# Solid mechanics and AI hybrid approach to mitigation of railway track buckling

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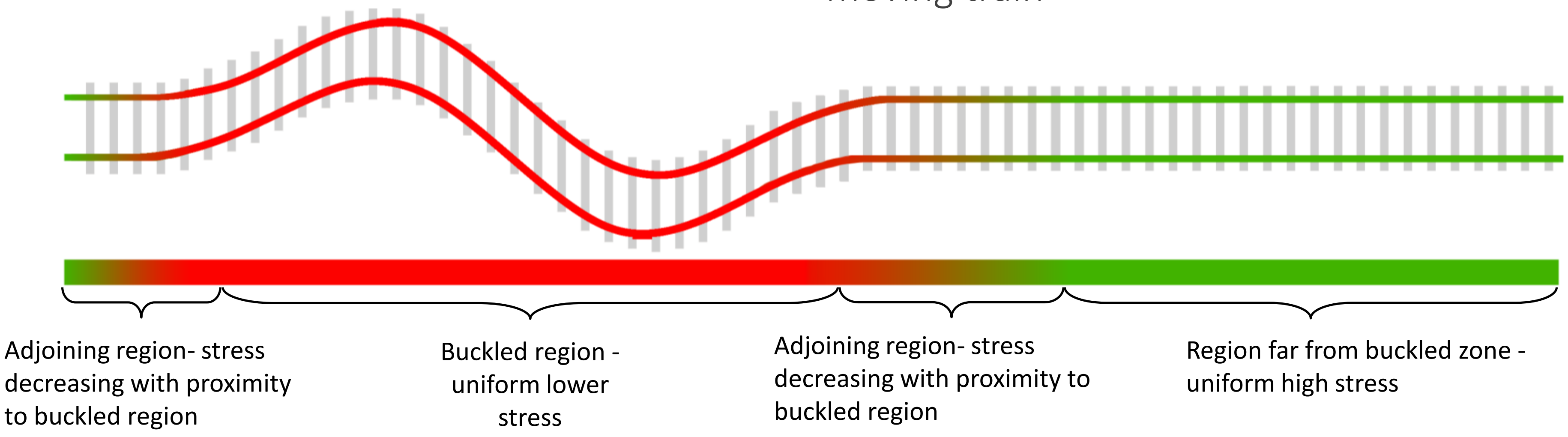
# Overview

1. Buckling of track
2. Introduction to fuzzy logic
3. Benefit of using a fuzzy logic model for track buckling prediction
4. Fuzzy logic inference method for predicting buckling temperatures
5. Results

