Analysis of Wheel Wear and Forecasting of Wheel Life for Transit Rail Operations: A Big Data Analysis

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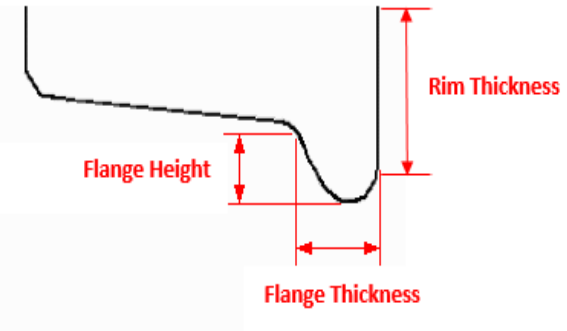
INTRODUCTION

- Under the UTC RailTeam, a Big Data analysis of transit vehicle wheel wear was performed
- Data was provided by NYCT as part of the NYCT's Integrated Wheel/Rail Characterization and Safety project
  - FTA sponsored program for the implementation of advanced wheel, track, and truck measurement and analytics systems.
  - NYCT team included KLD Labs, NRC Canada, Dayton T. Brown, Plasser American, Wayside Inspection Devices, and Instrumentation Services Inc.
  - The University of Delaware (UD) provided an independent third-party analysis.

- With UTC sponsorship, UD looked at the data collected from the perspective of potential for application of Big Data analytics to provide an enhanced analysis.
  - Focus was on wheel wear data analysis
  - Forecasting of wheel maintenance and replacement cycles

BACKGROUND

- Primary focus was to study the wear rate of wheels in the NYCT 7 Line fleet.
- Wheel profile measurements were made available from a KLD Automatic WheelScan system.
- Based UD's analysis of NYCT's current truing standards:
  - NYCT is truing primarily to maintain flange thickness.
  - Wheel truing* occurs when the flange thickness is measured at 24. mm.
  - A new or recently trued wheel will have a flange thickness of 32.1 mm
  - When a wheel is trued, the rim thickness decreases . Eventually, th rim thickness can no longer be decreased and the wheel has to b replaced (new wheel is installed).



Wheel Profile Measurements

* Wheel truing is a machining operation performed in the car shop to reshape the profile of the wheel and extend its service life

BACKGROUND

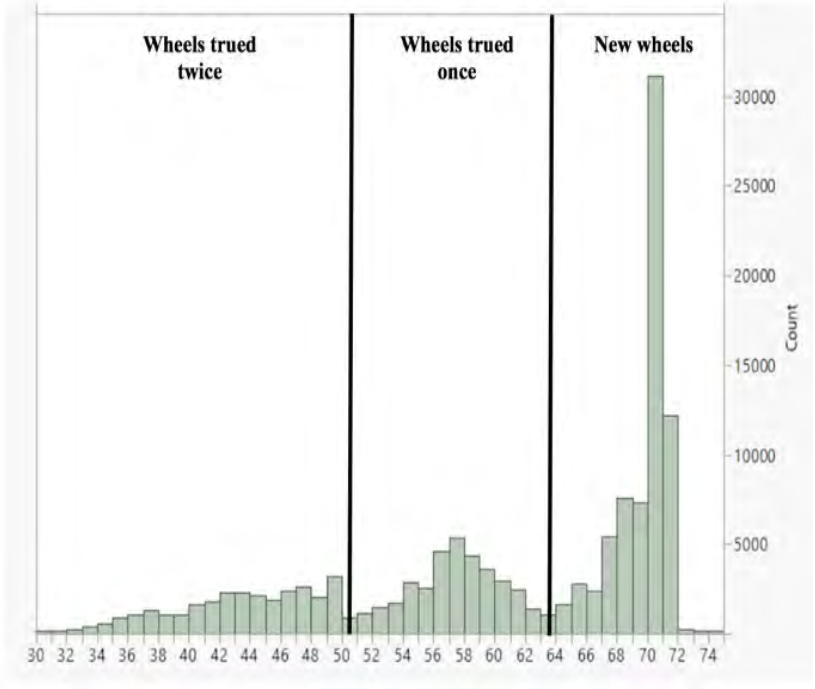
- The objective of this study was to:
  - Analyze the wear rates of the NYCT transit vehicle wheels.
  - Utilize this wear rate to predict wheel life.
  - Identify wheels that have “excessively” high rates of wheel wear.

