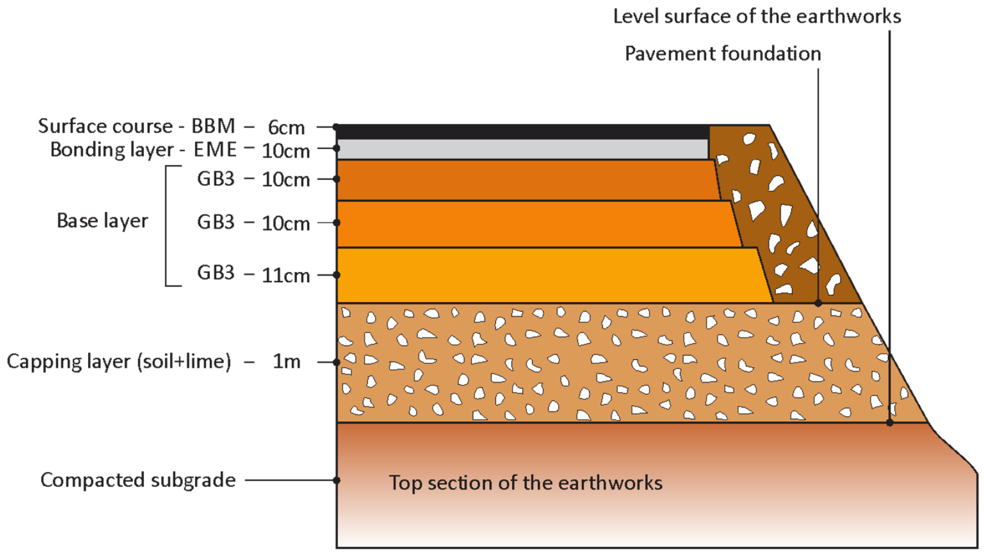
Weight Station

DESCRIPTION OF THE EXPERIMENTAL SITE

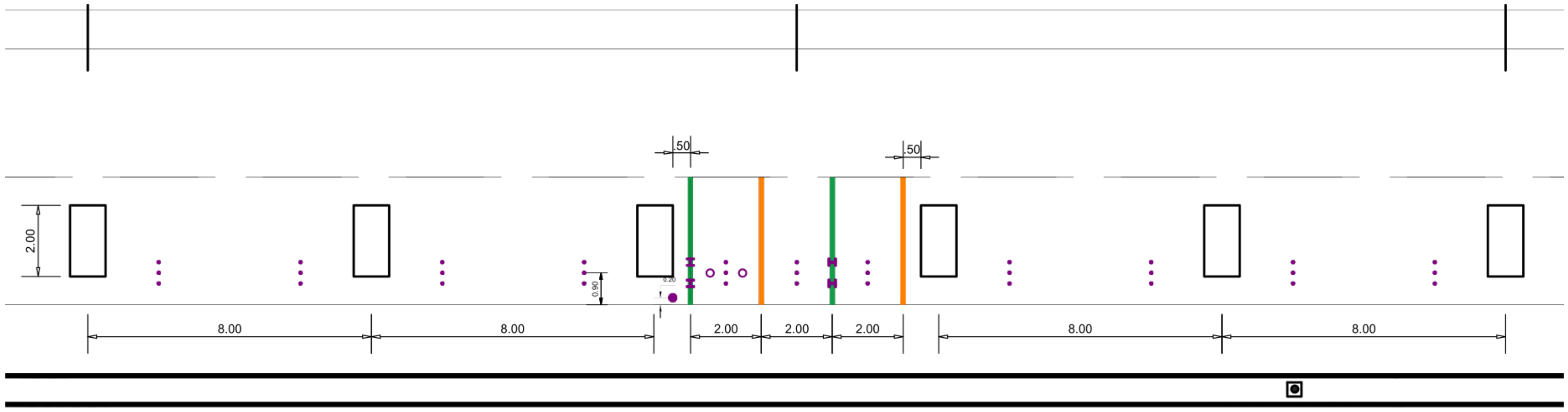
COST – 323 (1996). *Weigh-in-Motion of Road Vehicles*.