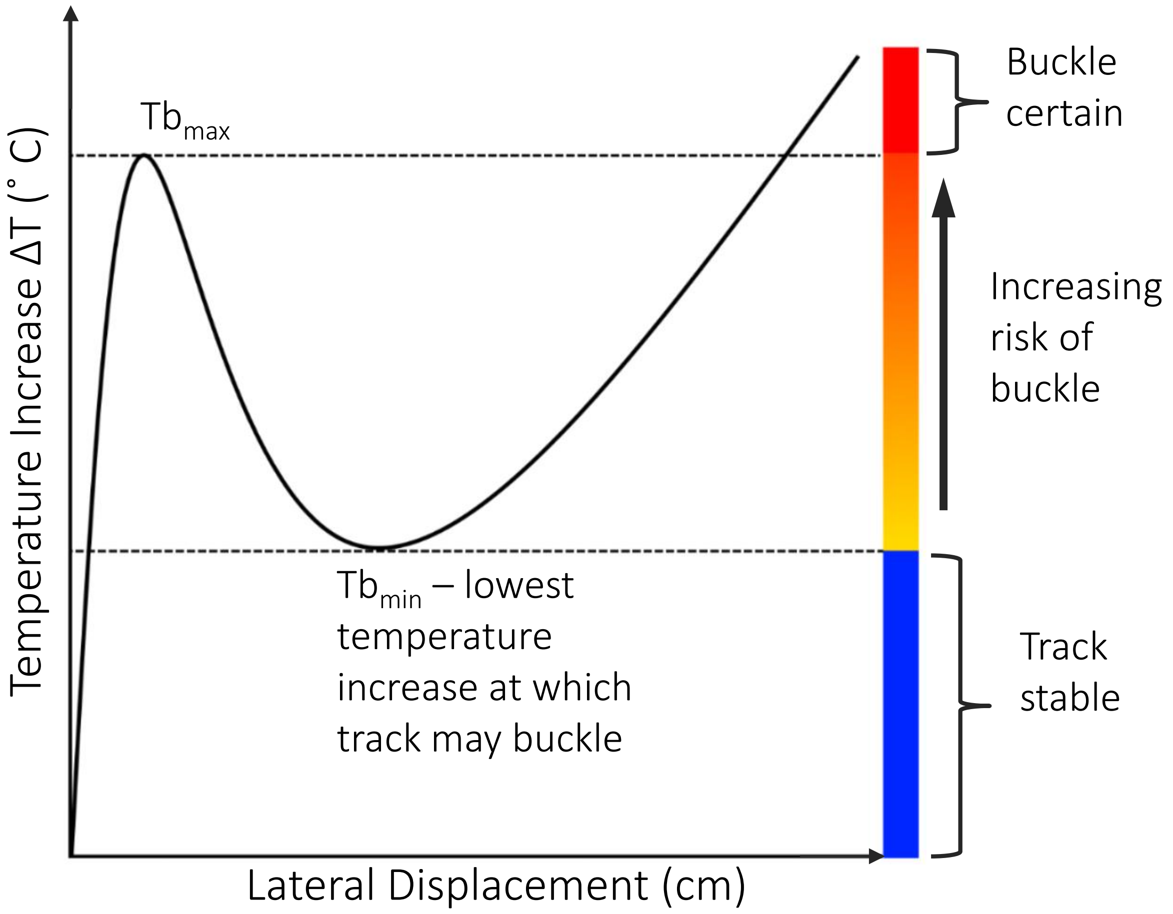
# Buckling of Track

- Buckles pose danger of derailment
- Caused by a build-up of expansion stress in the rail
- Can gradually develop in weak track
- Explosive buckles can occur, ahead of or under a moving train



# Buckling of Track

- Complex mechanism of many variables
- $T_{min}$ and $T_{max}$ characterise the buckling behaviour for a section of track
- Track properties have a significant effect on buckling temperatures
- Conventional models rely on knowledge of engineering variables and are computationally expensive to apply



