Condition Evaluation of Railway Tracks

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CANADIAN RAIL RESEARCH LABORATORY
Building the future for Canadian railways.

Introduction

(CN, 2021)

(Young, 2009)

Canada has the third-largest rail network in the world.

There are 2 main Railways in Canada:

- CNR- largest railway in Canada spanning approx. 20,000 miles (CNRC,2013)
- CPR- approx. 14,000 miles (Lavallé,2008).

Maintenance of such a large network is very challenging for railway industry.

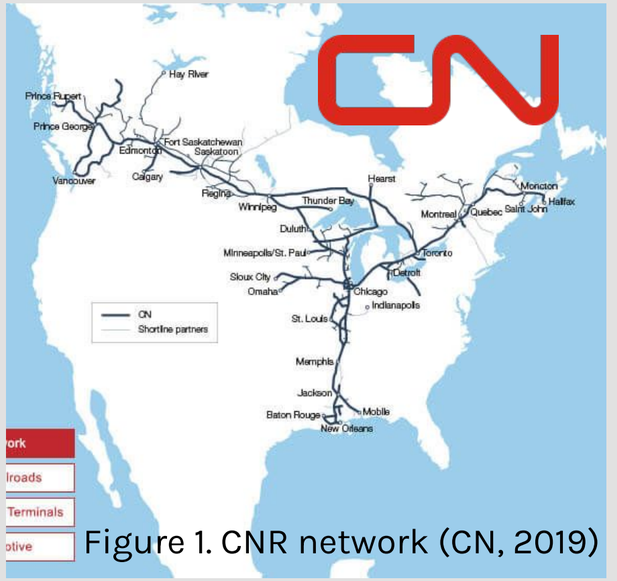


Figure 1. CNR network (CN, 2019)

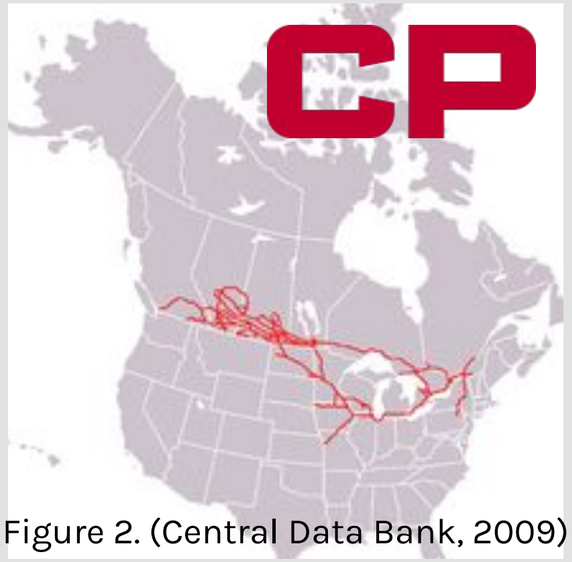


Figure 2. (Central Data Bank, 2009)

Introduction

The mission of the Canadian Railway Research Laboratory (CaRRL) is to improve track safety and maintenance through developing new innovative technologies and methods.

Figure 3. Dr. Michael Hendry unveils the new $10 bill (Photo by Zoltan Kenwell, University of Alberta).

Figure 4. CaRRL at Engineering Expo 2014 (Photo by Parisa Haji Abdulrazagh, University of Alberta).

Objective

Evaluate and assess conditions of a track with cutting-edge technologies to help reduce the risk of track failure in railway operation and increase track safety and efficiency.

Figure 5. CaRRL researchers are performing a field measurement (Photo by Parisa Haji Abdulrazagh, University of Alberta).

Background Information On Railway Components

-**Rails** provide a smooth running surface that guides trains

-**Sleepers/ties** transmit the load of the train from the rail to the ballast layer

- **Tie plates** create a smooth and uniform bearing surface between the rail and the tie.

- **Fasteners** connect rail or track components together.

-**Ballast** transfers and distributes the applied load to the subgrade beneath. It also needs good drainage and resistance to movement of ties/sleepers.

