Options for Providing Reliable Axle Load Data for Mechanistic-Empirical Pavement Design in Manitoba

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Presentation Outline

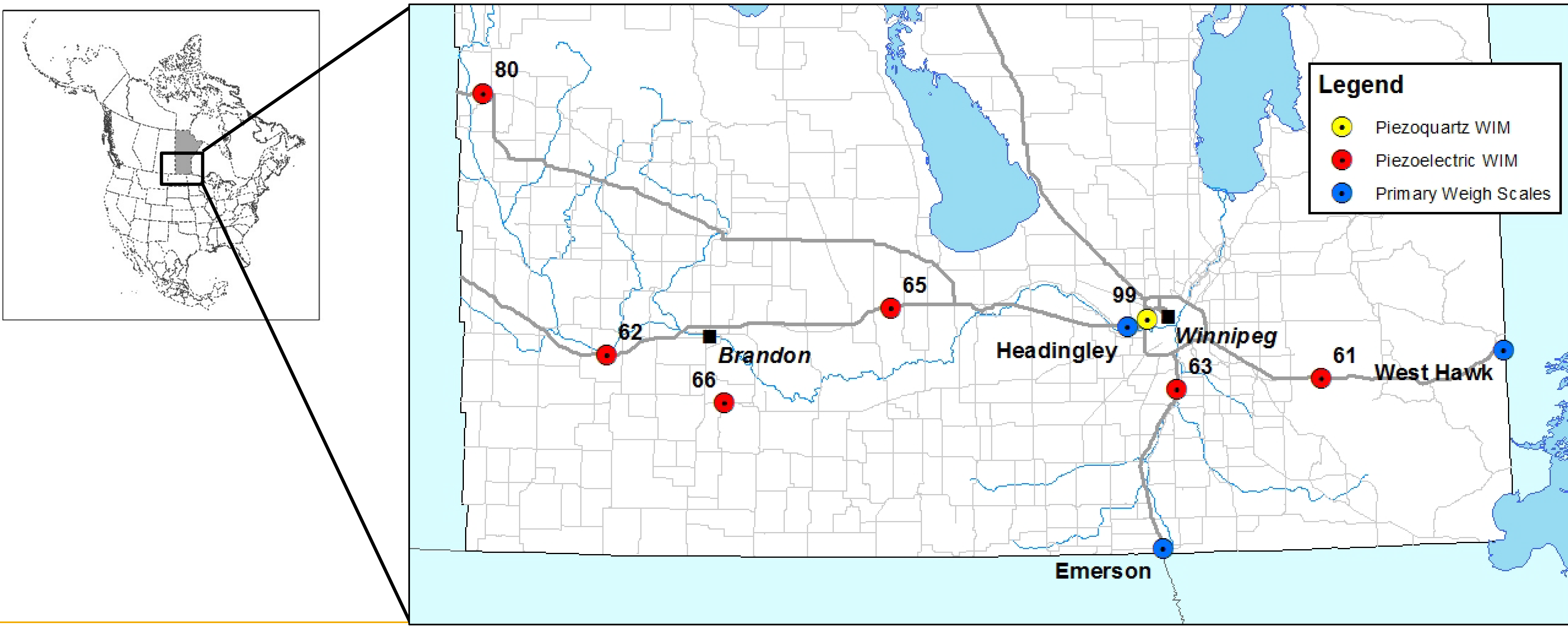
1. Introduction
2. Data Options and Data Quality Principles
3. Analysis Approach
4. Static Weigh Scale Accuracy
5. Piezoelectric WIM Accuracy
6. Piezoquartz WIM Accuracy
7. Summary of Findings

Introduction

- Jurisdictions are moving towards more innovative pavement design
  - New approach involves mechanistic-empirical principles
  - AASHTOWare Pavement ME Software
- The University of Manitoba provides input data to support this design approach in Manitoba
  - Axle load spectra by vehicle class
  - Truck traffic volume by vehicle class
  - Temporal distributions
  - Others

Introduction

- Manitoba has several options for providing axle loading data
- **Key question**: Which data are best to use for pavement design?



Data Options

- **Option 1:** Use truncated 2014 WIM data from six existing (legacy) piezoelectric WIM sites
- **Option 2:** Use data from 2013, 2015, and 2016 Manitoba static weigh scale surveys
- **Option 3:** Use data from one new piezoquartz WIM site

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How Do We Select the Best Option?