			WIM site classes		
			I Excellent	**II Good**	**III Acceptable**
Rutting (3 m - beam)		Rut depth max. (mm)	≤ 4	≤ 7	≤ 10
Deflection (quasi-static) (13 t - axle)	Semi-rigid Pavements	Mean deflection (10^{-2} mm) Left/Right difference (10^{-2} mm)	≤ 15 ± 3	≤ 20 ± 5	≤ 30 ± 10
	All bitumen Pavements	Mean deflection (10^{-2} mm) Left/Right difference (10^{-2} mm)	≤ 20 ± 4	≤ 35 ± 8	≤ 50 ± 12
	Flexible Pavements	Mean deflection (10^{-2} mm) Left/Right difference (10^{-2} mm)	≤ 30 ± 7	≤ 50 ± 10	≤ 75 ± 15
Deflection (dynamic) (5 t - load)	Semi-rigid Pavements	Deflection (10^{-2} mm) Left/Right difference (10^{-2} mm)	≤ 10 ± 2	≤ 15 ± 4	≤ 20 ± 7
	All bitumen Pavements	Mean deflection (10^{-2} mm) Left/Right difference (10^{-2} mm)	≤ 15 ± 3	≤ 25 ± 6	≤ 35 ± 9
	Flexible Pavements	Mean Deflection (10^{-2} mm) Left/Right difference (10^{-2} mm)	≤ 20 ± 5	≤ 35 ± 7	≤ 55 ± 10
Evenness	IRI index	Index (m/km)	0 - 1.3	1.3 - 2.6	2.6 - 4
	APL[(1)]	Rating* (SW, MW, LW)	9 - 10	7 - 8	5 - 6

The rutting and deflection values are given for a temperature below or equal to 20°C and suitable drainage conditions.



DESCRIPTION OF THE EXPERIMENTAL SITE



LabTrans

Legend

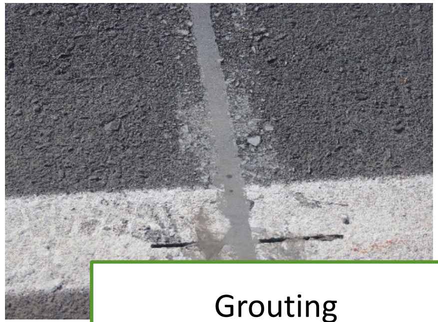
- Inductive Loop
- Geophone
- Vertical strain gage
- Temperature gauge
- Polymer sensor
- Ceramic sensor
- Transversal and longitudinal strain gage

DESCRIPTION OF THE EXPERIMENTAL SITE


Marking and cutting the pavement


Cleaning the openings


Sensor installation


Grouting


Surface grinning


HS-WIM system

METHODOLOGY

The proposed method is a correction of the weight as a function of:

- Temperature of the pavement
- Vehicle speed

Statistical Correction Model

$$C(T,S) = \begin{cases} T \in [T_{1,l}, T_{1,u}) \rightarrow a_1 S + b_1 \\ T \in [T_{2,l}, T_{2,u}) \rightarrow a_2 S + b_2 \\ T \in [T_{3,l}, T_{3,u}) \rightarrow a_3 S + b_3 \\ \vdots \\ T \in [T_{n,l}, T_{n,u}) \rightarrow a_n S + b_n \end{cases}$$

TEST CAMPAIGN USING KNOWN VEHICLES

Test plan:

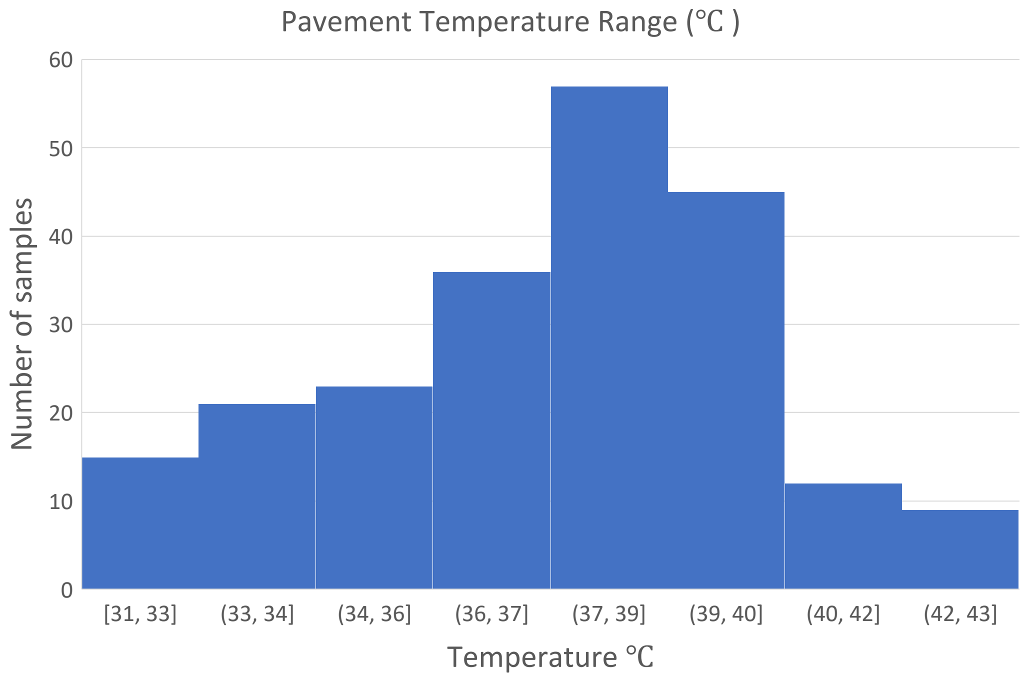
- Three types of vehicles.
- Seven (7) runs were planned for each vehicle, for each speed and lateral position.
- The three speeds chosen are:
  - **60, 70 and 80 km/h.**
  - **Lateral positioning: left, center and right.**
- The test calibration and test evaluations was performed on consecutive days:
  - **From May 5th to May 8th of 2019 – calibration.**
  - **May 9th of 2019 - test for evaluation.**

TEST CAMPAIGN USING KNOWN VEHICLES

Table 1. Axle weight of each axle of the three reference vehicles

Vehicle	Axle 1 (kN)	Axle 2 (kN)	Axle 3 (kN)	Axle 4 (kN)	Axle 5 (kN)	Axle 6 (kN)
3 axles	53.710	97.048	76.995	–	–	–
5 axles	56.774	102.881	95.054	81.008	67.235	–
6 axles	51.456	90.810	68.190	78.408	81.309	64.286

