HEAVY HAUL SEMINAR

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JUNE 10-12, 2025

WRI2025HH

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HEAVY HAUL - JUNE 11-12, 2025

TRAIN MARSHALLING MODEL TO IMPROVE OPERATIONAL RELIABILITY OF MANIFEST TRAINS

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WRI2025HH

Network Planning & Transportation Engineering

- Based out of Edmonton, Alberta
- Focus on Transportation Engineering Projects, Capacity Planning and Operations Analysis
- Responsible for entire CN network

Ngoan Do, PhD
Senior Planner Transportation Planning

- PhD in Civil Engineering
- Qualified Conductor
- Part of Network Planning Group responsible for
  - Line and terminal capacity
  - Infrastructure planning
  - Operational Analysis

Doug Bailey, P.Eng
Engineer Transportation Planning

- 3 years at CN
- Registered Professional Engineer
- Bachelor of Mechanical Engineering Degree
- Qualified Conductor and Conductor Locomotive Operator
- 4th Generation CN Railroader

Background

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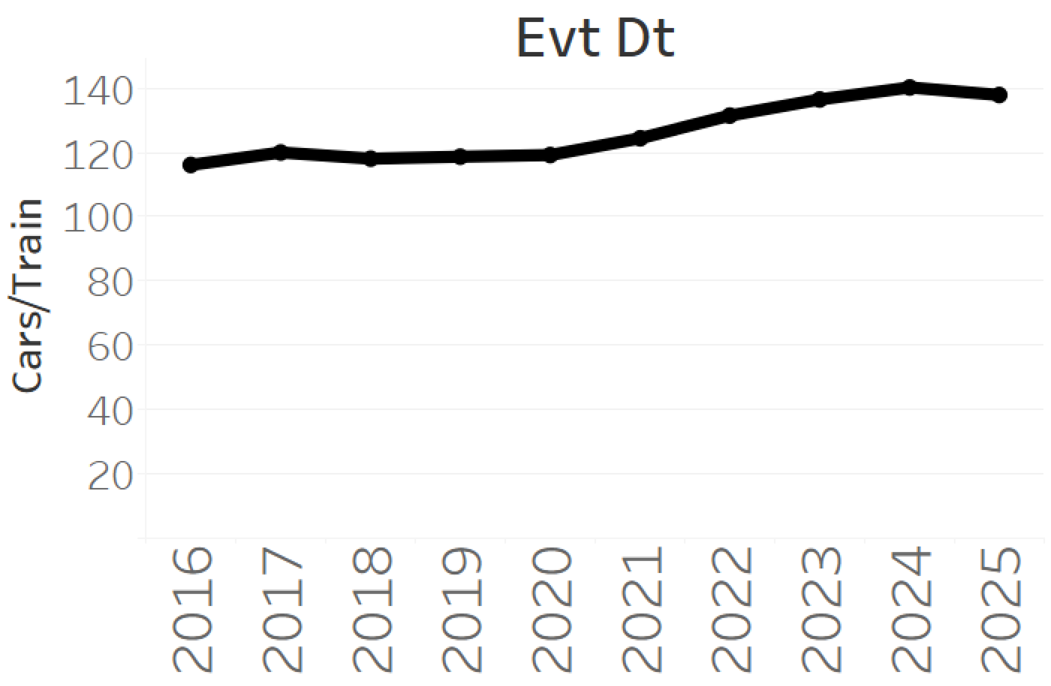
- The length of manifest freight trains has generally increased in recent years.
- Longer train length has been associated with a higher rate of disruption due to train separations, especially in trains having cars equipped with end-of-car cushioning devices (EOCC).
- Best practices for marshalling trains with EOCC cars are available, but they may not be universally adopted by the railway industry due to substantial impacts to train operations.
- There is an urgent need to establish an effective tool to prevent separations

Train Separation by Type (%) in a specific corridor

Trn Type	2017	2018	2019	2020	2021	2022
Manifest	94%	93%	100%	97%	81%	86%
Bulk	6%	5%	0%	4%	19%	14%
Intermodal	0%	1%	0%	0%	0%	0%

Average Cars per Train - Manifest



Problem

A specific corridor on CN has historically been the most problematic for train separations because of:

- undulating grade
- frequent manifest trains
- high quantity of end-of-car cushioning (EOCC) equipped cars

These factors all increase the risk of train separation

Operational Delays

Train separations result in significant disruption to network operations. This leads to trains running off schedule, recrews, and delayed shipments

