University of Huddersfield
Institute of Railway Research

Optimisation of Wheelset Maintenance using Whole System Cost Modelling

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RSSB ATOC Association of Train Operating Companies Network Rail Rail Research UK Association

V/T SIC
Vehicle / Track System Interface Committee

Overview

- Background
- Vision of VTISM
- Wheelset Maintenance Strategy
- Damage rates and WPDM
- Wheelset Costs
- Whole System Costs
- Summary
- Acknowledgements

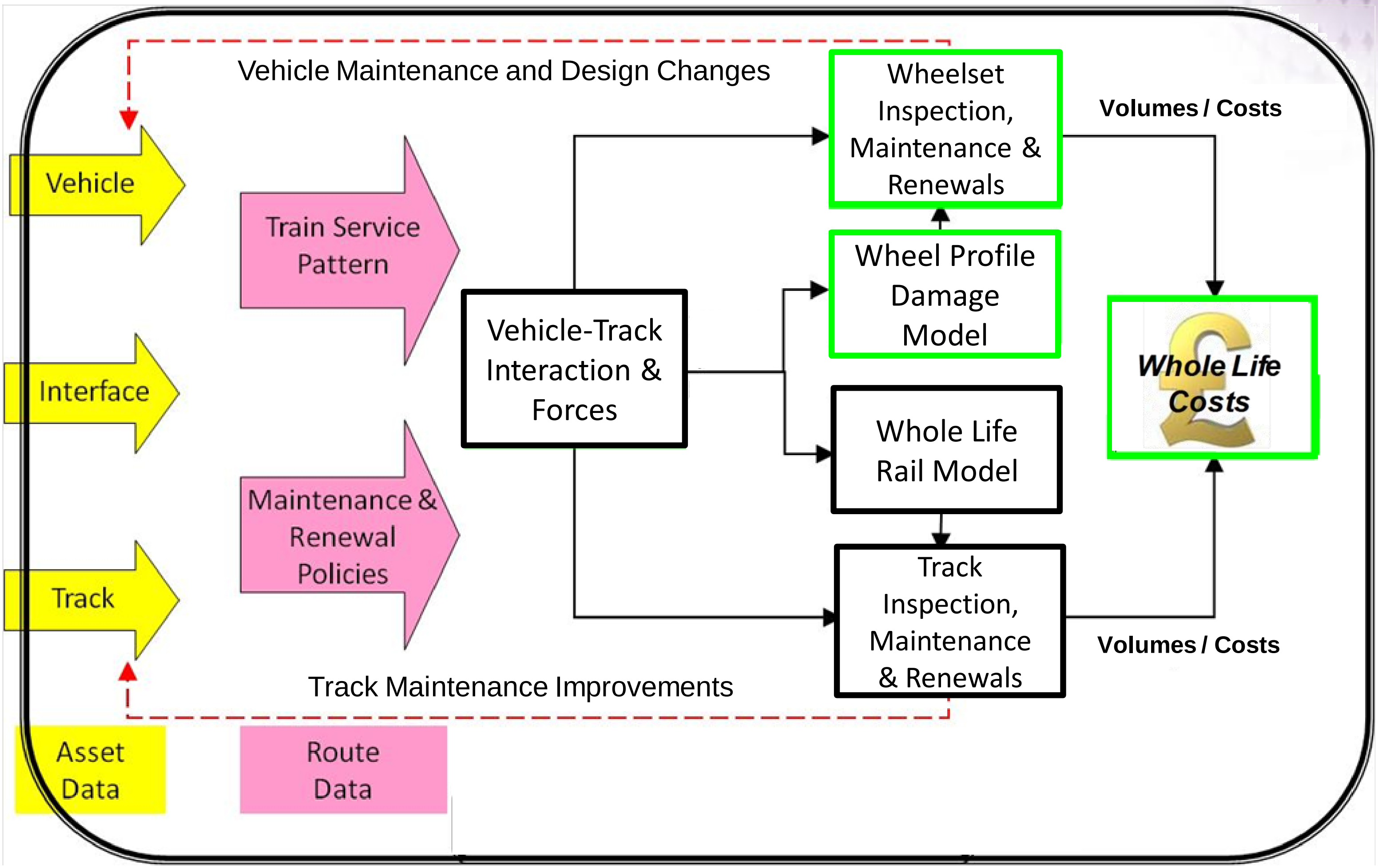
Background

- Wheelset maintenance and renewal activities account for a large proportion of a fleets whole-life costs
- Influenced by a large number of factors:
  - Depot constraints
  - Wheel tread damage
  - Fleet availability
  - Vehicle design
- Optimisation of maintenance and renewal regimes will help to increase wheelset life and reduce costs