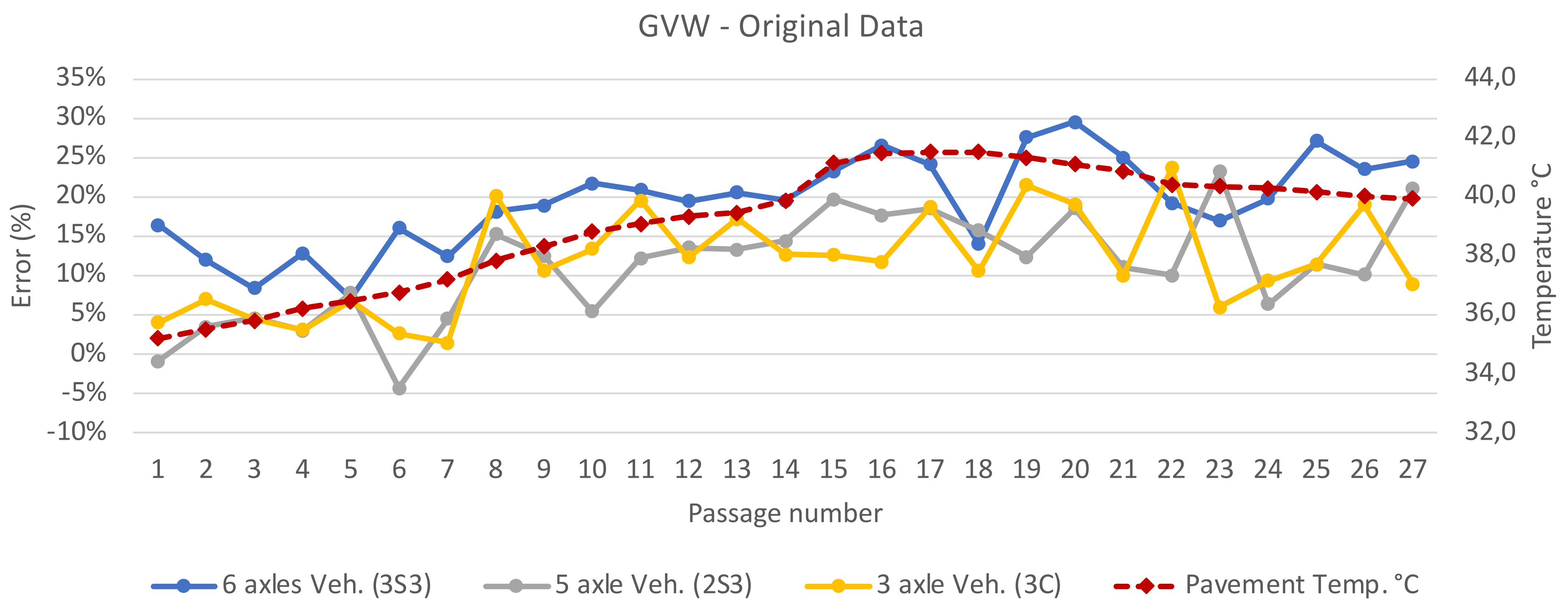
PRACTICAL APPLICATION



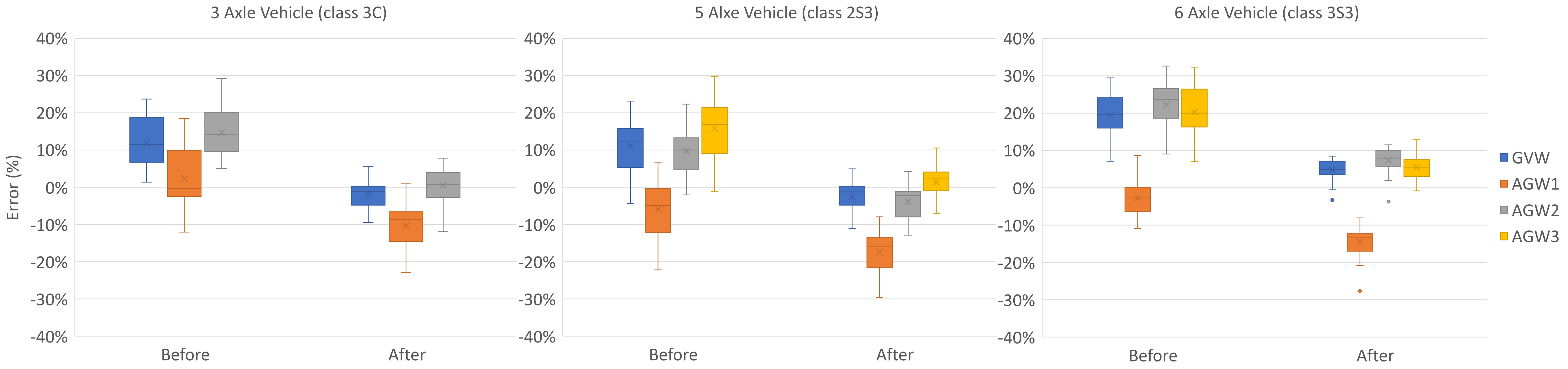
$$C_{\text{ceramic}}(T,V) = \begin{cases} T \in [33{,}854, 37{,}459) \rightarrow 0{,}021S + 0{,}816 \\ T \in [37{,}459, 40{,}421) \rightarrow 0{,}018S + 0{,}803 \\ T \in [40{,}421, 41{,}553) \rightarrow 0{,}016S + 0{,}811 \\ T \in [41{,}553, 43{,}838) \rightarrow 0{,}018S + 0{,}750 \end{cases}$$