(AREMA, 2019)

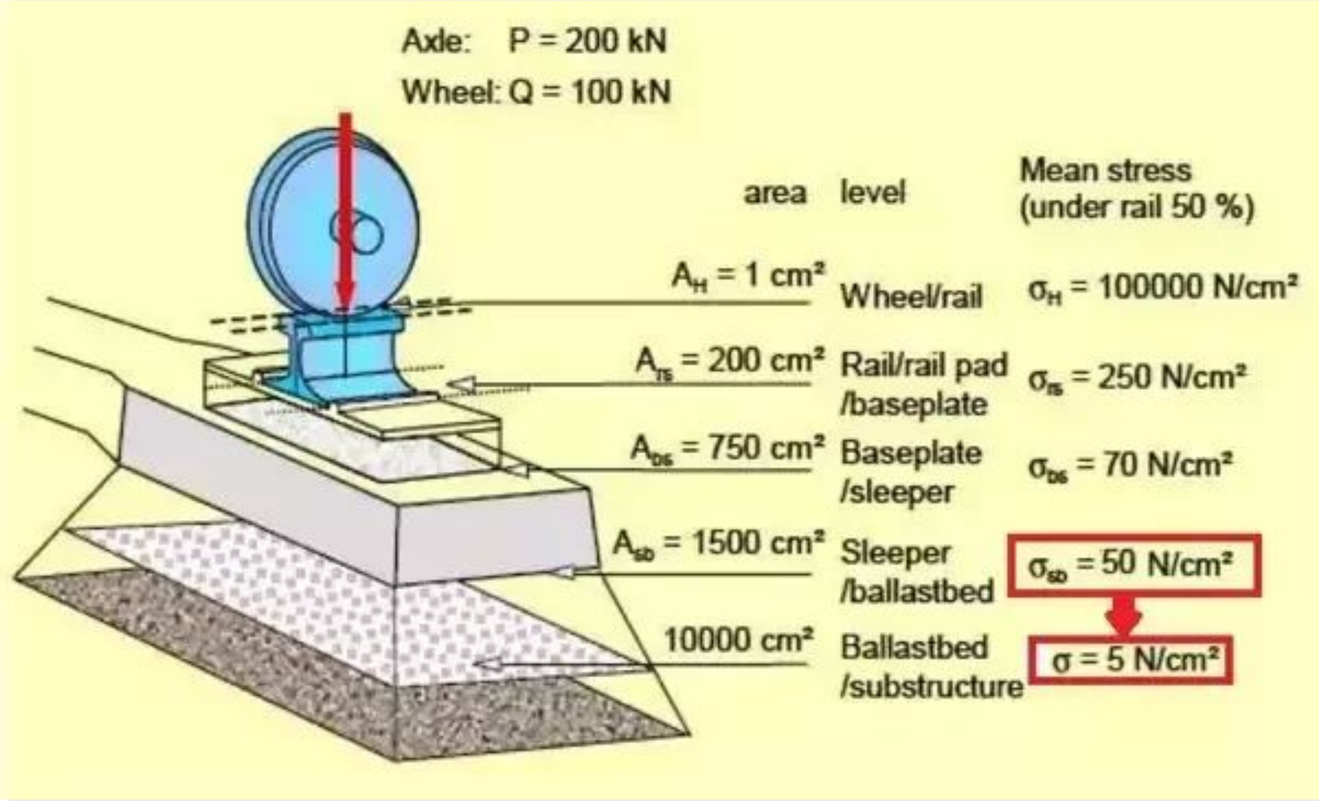


Figure 6. Load distribution diagram (Global Associates, 2021).