Data quality principles:

1. **Accuracy:** Use equipment which most accurately represents true weights
2. **Geographic Coverage:** Maximize geographic dispersion as well as load classification dispersion
3. **Temporal Coverage:** Maximize temporal coverage
4. **Data Availability:** Collection effort and future plans for equipment

Analysis Approach

- **Question 1:** How confident are we with the static weights?
  - Observe operational practices
  - Collect and analyze data
- **Question 2:** How accurate are the piezoelectric sensors?
  - Determine test variable using weigh scale surveys
  - Check for post-calibration fluctuations using statistical tests
- **Question 3:** How accurate are the piezoquartz sensors?
  - Truck pairing survey

Question 1: Confidence in Static Weights

- Source data:
  - Scale is certified annually for a issuing legal citation for a weight violation
  - Surveys conducted June 18, July 29/30, Nov 25/26, Mar 1/2
  - All trucks (laden and empty) were pulled over when lights were flashing and weighed
  - Some fluctuation in weight readings observed

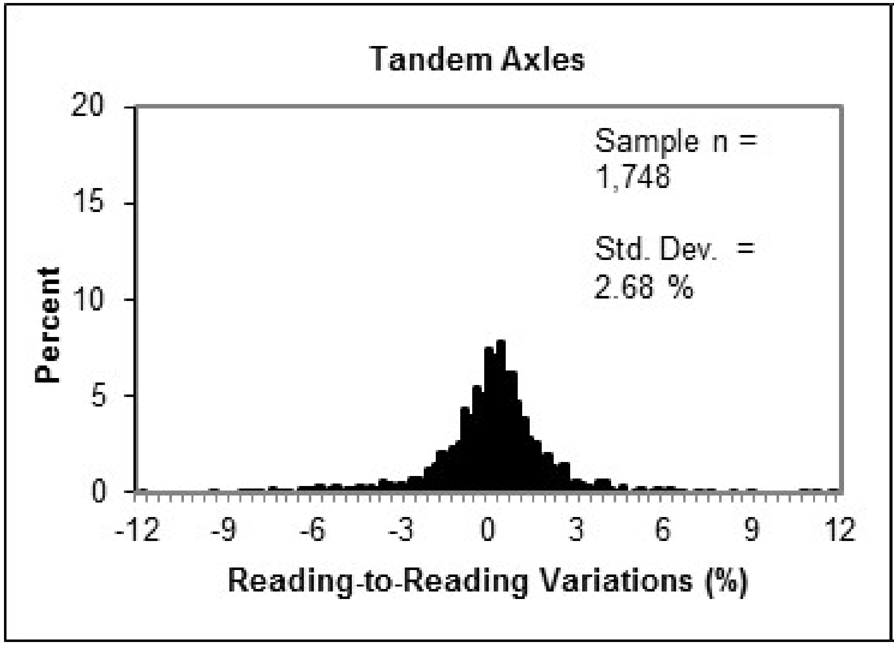
Weigh-Tronix WI-130 Model
Source: http://www.wtxweb.com/literature/130_u.pdf

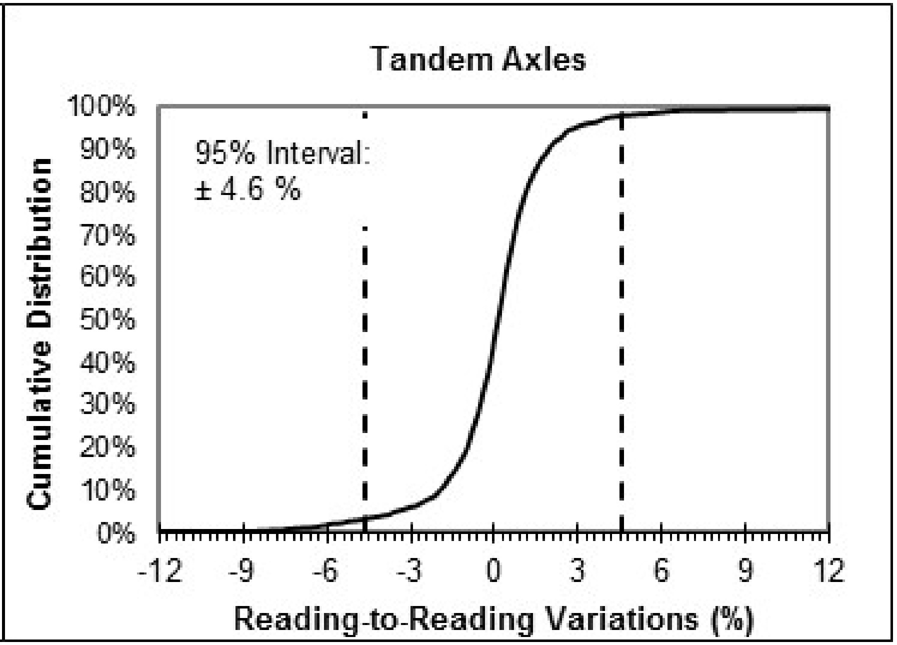
Question 1: Confidence in Static Weights