# Fuzzy Logic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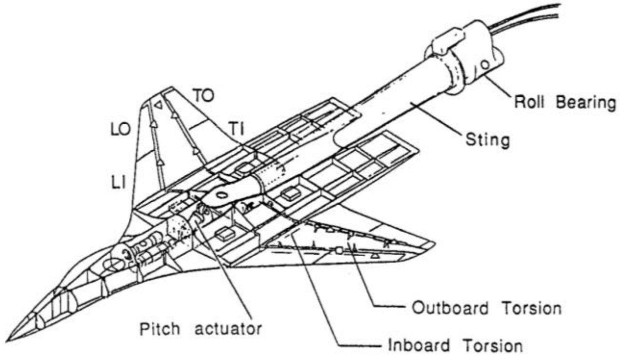


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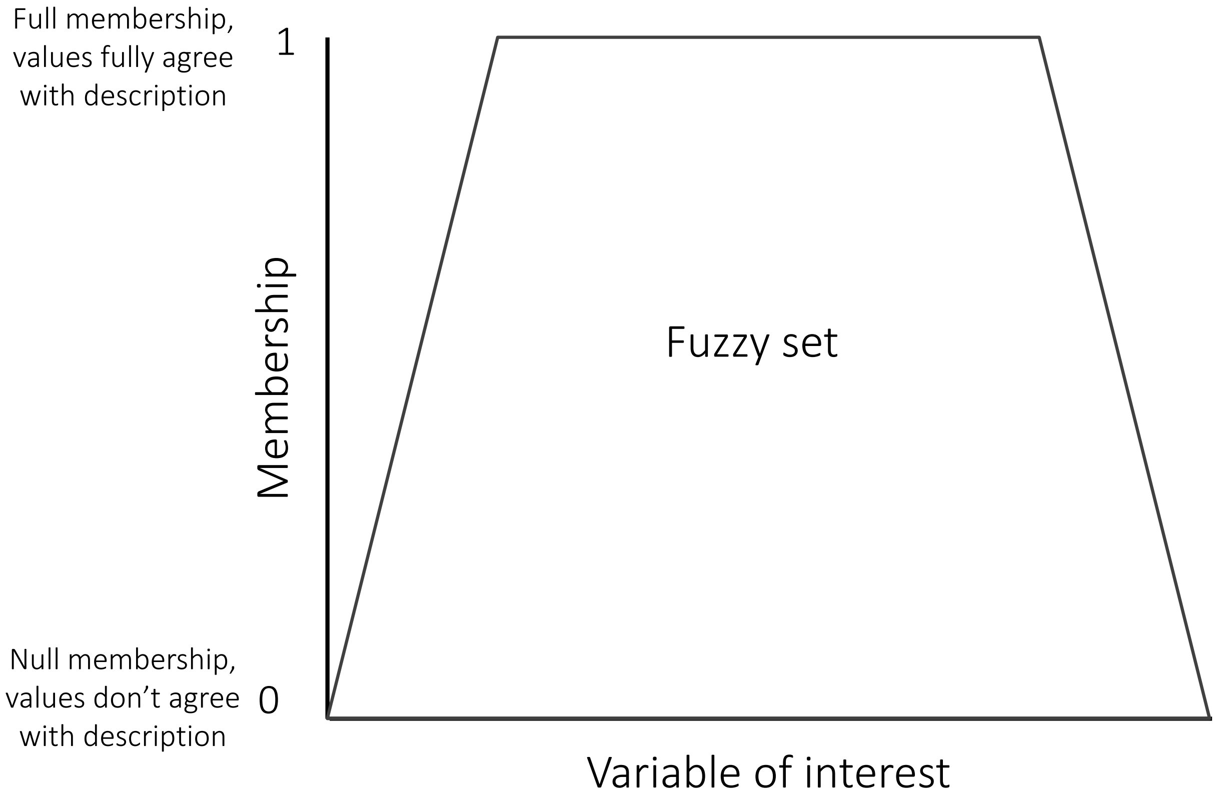
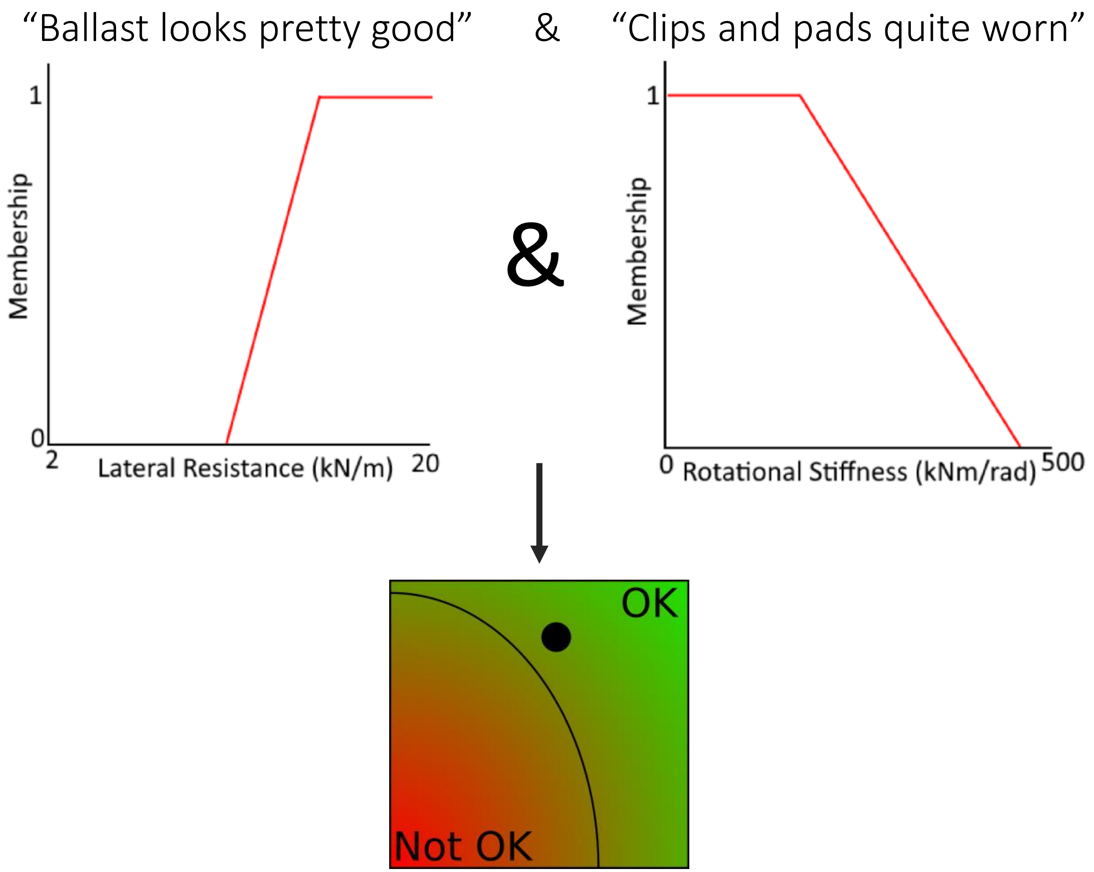
# Fuzzy Logic Models