Technologies For Railway Condition Assessment

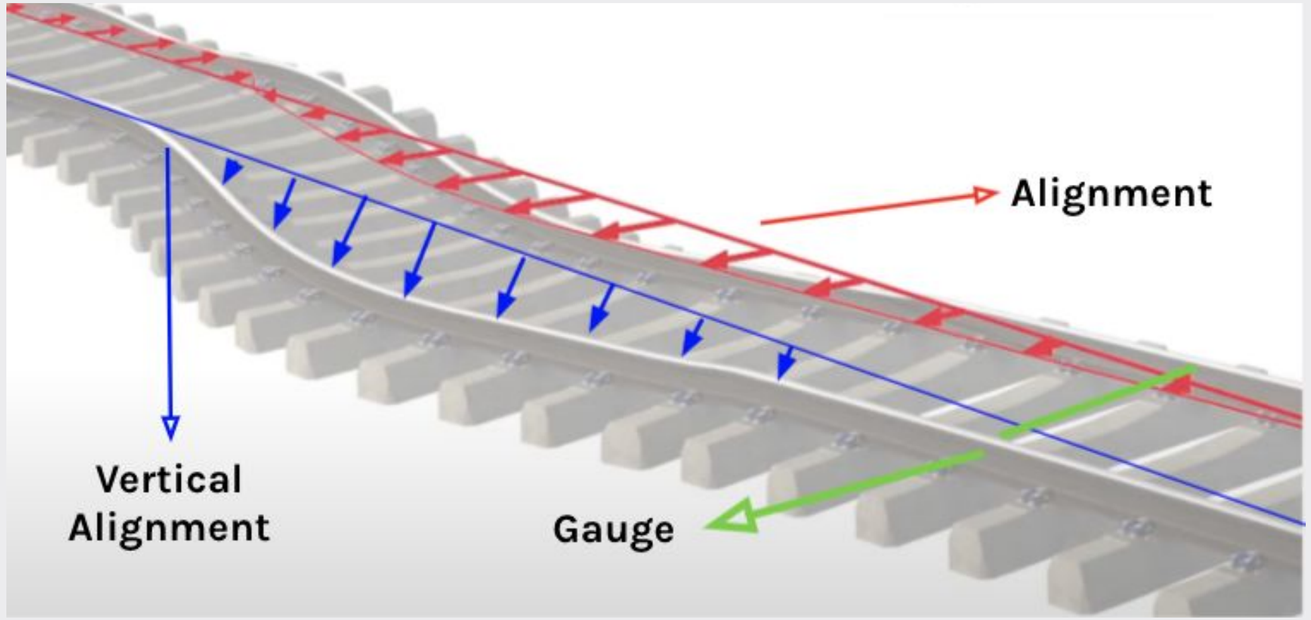


Figure 8. Diagram for track geometry deviations (Theurer, 2017).

Figure 7. CN's geometry inspection vehicle (BArailsystem, 2014).

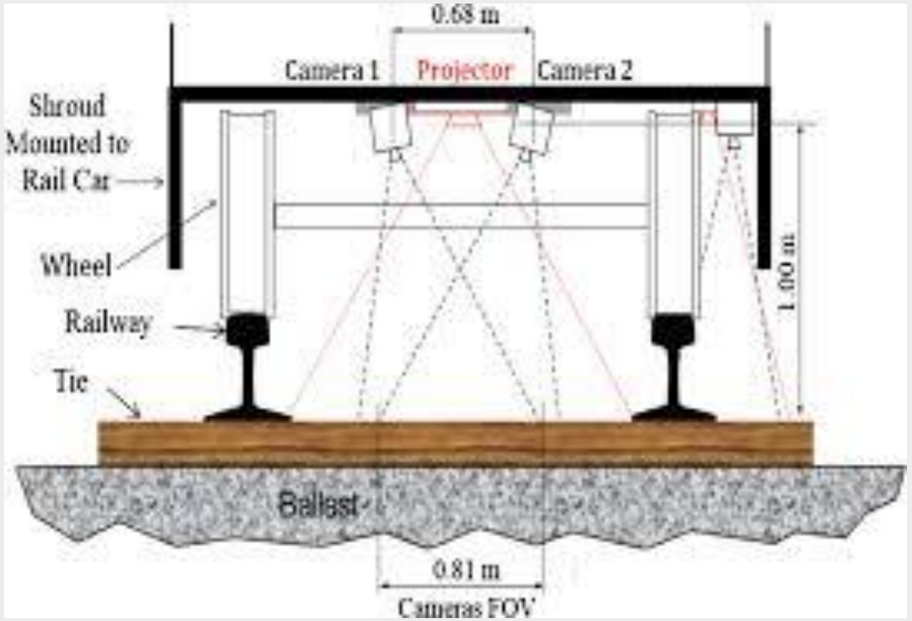


Figure 9. Track geometry inspection system (Sabato, 2017).

Technologies for Railway Condition Assessment

Vertical Track Deflection (VTD) Measurement System

- Used to measure vertical displacement of train
- This vertical displacement can help quantify soft subgrades

(Dr. Parisa, personal communication)