- Method:
  - To avoid the “lurching” effect of stopping, and prevent excessive queues, trucks rolled over scale at ~5 km/h (dynamic effects)
  - Two “acceptable” measurements were taken per axle group to measure variations of scale readings
  - Gives a measure of “repeatability” or “stability”

Source: Google Earth

Question 1: Confidence in Static Weights





Question 1: Findings

- Once readings stabilize, reading-to-reading variations are not significant
- When comparing readings to billed weights, accuracy was high (average bias = +0.7% steering axle, +0.8% tandem axle)
- We are confident in using the static weight measurements as “ground-truth”

Question 2: Piezoelectric Accuracy

Method:

Step 1: Determine Test Variable for "Ground-Truth"

→

Step 2: Study Test Variable to Establish "Ground-Truth"

→

Step 3: Evaluate WIM Data Against "Ground-Truth"

→

Step 4: Extension of Step 3; Evaluate Shorter-Term WIM Data

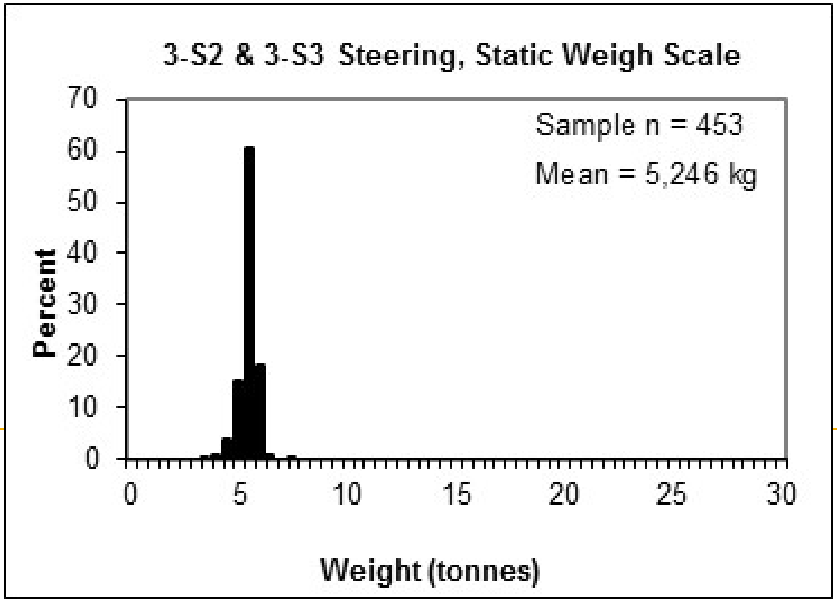
Step 1: Investigate steering axles of common tractor-semitrailer configurations. Cab and engine size is somewhat "standardized". Test variable = steering axle loads.

Question 2: Piezoelectric Accuracy

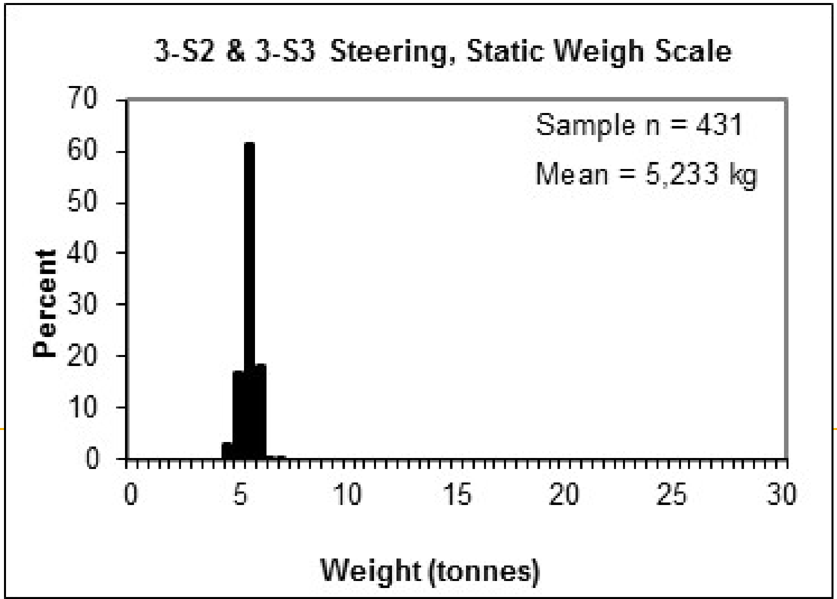
Step 2: Study Steering Axle Loads at Static Weigh Scale to Establish "Ground Truth"