- These forecasts and projections will allow for an assessment of the performance of NYCT’s vehicle fleet from a wheel wear perspective, and perhaps examine current NYCT maintenance standards to see if they can be further optimized.

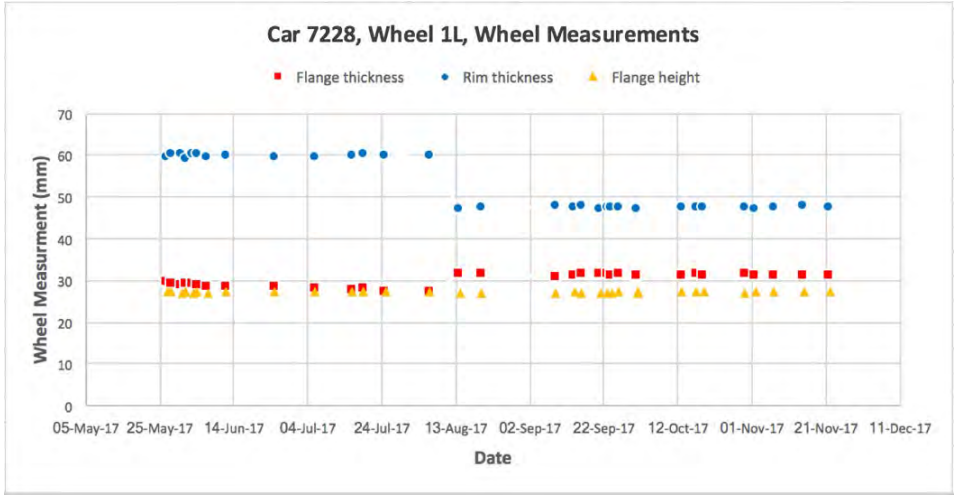
DATA SET AND PRELIMIARY ANALYSIS

- The NYCT 7 Line fleet consisted of nearly 500 cars and 4,000 wheels, each of which was measured each time it passed the WheelScan (several times a week).
  - Each car was equipped with an RFID tag, so individual wheels and their associated wear data could be identified.
- Dataset contained all measurements from June 1, 2017 – April 30, 2018.
- Dataset consisted of over 140,000 data points.
  - Each data point represented one full set of wheel measurements.
- In order to best to understand the data that is being worked with, preliminary analysis included Exploratory Data Analysis (EDA)
  - EDA provides a preliminary assessment of the data to identify potential relationships within the dataset.

EXPLORATORY DATA ANALYSIS

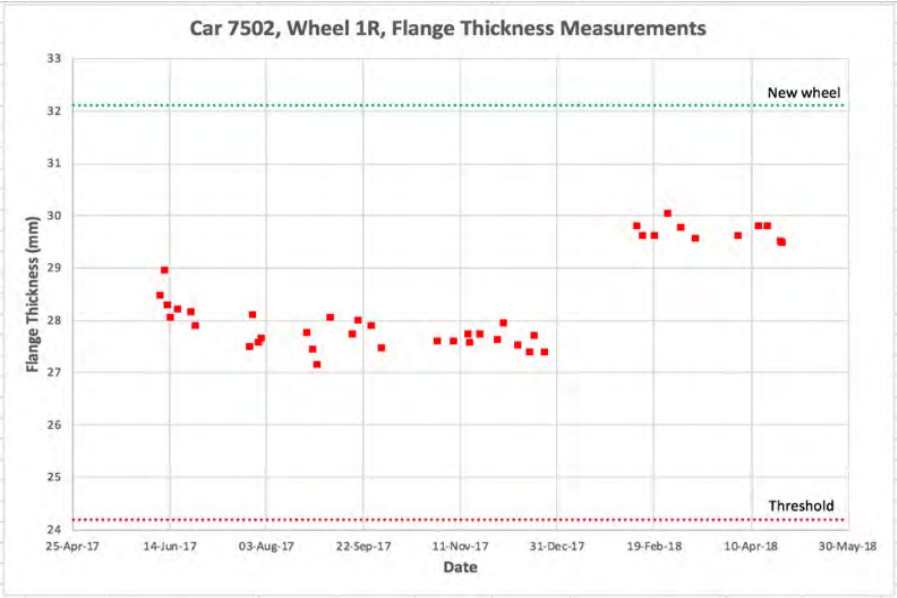


Histogram of Rim Thickness



Plot of Wheel Measurements for Car 7228, Axle 1, Left Wheel

CALCULATION OF WEAR RATES



Plot of Flange Thickness for Car 7502, Axle 1, Right Wheel

- Exponential regression was used.