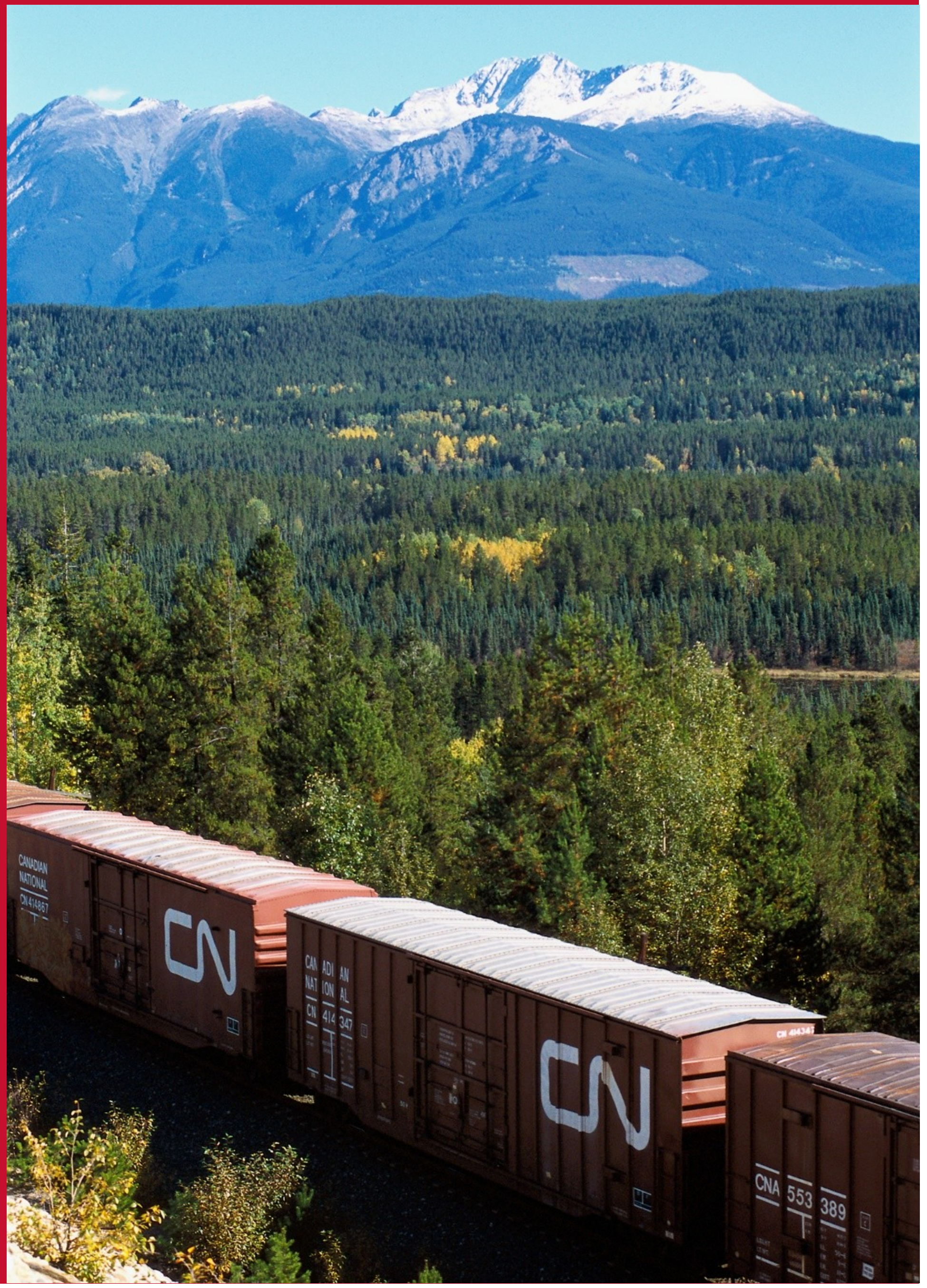
Increased Exposures

When a train separation occurs, it is exposing the crew to increased safety hazards

Equipment Damage

Oscillations in buff/draft forces through a train and undesired emergency brake applications result in a higher incidence of equipment and lading damage

Reducing The Risk



PREVIOUS METHODS

Various methods have been tested to reduce train separations in the past, with varying levels of success. Speed restrictions, length/tonnage restrictions and locomotive “cruise control” initiatives have all been used. However, train separations were still occurring with minimal reductions.