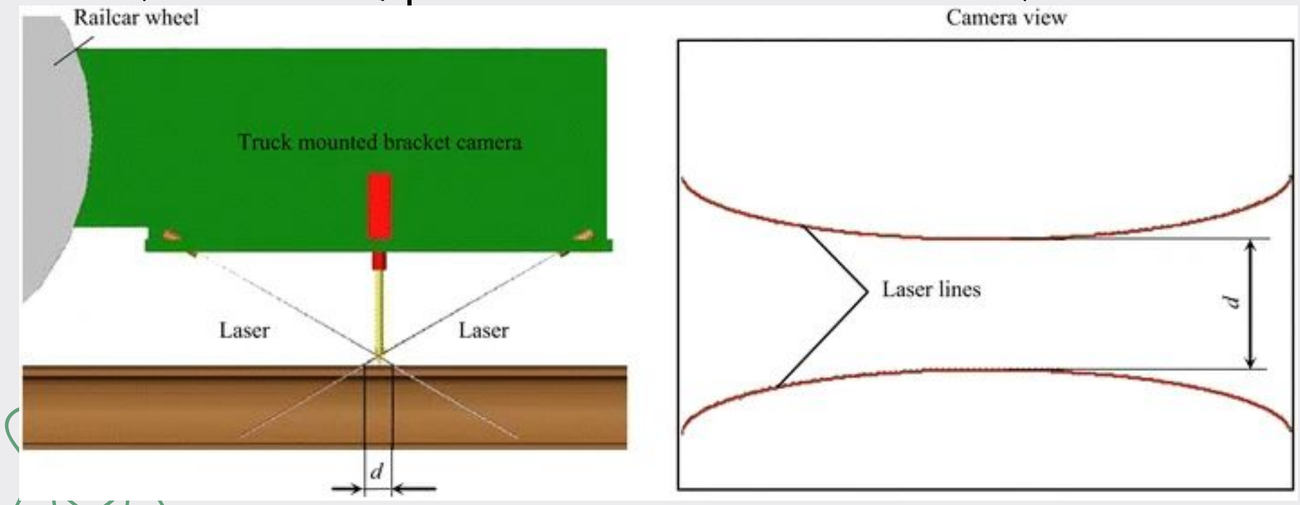


FIgure 10. The diagram for VTD measurement system (Wang et al., 2016).

Instrumented Wheelset (IWS) Measurement System

- Measures the contact force (vertical, longitudinal and lateral) between the rail and the wheel.

(Dr. Parisa, personal communication)

Figure 11. IWS wheel model (Government of Canada, 2019).

Procedure of Data Analysis

In this research we studied roughly 300 km of track from Edmonton to Jasper.
How we did this :

1. Retrieve coordinates

We retrieved the coordinates of the track from google earth and organized over 1000 coordinates in an excel spreadsheet.

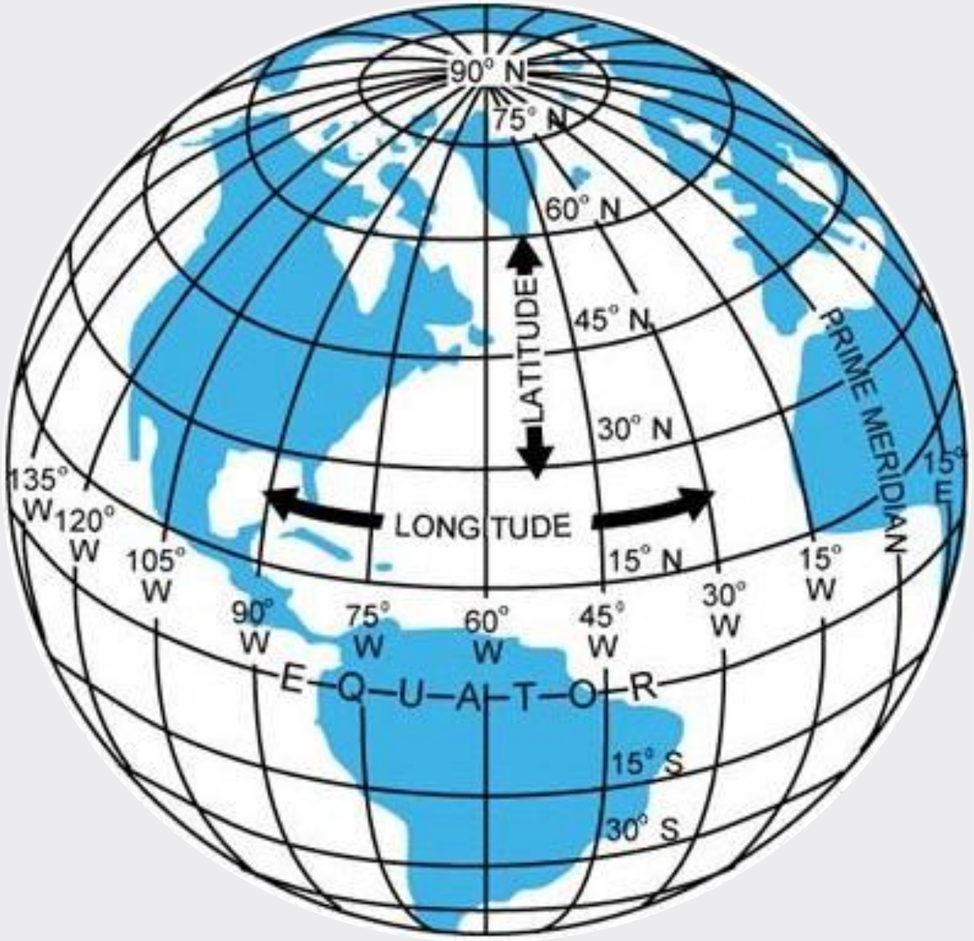


Figure 12. Earth latitude and longitudes lines (Panakkal, 2016).