- Data collected in June and July at static weigh scale confirmed the stability of steering axle loads for 5 and 6-axle tractor semitrailers
- Independent group comparison test conducted:
  - Statistical similarity confirmed (p-value of 59%, typical cut-off = 5%)

June 18, 2015



July 29/30, 2015



Question 2: Piezoelectric Accuracy

Step 2: Study Steering Axle Loads at Static Weigh Scales to Establish “Ground Truth”

	June	July	Nov	Mar
Mean Steer Weight	5246 kg	5233 kg	5216 kg	5158 kg

	June-July	June-Nov	June-Mar	July-Nov	July-Mar	Nov-Mar
Similarity (p-value)	0.59	0.25	< 0.001	0.49	0.01	0.03
% Diff of means	-0.24	-0.56	-1.66	-0.32	0.32	-1.11

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Question 2: Piezoelectric Accuracy

Step 3: Test WIM Steering Axle Loads Against "Ground Truth"

	1st Week Post-cal	2nd Week Post-cal	3rd Week Post-cal	4th Week Post-cal
Station 61 Avg. Weight	6011 kg	6304 kg	5896 kg	6289 kg
Station 62 Avg. Weight	6936 kg	5533 kg	5033 kg	5522 kg
Station 63 Avg. Weight	4768 kg	5272 kg	5865 kg	5888 kg
Station 65 Avg. Weight	6002 kg	5216 kg	4801 kg	4775 kg
Station 66 Avg. Weight	5132 kg	4733 kg	4087 kg	3889 kg
Station 80 Avg. Weight	6256 kg	4745 kg	4435 kg	4768 kg
Station 99 Avg. Weight	5528 kg	5450 kg	5236 kg	-

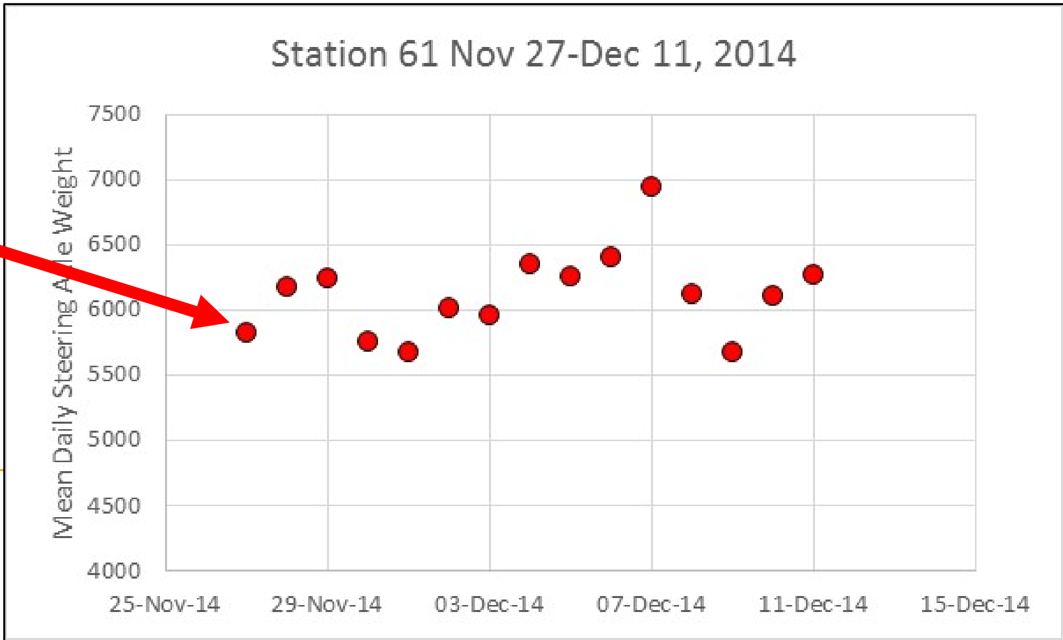
Although no statistical similarity was found for any station, S99 (piezoquartz) was the most consistent station.