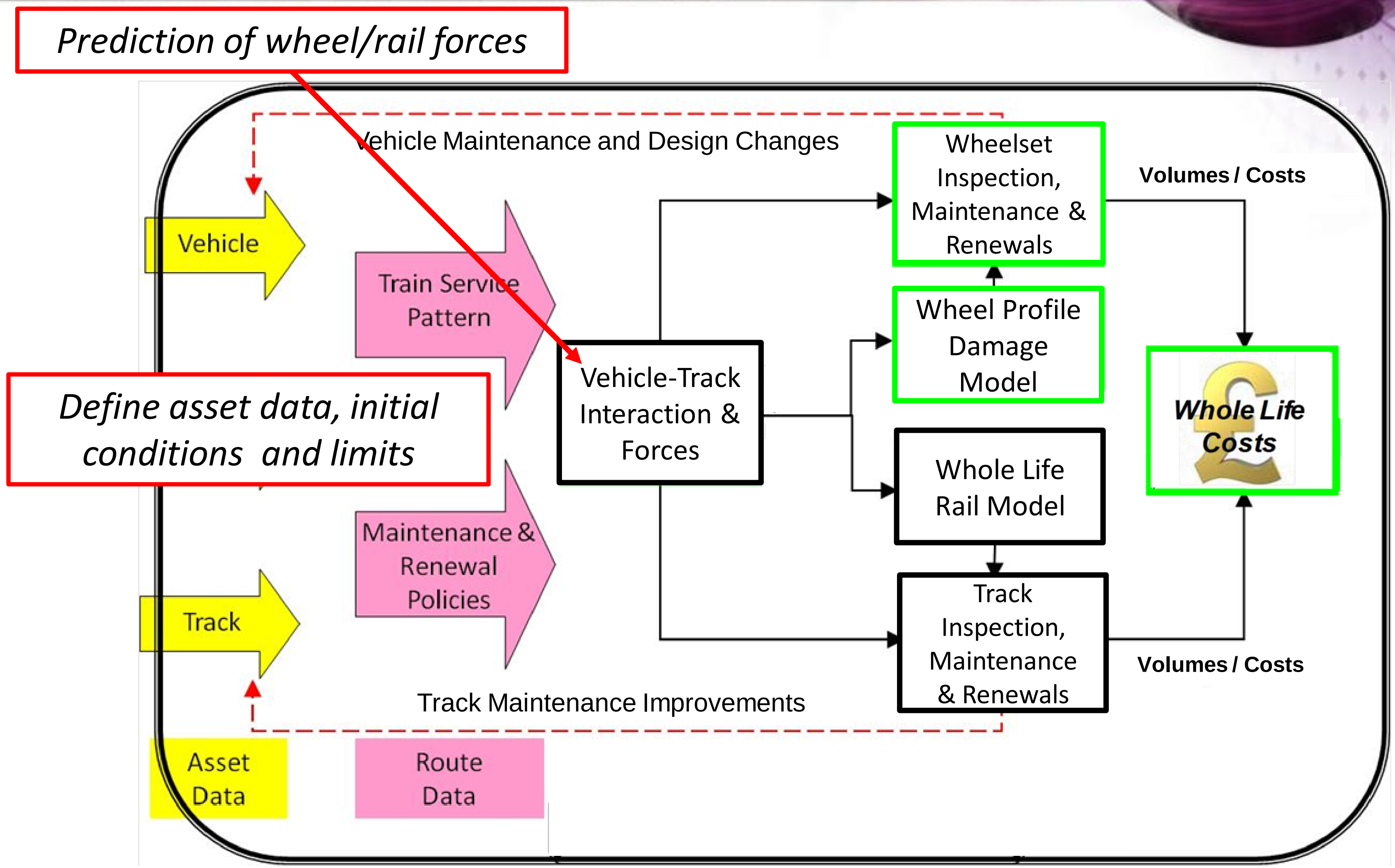
Background

- Tools currently exist for prediction of track damage, replacement and maintenance costs
  - Whole Life Rail Model (rail RCF & wear)
  - Track-Ex (NR decision support tool)
  - VTISM (links vehicle-track characteristics to track costs)
- Stage 2 development of VTISM enhanced the rolling stock modelling capabilities
  - Strategic planning of wheelset maintenance and renewal activities
  - Examine benefits and cost impact of a range of different scenarios
  - Optimise wheelset management strategies
- These enhancements go some way to determining the whole life costs for the complete system (vehicle-track)