Procedure of Data Analysis

2. Coordinates → Distances

Then we transferred the coordinates to distances using haversine formula to measure the distance of the track features from Edmonton over the earth's surface. We coded these calculations in MatLab.

Haversine formula:

$$a = \sin^2(\Delta\varphi/2) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2(\Delta\lambda/2)$$

$$c = 2 \cdot \operatorname{atan2}(\sqrt{a}, \sqrt{(1-a)})$$

$$d = R \cdot c$$

where φ *is latitude,* λ *is longitude,* R *is earth's radius (mean radius = 6,371km); note that angles need to be in radians to pass to trig functions!*

```
const R = 6371e3; // metres
const φ1 = lat1 * Math.PI/180; // φ, λ in radians
const φ2 = lat2 * Math.PI/180;
const Δφ = (lat2-lat1) * Math.PI/180;
const Δλ = (lon2-lon1) * Math.PI/180;

const a = Math.sin(Δφ/2) * Math.sin(Δφ/2) +
          Math.cos(φ1) * Math.cos(φ2) *
          Math.sin(Δλ/2) * Math.sin(Δλ/2);
const c = 2 * Math.atan2(Math.sqrt(a), Math.sqrt(1-a));

const d = R * c; // in metres
```

Figure 13. Haversine formula to calculate the great-circle distance between two points (Chris Veness, 2021).

Procedure of Data Analysis

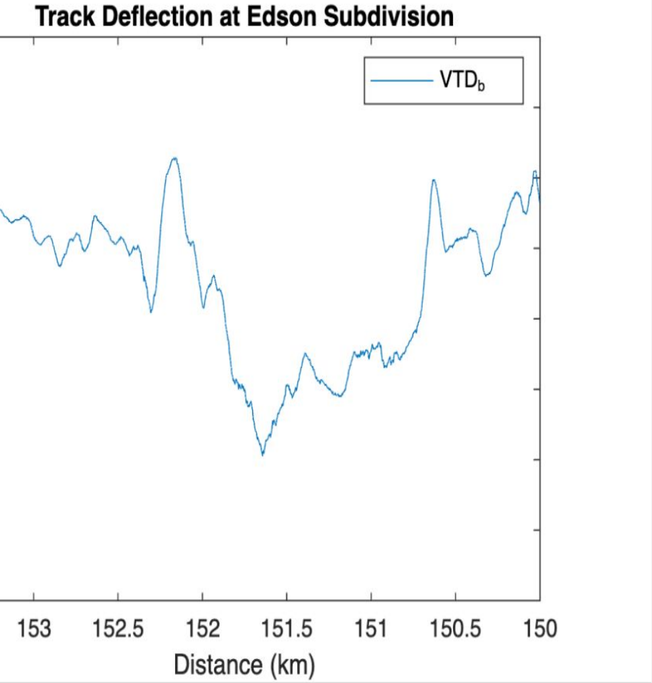
3. Measured and graphed the technologies data

We preprocessed the VTD and IWS data by removing some noises/inconsistencies. Then Using MatLab we coded and graphed the data.

```
%---- Calculate the VTD from Edson102W20150723VTD
Yrel_L_mm=Mrail(516753:527190,3).*25.4;%inch to mm.
Yrel_R_mm=Mrail(516753:527190,4).*25.4;%inch to mm.
Average_L_mm=Mrail(516753:527190,5).*25.4;%inch to mm.
Average_R_mm=Mrail(516753:527190,6).*25.4;%inch to mm.
%StdDev_L_mm=Mrail_4(516753:527190,7).*25.4;%inch to mm.
%StdDev_R_mm=Mrail_4(516753:527190,8).*25.4;%inch to mm.

%----Moving Average Filter
Yrel_ave_mm=(Yrel_L_mm+Yrel_R_mm)/2;
Average_ave_mm=(Average_L_mm+Average_R_mm)/2;
windowSize=64;%0.01245 mile=20.0363328 m
%num=ones(1,windowSize)/windowSize;
%den=[1];
%Yrel_filter=filter(num,den,Average_ave_mm);%1st method.
VTD_sub=movmean(Average_ave_mm,windowSize);%2nd method: I will use this to

y = normpdf(VTD_sub);%y = normpdf(VTD_sub,0,1);
%plot(VTD_sub,y)
```



lectionvalues.m × + Figure 1 × +

Figure 14. Graphing VTD data through MatLab (Haji Abdulrazagh. 2019)

Procedure of Data Analysis

4. Statistical analysis

Applied statistical analysis to find mean and standard deviation to help quantify the conditions of the subgrade and track.