TRAIN MARSHALLING

Speed, length, and tonnage restrictions limit operational efficiency. An optimal solution to reducing the risk of train separations would be to optimize the train marshalling and follow known train marshalling best practices.

QUANTIFY THE RISK

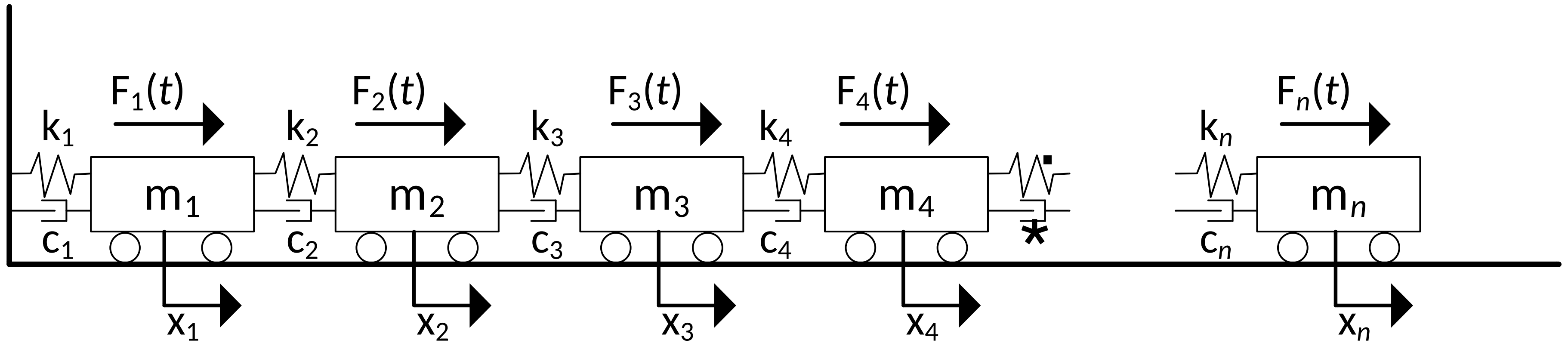
Train marshalling best practices can be used to quantify the risk of a train consist experiencing a train separation. If the risk is known, a go/no-go decision can be made, and the risk can be controlled.

THE SOLUTION:
SCORING TRAIN CONSISTS

HOW IT WORKS

A mathematical model was developed by:

- Simplifying the equation of motion of a multi-degree of freedom system (a train)
- Emphasizing the distribution of loaded EOCC cars within a given train



$$S = \frac{N_{EOC}}{N} \times \sum_{i=1}^{n} F_i = \frac{N_{EOC}}{N} \times \sum_{i=1}^{N} \begin{cases} s_i \times m_i & \text{if the car is empty} \\ d_i \times s_i \times m_i \times k & \text{if the car is loaded friction draft gear} \\ (N - d_i) \times s_i \times m_i & \text{if the car is loaded EOCC} \end{cases}$$

s_i is the slack constant (2 if EOCC, 1 if Non-EOCC)
d_i is the car location (treated as moment arm)
N is the total number of cars
k is the order of the loaded Non-EOCC car in its non-EOCC block.