$$y = Ae^{kx}$$

Where: y = flange thickness (mm)
A = constant (mm)
k = wear rate (1/days)
x = time (days)

- Regression analysis model applied to each of the 4000 wheels in the fleet.
  - Population of A and k values obtained

RESULTS

- The following analyses were conducted in order to assess the performance of the NYCT's vehicle fleet from a wheel wear perspective and examine current NYCT maintenance standards to see if they can be further optimized:

  a. Forecasting Future Maintenance Events

  b. Analysis of Wheels with Known Lives (maintenance cycles)

  c. Examination of the Current Truing Process

  d. Investigation of Individual Wheels

FORECASTING FUTURE MAINTENANCE EVENTS

$$x = \frac{\ln(\frac{y_{threshold}}{A})}{k} - \frac{\ln(\frac{y_{last}}{A})}{k}$$

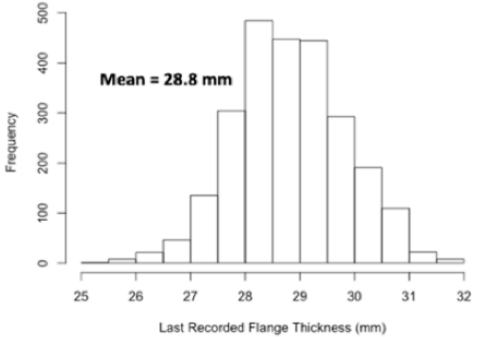
Where: x = time to reach the flange thickness threshold (days)

A = constant (mm)

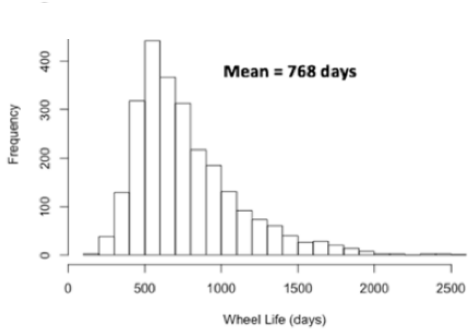
k = wear rate (1/days)

$y_{threshold}$ = 24.2 mm

y_{last} = the last recorded flange thickness measurement (mm)



Histogram of Last Recorded Flange Thickness (mm)



Histogram of Last Predicted Wheel Life (days)

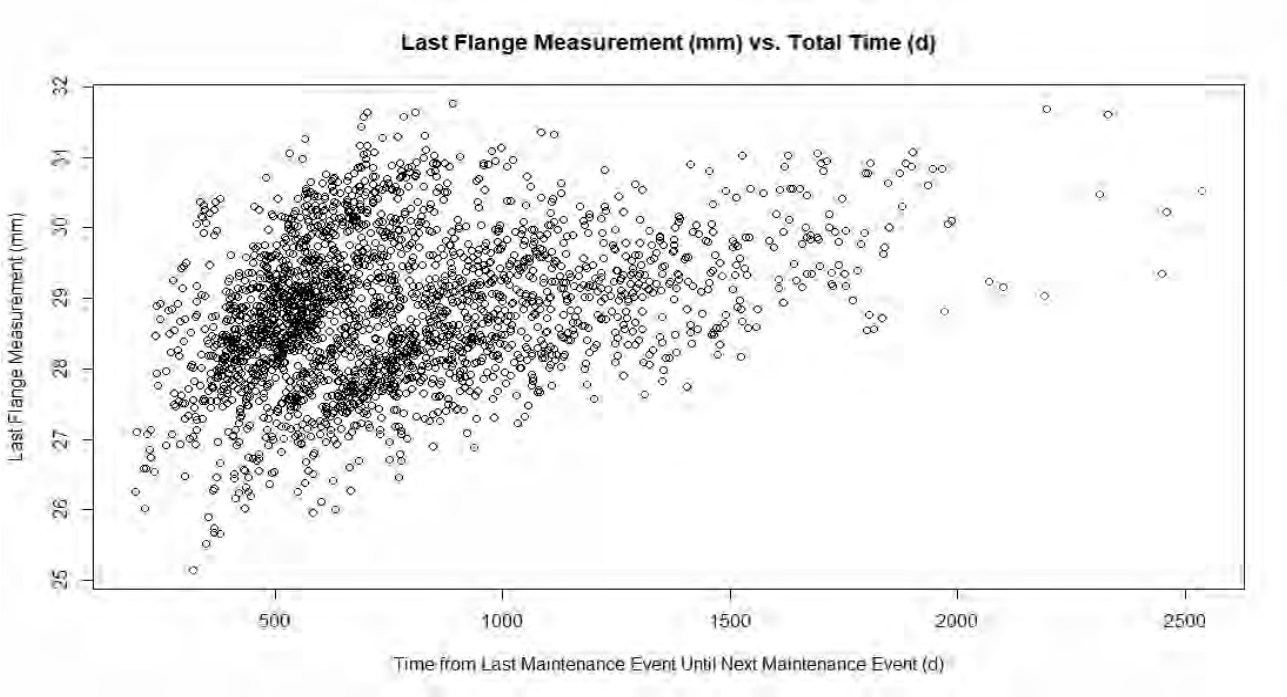
ISSUE:

Some wheels had too few data points and corresponding poor R^2 values

SOLUTION:

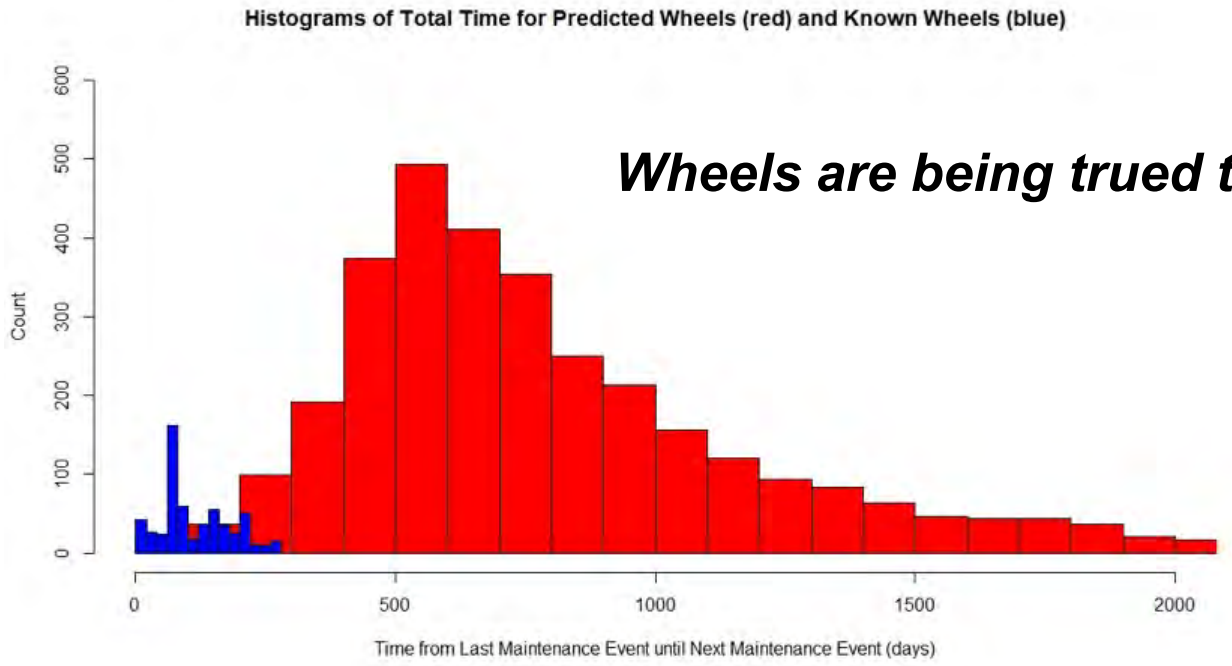
Only wheels with 10 or more data points and an R^2 greater than 0.50 were used