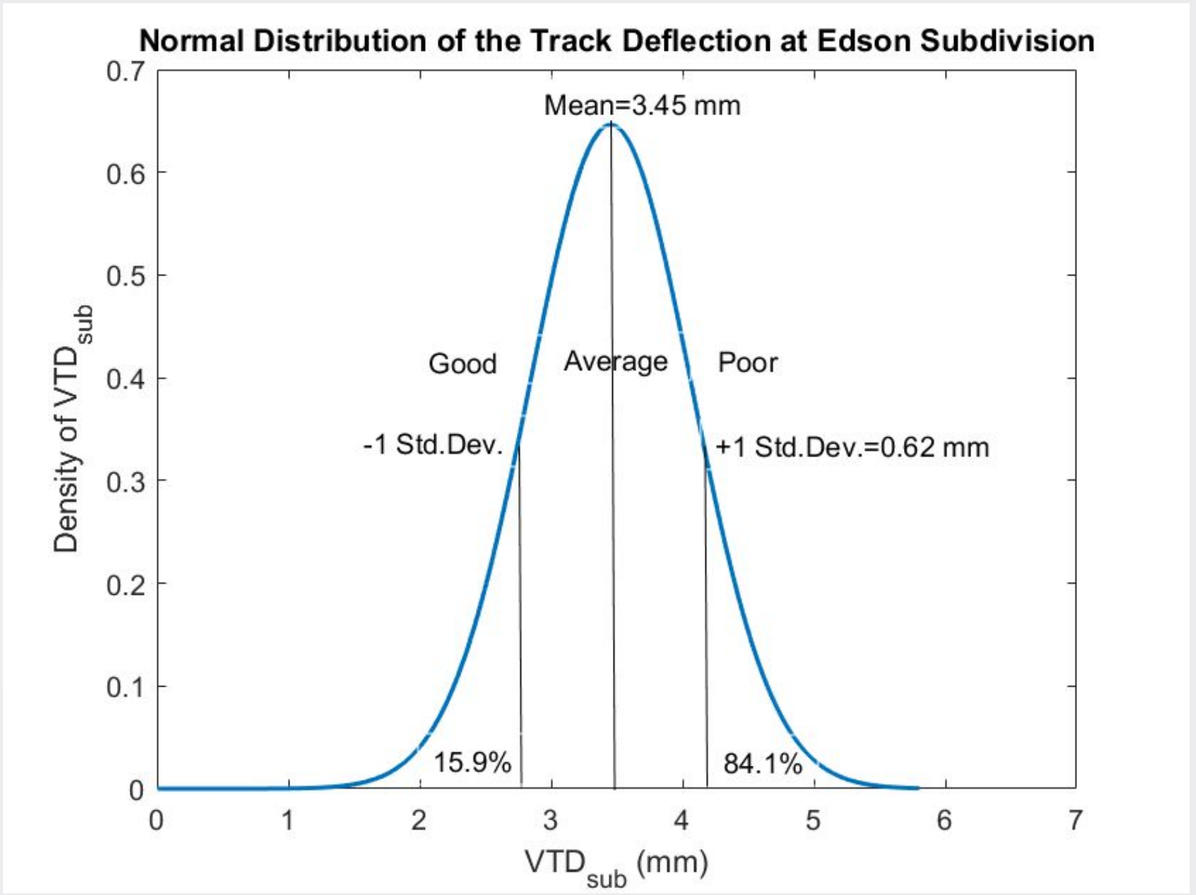


Figure 15. Normal distribution of the track deflection.

Results

- This is 3.5 km of the preprocessed VTD and IWS data
- This section of the track vertically deflects larger than 4.4 mm which correlates with the soft subgrade/vegetated area that image (a) portrays.