- Fuzzy sets provide descriptions of vagueness through membership values
- Sets are connected through rules
- Both sets and rules can be inferred from datasets
- Can model complex mechanisms, are lightweight and don’t need lots of data
- Can compute using linguistic variables – vague and uncertain inputs



# Fuzzy Logic for Buckling Prediction

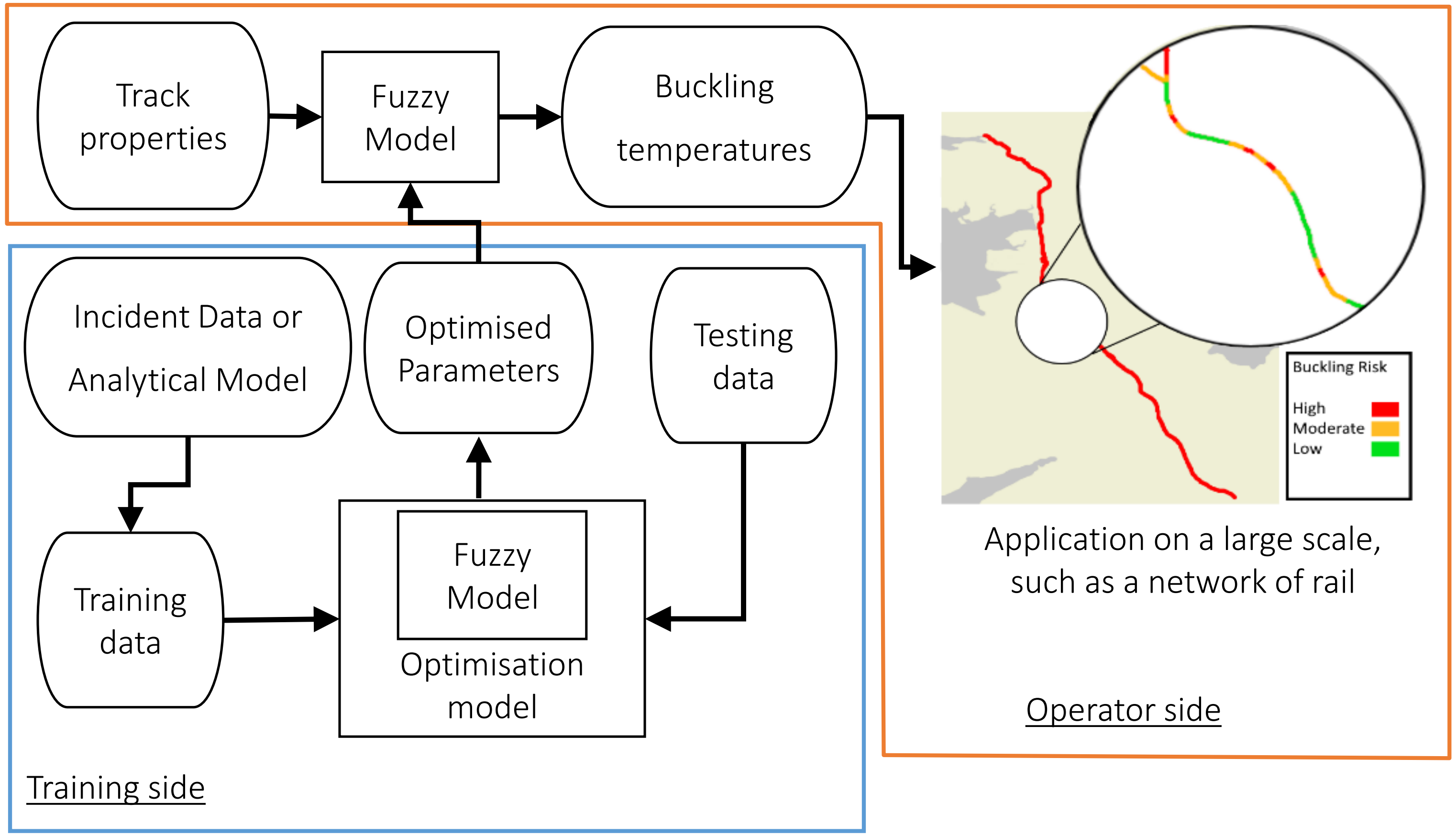
- Track properties usually determined through testing and uncertain for majority of real-world track
- A fuzzy set provides a computational understanding of the vagueness and can be utilised by the fuzzy model
- Multiple fuzzy sets interact following strict rules grounded in physics
- Already recorded or accessible information made useful