FORECASTING FUTURE MAINTENANCE EVENTS



Plot of Last Recorded Flange Thickness vs. Predicted Wheel Life

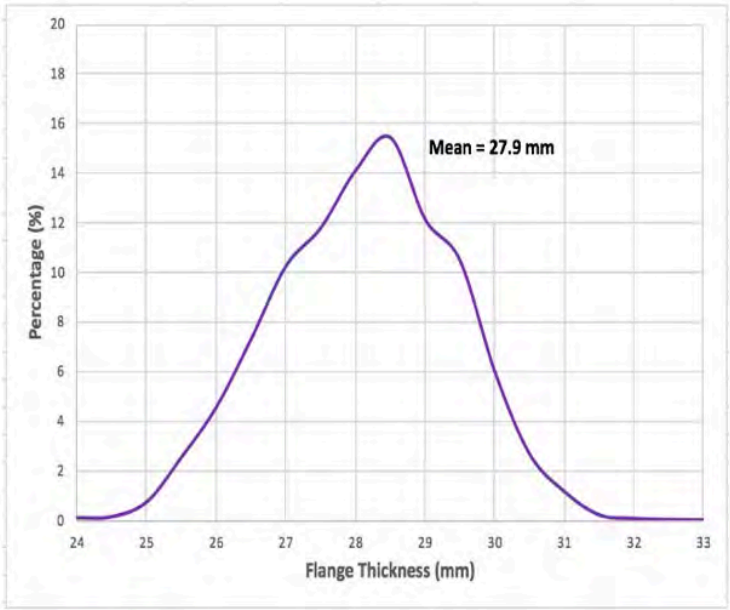
ANALYSIS OF WHEELS WITH KNOWN LIVES



Wheels are being trued too early!

Histogram of Wheel Life for Predicted (red) and Known (blue) Wheels

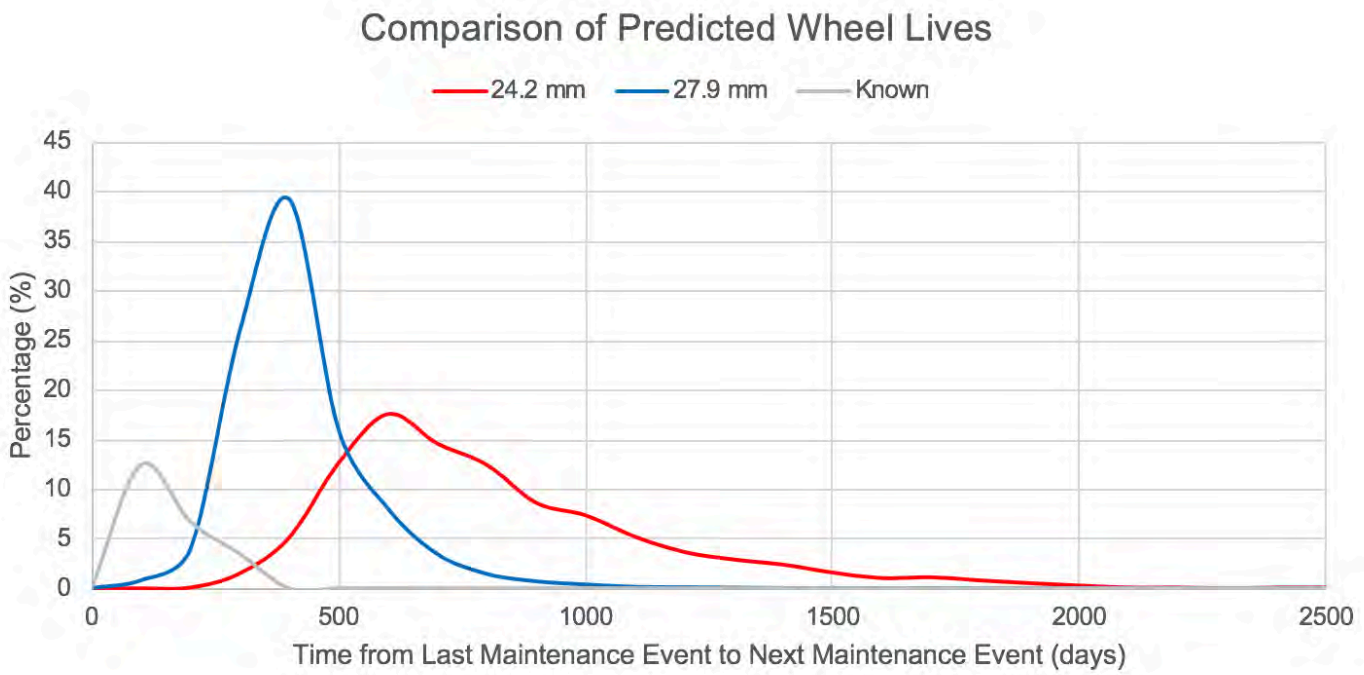
EXAMINATION OF THE CURRENT TRUING PROCESS



Histogram of All Known Last Flange Thicknesses (mm)