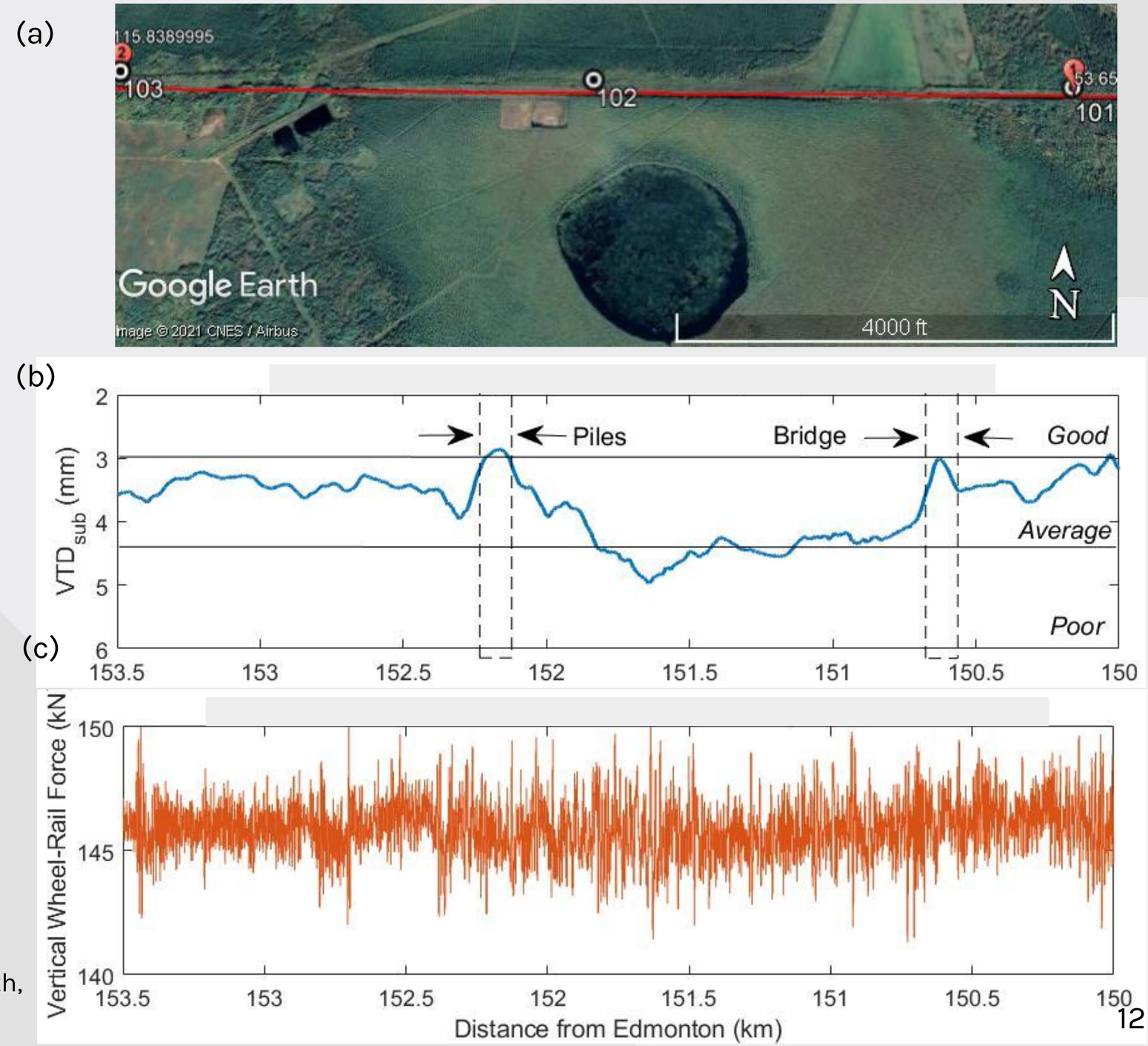


Figure 16. VTD and IWS measurements at a section of railway track traversing the organic deposits (Google Earth, 2021).

Conclusions

- Track evaluation is important for sustainability. If we can catch problems in the track before they lead to severe disasters we can save lives and money.
- These evaluations help engineers diagnose areas of the track that are more susceptible to deviation thus need top priority for remediation/maintenance actions.
- The more research we do on a track the easier it will be to take precautionary measures, as we will know how certain factors such as subgrade and geographic regions affect the track.

Next Steps...

- Using the data we've analysed, the CaRRL researchers will continue to develop a machine learning (ML) training algorithm that can be used to predict the response of unknown parameters of rail track from the available real-time measurements.