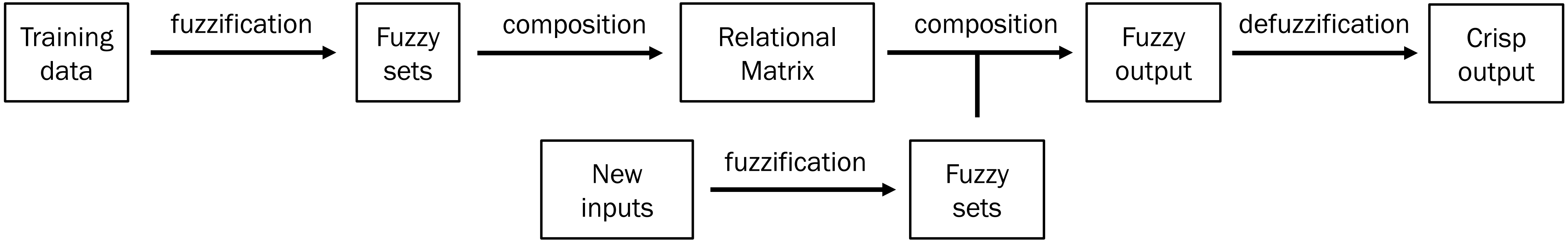

Numerical value of minimum buckling temperature

# Proposed Application of Methodology

- The aim:
  - Developing a fuzzy logic model for risk of buckling prediction
- Fuzzy model trained and optimised, tested
- Buckling temperatures calculated using input track properties
- Application for a network of rail, forming a map of buckling risk