$$C_{\text{polymer}}(T,V) = \begin{cases} T \in [33{,}854, 37{,}459) \rightarrow 0{,}020S + 0{,}668 \\ T \in [37{,}459, 40{,}421) \rightarrow 0{,}030S + 0{,}560 \\ T \in [40{,}421, 41{,}553) \rightarrow 0{,}031S + 0{,}559 \\ T \in [41{,}553, 43{,}838) \rightarrow 0{,}044S + 0{,}352 \end{cases}$$

SYSTEM ERRORS WITHOUT CALIBRATION



SYSTEM ERRORS AFTER CORRECTION



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Gustavo G. Otto et al.

presented by IDAHO TRANSPORTATION DEPARTMENT PACIFIC NW TRANSPORTATION CONSORTIUM PACTRANS REGION 10

MAIN RESULTS

Class	Entity	Errors before correction				Errors after correction			
		Min	Average	Max	St. dev.	Min	Average	Max	St. dev.
3C	**GVW**	**1,45%**	**11,79%**	**23,71%**	**6,32%**	**-9,44%**	**-1,95%**	**5,71%**	**4,08%**
	AGW1	-12,08%	2,30%	18,51%	8,47%	-22,85%	-10,28%	1,11%	6,38%
	AGW2	5,09%	14,71%	29,22%	6,63%	-11,89%	0,62%	7,82%	4,39%
2S3	**GVW**	**-4,29%**	**11,14%**	**23,19%**	**6,78%**	**-11,05%**	**-2,55%**	**4,98%**	**4,04%**
	AGW1	-22,19%	-5,85%	6,58%	7,83%	-29,57%	-17,46%	-7,97%	5,52%
	AGW2	-1,98%	9,70%	22,38%	6,33%	-12,88%	-3,78%	4,29%	4,17%
	AGW3	-1,00%	16,00%	30,00%	7,27%	-7,00%	1,00%	11,00%	4,30%
3S3	**GVW**	**7,16%**	**19,48%**	**29,51%**	**5,80%**	**-3,21%**	**4,86%**	**8,57%**	**2,72%**
	AGW1	-10,98%	-2,69%	8,64%	4,72%	-27,68%	-14,52%	-8,10%	4,26%
	AGW2	9,11%	22,32%	32,59%	5,98%	-3,73%	7,36%	11,53%	3,34%
	AGW3	7,06%	20,25%	32,36%	6,72%	-0,77%	5,50%	12,95%	3,08%

CONCLUSIONS

- The proposed method has the potential to correct the average values of the errors observed, placing all the errors closer to zero.
- It reduces the spread of the errors, as observed by the standard deviation before and after the correction.
- Limitation of the present work is that the temperatures observed during data collection were not those usually observed in practice, since the weather was mild, and the pavement wasn't exposed to the sun.
- Therefore, future studies could test the proposed model with higher temperature amplitudes. Future studies could also test the proposed method in other contexts, such as HS-WIM systems using different technologies from the ones used in this study.

THANK YOU!!!

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