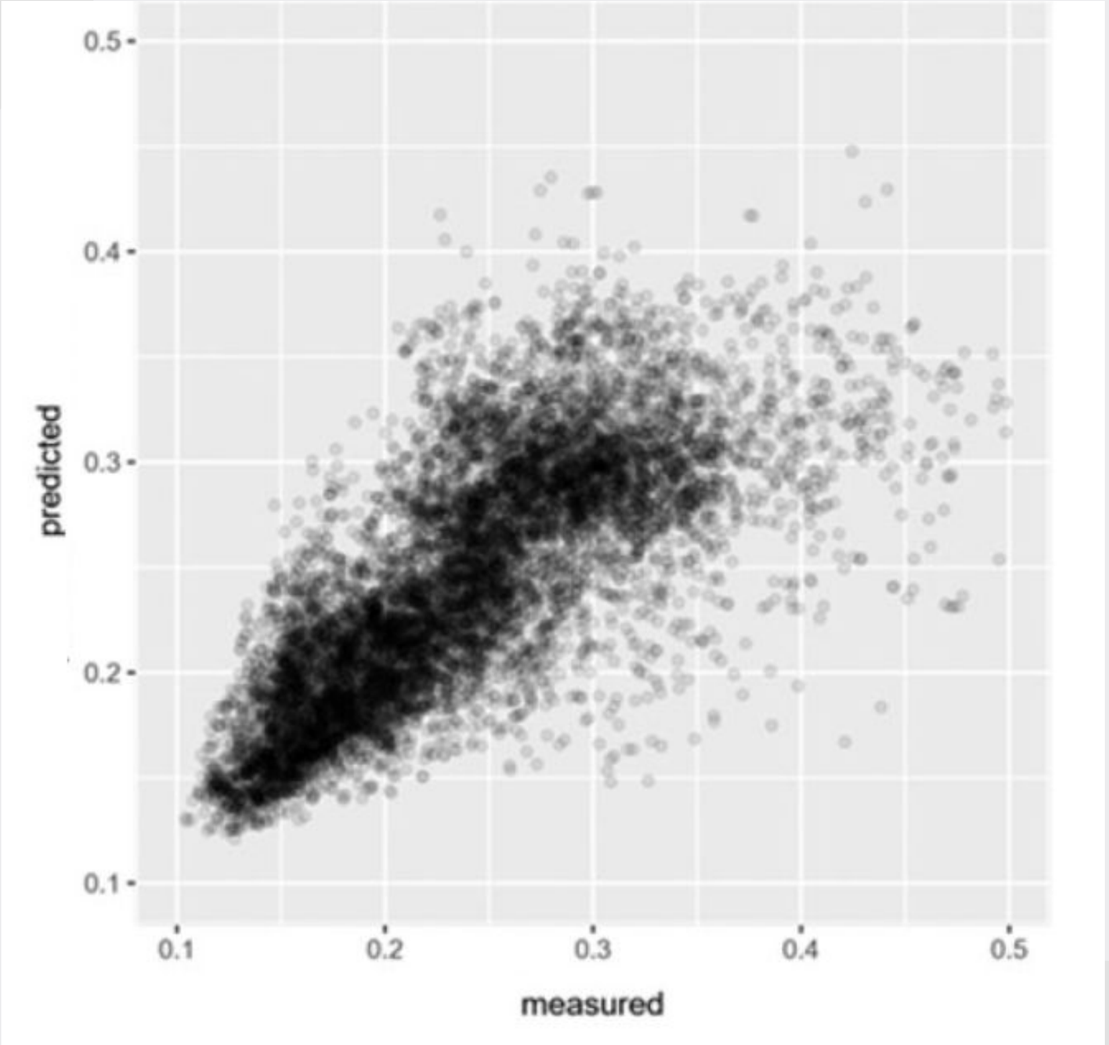
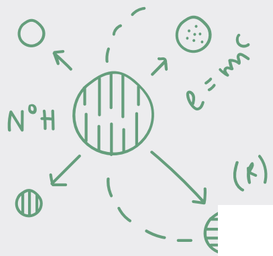


Figure 17. The predicted values by ML vs. actual (observed) values (*adapted from* Roghani *et al.*, 2021).



Thank You!

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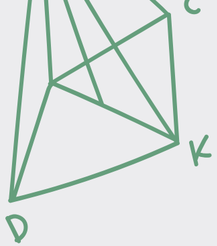

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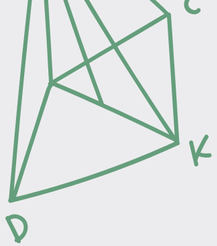

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