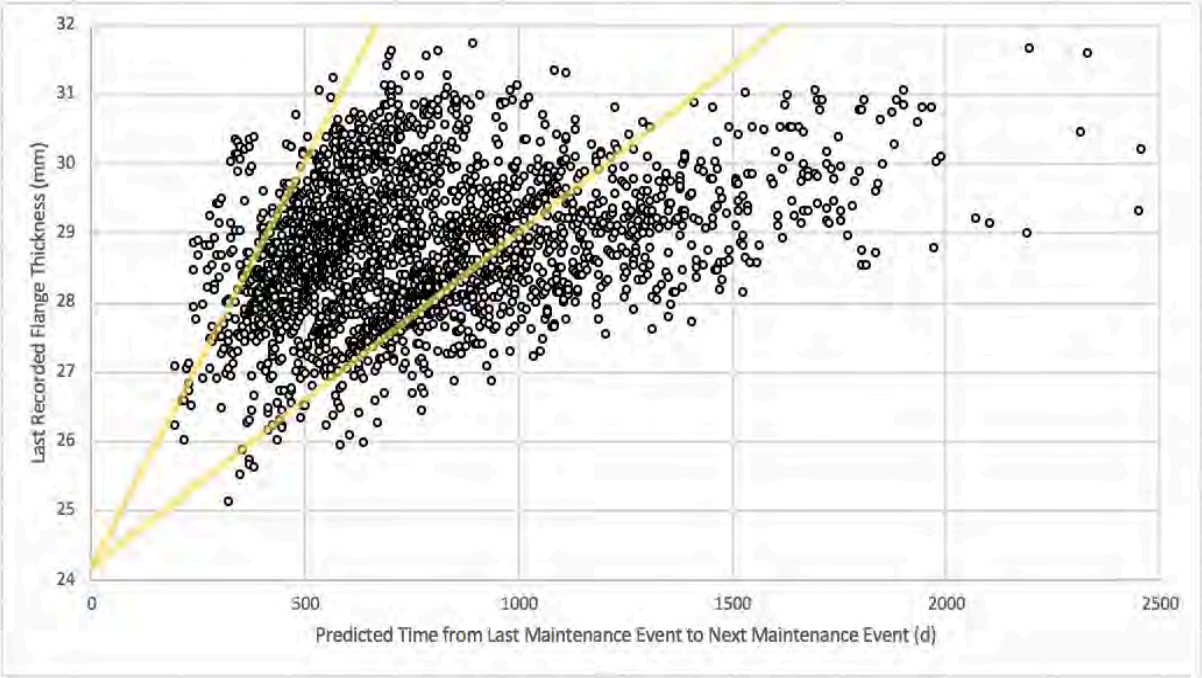
- On average, wheels are being trued when their flange thickness is 27.9 mm
  - 3.7 mm wasted
- May be due to the fact that all four wheels of a truck are trued whenever one wheel first reaches the maintenance limit. Thus, the remaining three wheels would all have higher flange thicknesses.
- May be more cost effective to true on an axle (2 wheel) rather than truck (4 wheel) basis
- Look at allowing “first” wheel to continue to wear prior to truing.
  - Is this a safety issue?

EXAMINATION OF THE CURRENT TRUING PROCESS



Comparison of Predicted Wheel Lives (mm)

INVESTIGATION OF INDIVIDUAL WHEELS



Plot of Last Recorded Flange Thickness vs. Predicted Wheel Life with Performance Bands

CONCLUSIONS

- The objective of this study was to assess NYCT's current wheel maintenance procedures, based on analysis of the wear rates of the wheels.
- Based on the analyses presented, the following conclusions can be made:
  - Exponential regression is appropriate for calculating the wear rate of these wheels.
  - NYCT may be truing their wheels too early. Altering these practices may prove to be economically advantageous.
  - There is a subpopulation of wheels that exhibits very high rate of flange wear and as such can be classified as "bad actors". It is of practical significance to be able to identify and understand these bad actor wheels, so that they may be more regularly inspected and maintained.

FUTURE WORK

- Based on the results of this study, there is an opportunity for further work:
  - Incorporation of data from other measurement systems, such as angle of attack and L/V measurements.
  - Use of alternate regression models such as bilinear regression
  - Isolating and analyzing the wheels that are controlling maintenance.
  - Applying advanced statistical and big data techniques to better create the wheel performance bands.

ACKNOWLEDGEMENTS

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- ☆ *Federal Transit Administration*
- ☆ *United States Department of Transportation*
- ☆ *KLD Labs, NRC Canada, Dayton T. Brown, Plasser American, Wayside Inspection Devices, and Instrumentation Services Inc.*
- ☆ *UTC RailTeam*

THANK YOU!

ANY QUESTIONS?