Question 2: Piezoelectric Accuracy

Step 4: Evaluate WIM Data on Finer Time Scale (Within 1 Week Post-Calibration)

- Literature states that piezoelectric sensors are sensitive to temp.
- Piezoelectric sensors also exhibited significant day-to-day variations of 5 and 6-axle tractor semitrailer steering axle weights
- May be able to “correct” weights to obtain a useable data sample

Station 61 calibrated on Nov 27, 2014



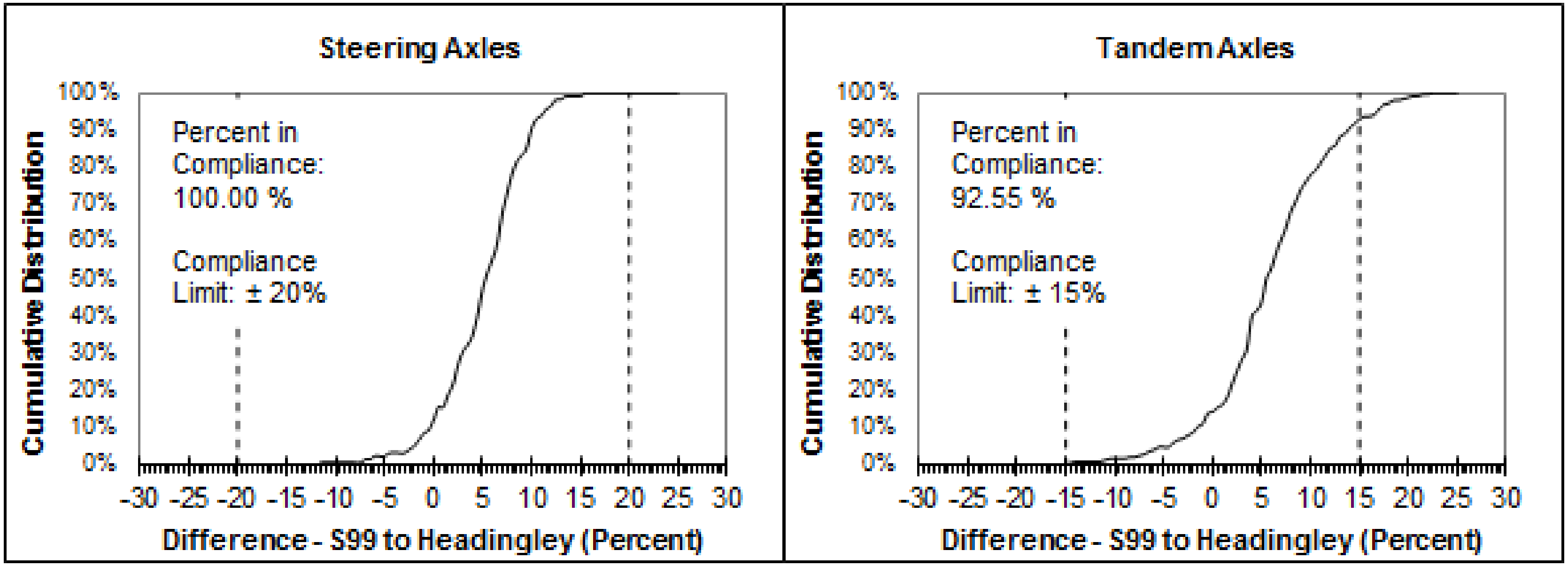
Question 2: Findings

- The accuracy of piezoelectric WIM sensors appears to fluctuate, potentially immediately post-calibration
- Measurements are sensitive to temperature variations (these may be “correctable”)
- If available, other options should be considered