# Inference and Prediction Methodology

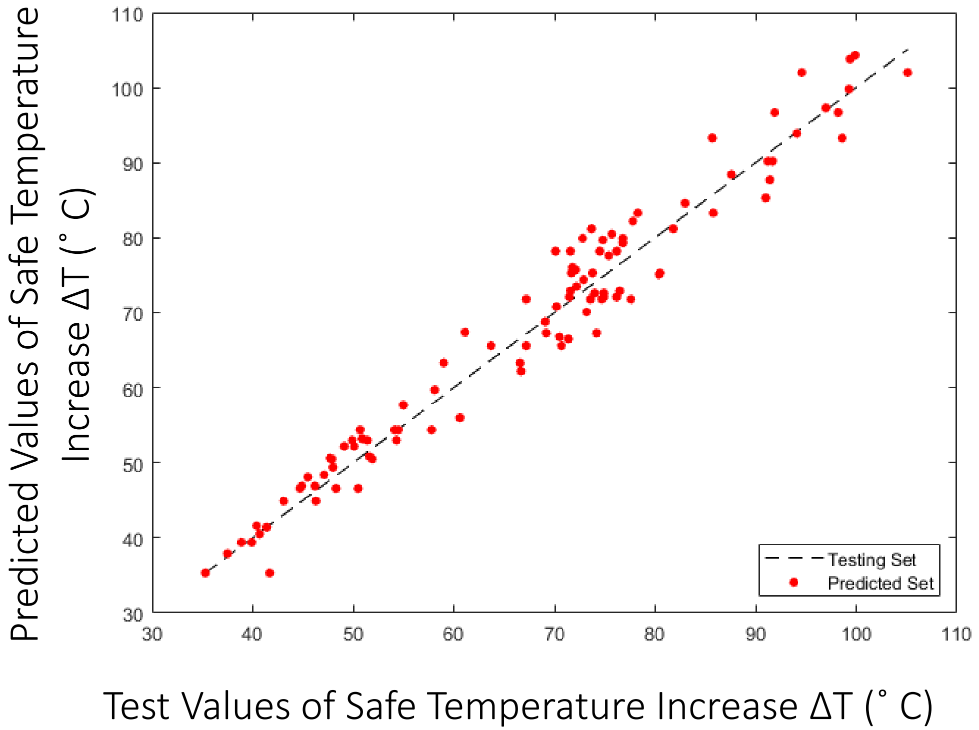



- Training data is supplied to the model
- Training data is fuzzified
- Relational matrix is constructed from the fuzzy training data

- New input data is fuzzified
- Fuzzy output is calculated from composition of fuzzy input and relational matrix
- Fuzzy output is defuzzified to give a single numerical value

# Results

- Lateral resistance, longitudinal resistance and fastener torsional stiffness used to predict minimum buckling temperature increase
- Training data supplied by analytical model, tested for 100 buckling scenarios
- Results improved, giving 2.3% error
- Proved to be rapid in calculation and required a training data size of just 27 points

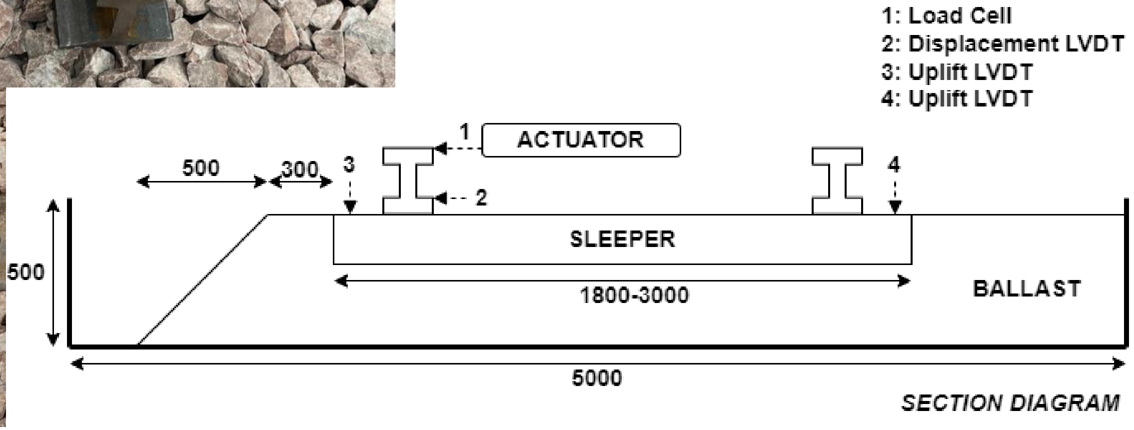


# Conclusions

- High accuracy, low calculation time without reliance on large training datasets makes for a good alternative to conventional models
- Method is not confined to a single dataset, buckling scenario or even the field of track buckling
- Well suited to predicting large volumes of data with a mix of numerical and linguistic variables

# Future Directions

- Further implementation and testing of qualitative inputs
- Lateral resistance testing to establish representative values
  - Single sleeper push tests in a ballast box
  - Steel, concrete and wooden sleepers investigated in both compacted and loose ballast



# Contacts & Acknowledgments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