Practical Re-Marshalling Example

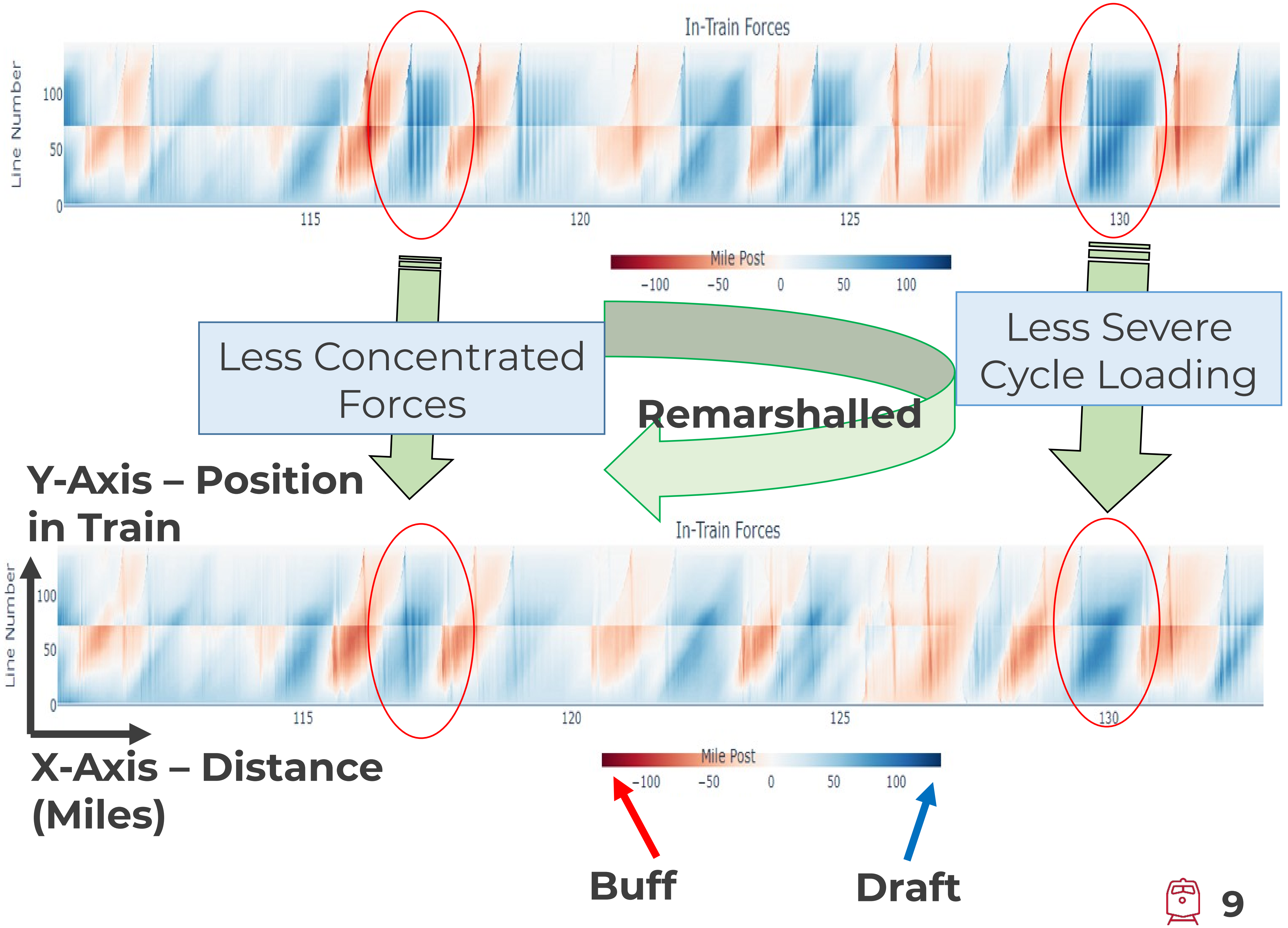
Train Profile of a failed train

- Moving a block of loaded non-EOCC cars to the head-end of the train reduces the score to below the threshold