Question 3: Piezoquartz Accuracy

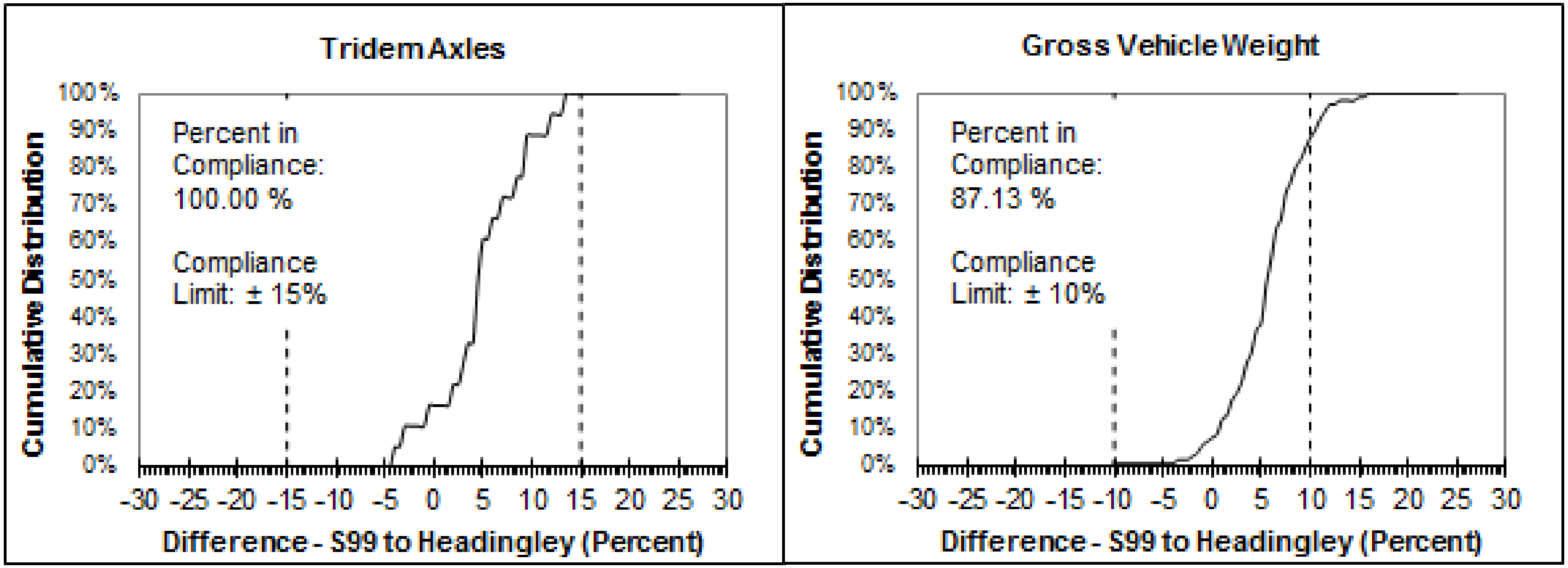
- Since we are confident in the static weight data, we can use this as a "ground-truth" to assess the accuracy of the new piezoquartz WIM sensor
- Method:
  - Install camera at piezoquartz WIM to identify characteristics of trucks
  - Manual identification of these same characteristics (e.g., truck configuration, body type, colour) at nearby static weigh scale
  - 120 truck pairs were identified
  - Comparison against ASTM E-1318

Question 3: Piezoquartz Accuracy



Note: Station 99 last calibrated on November 26, 2014

Question 3: Piezoquartz accuracy



Note: Station 99 last calibrated on November 26, 2014

- ASTM standard was met or nearly met for single, tandem, tridem, GVW

Question 3: Findings

- Relative to "ground-truth" data, the piezoquartz WIM sensors met or nearly net ASTM accuracy standards for a Type 1 system (high-speed operation away from a weigh scale)
- Existing literature and temperature analysis indicates that piezoquartz sensors are less susceptible to temperature fluctuations
- Appear to perform more reliably than Manitoba's piezoelectric sensors

Summary

Principle	Static Weigh Scale	Piezoelectric WIM	Piezoquartz WIM
Accuracy	Excellent	Fair	Good
Geographic Coverage	Limited	Fair	Limited
Temporal Coverage	Labor intensive to collect data. Automate?	Data must be truncated	Good
Data Availability		Good for now	Two additional installations scheduled

Summary

- There is a need to improve data collection capabilities at static weigh scales to improve data availability
- Piezoquartz sensors out-perform piezoelectric sensors
- The need to truncate data at piezoelectric sensors impedes temporal coverage
- Piezoquartz sensors perform well and provide good temporal coverage
- Increasing geographic and directional coverage will benefit Manitoba's data collection program

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Thank You!!

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