In-Train Force Validation – Simulation Testing

Draft/buff heat maps

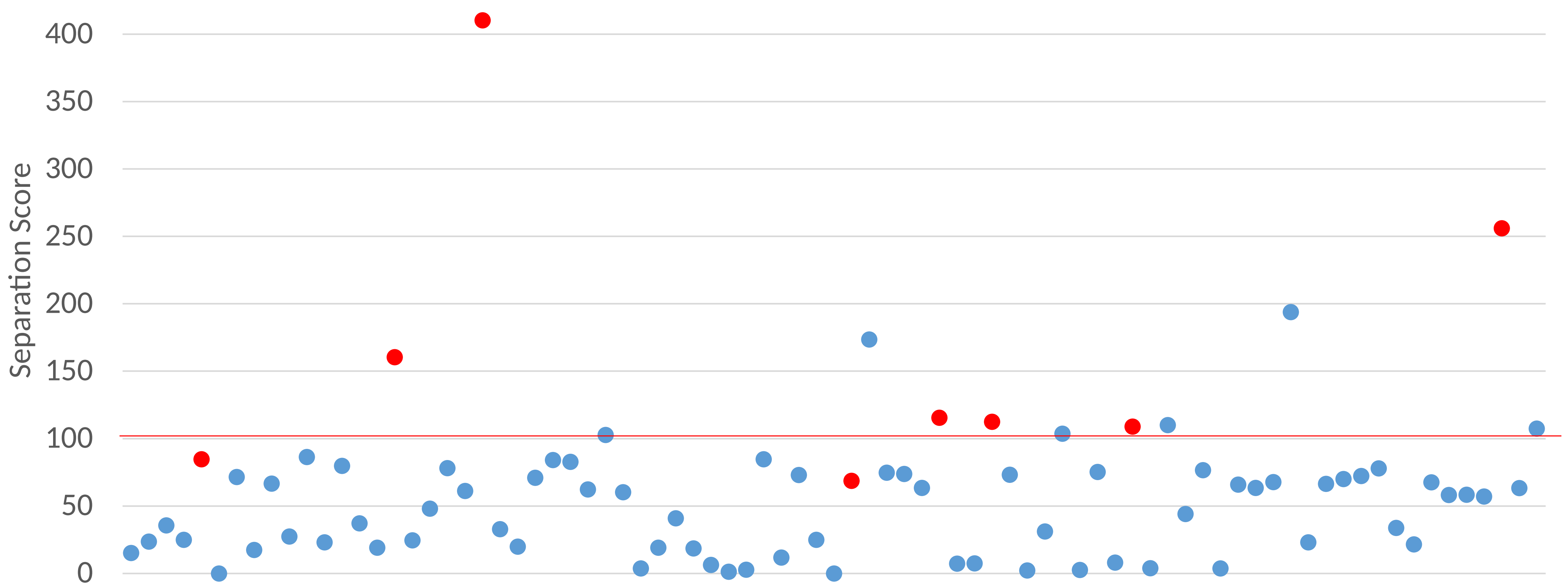
- Top graph shows the failed train with a score greater than the threshold
- Bottom graph shows the same train, remarshalled to have a score less than the threshold
- **Remarshalling the train resulted in lower force magnitudes, as well as less severe cyclical loading**
- **Numerous simulations** of different trains were completed to validate the theory



STATISTICAL CLASSIFICATION

- The graph on the right shows the scores of one quarter worth of a specific daily train
- As the score increases, the risk of train separation increases
- Trains that had a score <100 were less likely to separate
- Trains that had a score >100 were more likely to separate
- Trains with a score >100 should be remarshalled

Q1 data of a specific problematic train ID



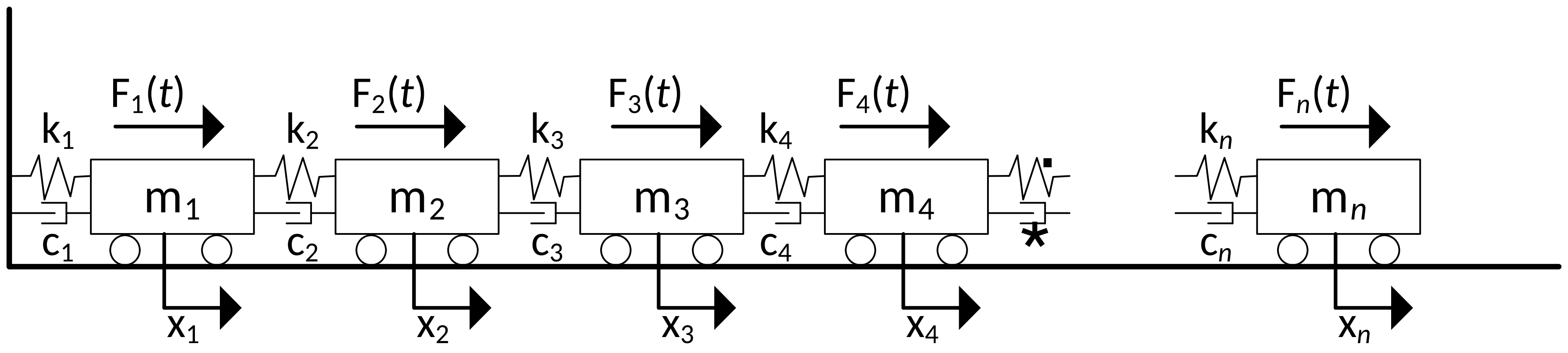
Each dot represents a unique train ID
X-axis represents train IDs
Y-axis represents the score of that train
Red dots = Trains that experienced a separation
Blue dots = Trains that did not experience any mechanical disruptions

REPORT

FAILURE NON-FAILURE

Long Train ID

FINALIZE THE FORMULA



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HISTORICAL ANALYSIS OF 1-YEAR TRAIN DATA

Trains Scoring >100

13%

of total trains on route

Trains Scoring >100 that separated

60%

of flagged trains separated

False Negative %

41%

of separations scored under 100

IMPLEMENTATION

AUTOMATED MARSHALLING CHECK PROCESS

At CN, an automated marshalling check process has been implemented to verify that train marshalling rules are complied with before departure of a train. The system automatically calculates the score of a train and flags when a score threshold is exceeded, indicating the train needs to be marshalled differently

```
[redacted]          **** Marshalling Report ****            [redacted]
[redacted]       - Train separation car detail info -       [redacted]

                          Train Summary
-----------------------------------------------------------------------------
                          Train: [redacted]
                      PASS/FAIL: FAIL
                      Threshold: 100.00
                Total Equipment: 138
                     Total EOCC: 59
                    Total Score: 111.91
-----------------------------------------------------------------------------

 Trn Car  Car     L Car  Length      | EOC  Blk  Eqp   |
 Seq Init Numb    E Kind ft   in Wgt | Type Cntr Score | YRDBLK Trk/Train  Seq
 --- ---- ------ - ---- --- -- --- | ---- ---- ----- | ------ ---------- ---
   1 CN     2294    ENG              | LOCO          0 |
   2 CN     3177    ENG              | LOCO          0 |
   3 [redacted] 2022[redacted] E T5F  50  4 034 | NEOC 0 | [redacted]   3
   4 [redacted]  202[redacted] E T4F  48 11 032 | NEOC 0 | [redacted]   4
   5 [redacted] 2022[redacted] E T5F  50  4 034 | NEOC 0 | [redacted]   5
   6 [redacted]   51[redacted] E CXG  58  5  34 | NEOC 0 | [redacted]   6
```

JOB AID

A job aid was created for employees, so they understand how to remarshal the train in the event a score exceeds the defined threshold

BENEFITS

The process identifies the optimal marshalling before a crew assembles a train, reducing time spent in the yard and the risk of a train separation online

RESULTS

- After one year, there was **33% reduction** in train separations.
- Traffic levels (gross tons and train length) were consistent across both years
- Implementation of the process has resulted in minimal operational impact

Quarter	2023 Total Incidents	2024 Total Incidents	Improvement (%)
1	14	7	+50%
2	10	13	-30%
3	14	6	+57%
4	10	6	+40%
Total	48	32	**+33%**

	2023	2024
Total Number of Trains	749	747
Average Trains per Day	2	2
Average Operating Grs Ton	8,181	8,070
Average Train Length (ft)	10,958	10,755
Average EOC Cars per Train	38	37

EXECUTION

Testing period

Before officially implementing the rule, there was a testing period that served multiple purposes:

- Verify that the system is alarming correctly
- Observe field implementation of the process
- Test if the process reduces separations

Adoption

The testing period was successful, and the process has been adapted without issue in the field

2024 Statistics

2024 Statistics show that the marshalling scoring alarm had minimal impact on standard train-building procedures

Low Impact

There were 151 trains that had the alarm appear during pre-departure checks and 81 trains that had multiple alarms. Apart from three of these trains, all of them were remarshalled without issue

2024 Statistics	
Trains checked for Scoring Alarm	747
Trains with Score Alarm during pre-departure marshalling checks	151
Trains with multiple Score Alarms during pre-departure marshalling checks	81
Trains with Score Alarm violations after departure	3*
* One of these three trains separated online	

Benefits

Safety

Fewer train separations means fewer undesired emergency stopping events, reducing the risk of derailment. Separations also increase the potential for crew member injury during emergency stops and when reassembling the train. Reduction in train separations has reduced the risk and exposures to crews.

Corridor efficiency

Train separations lead to recrews and delays to other trains on the territory. The reduction in separations has increased the efficiency of train operations on the corridor.

Equipment

Through simulations, it has been proven that the marshalling scoring system encourages proper marshalling, which results in lower in-train forces. Because of the lower forces, equipment and lading damage is reduced.

FURTHER IMPLEMENTATION

EXPAND TO LARGER TERRITORY AND TRAINS

- Further review has shown that this specific scoring model cannot be applied to other trains/subdivisions due to differences in types of traffic, typical train speed and track profiles.
- Scoring models need to be tailored for specific situations
- Another model has been developed with plans to roll-out on another vital CN corridor

CONCLUSION

RISK

Using data analysis and simulation tools, a mathematical model can be developed to quantify the risk of train separation on specific trains and corridors

IMPLEMENTATION

The automated marshalling check process can use the mathematical formula to control the risk and identify to employees when the risk is too high

BENEFITS

Quantifying and controlling the risk has reduced train separations, which has increased safety, operational efficiency and reduced equipment damage

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Questions?

Thank You!

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