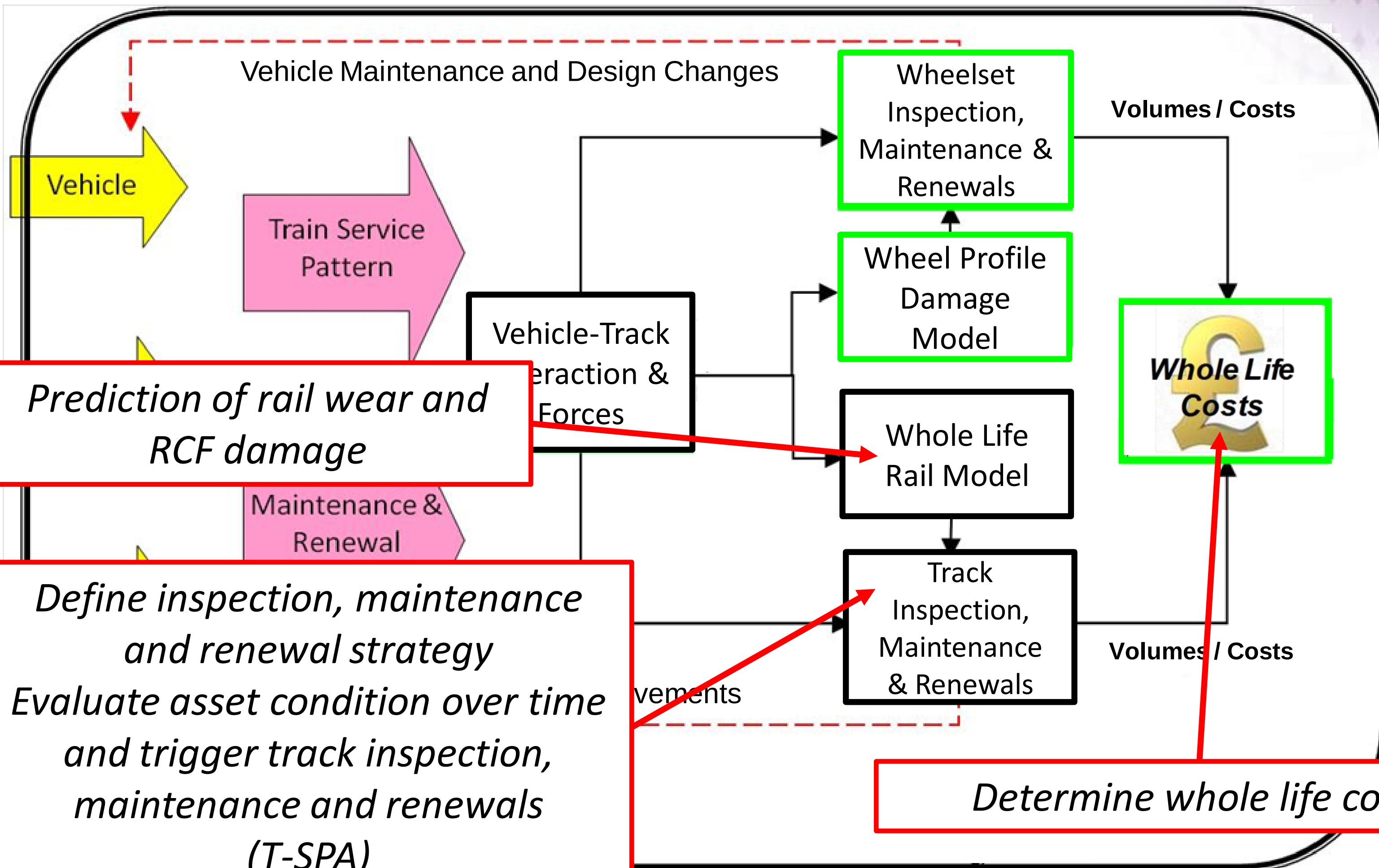
Vision of VTISM



Vision of VTISM



Vision of VTISM

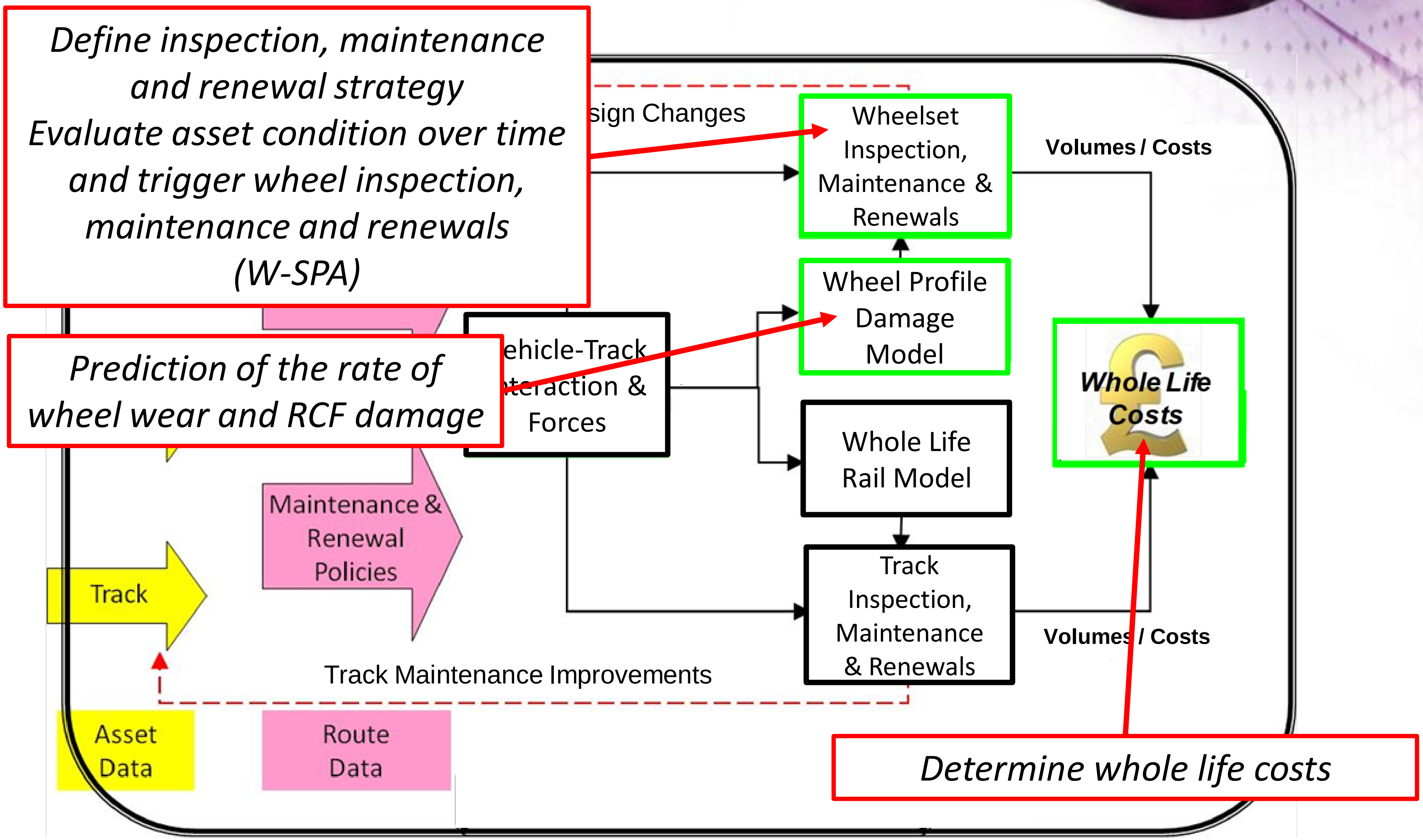


Prediction of rail wear and RCF damage

Define inspection, maintenance and renewal strategy
Evaluate asset condition over time and trigger track inspection, maintenance and renewals (T-SPA)

Determine whole life costs

Vision of VTISM



Wheelset Maintenance Strategy

- Class 100 Example
  - Regime Renewals Capping Budget
  - Regime Maintenance Capping Budget
  - Inspection Strategy
    - Strategy Capping Budget
    - Ultrasonic Test on mileage
    - Visual Inspection on mileage
    - Profile Measurement on mileage
    - Flat Depth Inspection on mileage
  - Wheel Turning Strategy
    - Strategy Capping Budget
    - (left_wheel_diameter > MinimumWheelDiameter
    - Turning on max flats
    - Turning on flange thickness
    - Turning on flange height
    - Turning on damage depth permitted
    - Turning on mileage
  - Wheelset Replacement Strategy
    - Strategy Capping Budget
    - Bogie Overhaul
    - Wheelset Replacement

Inspection Strategy
Applied if mileage since last inspection is greater than the relevant inspection interval

Wheel Turning Strategy
Triggered if condition reaches a pre-defined limit (i.e. flange thickness is less than the minimum permitted flange thickness)

Wheelset Replacement Strategy
Triggered if condition reaches a pre-defined limit (i.e. wheel diameter is less than the minimum diameter for running

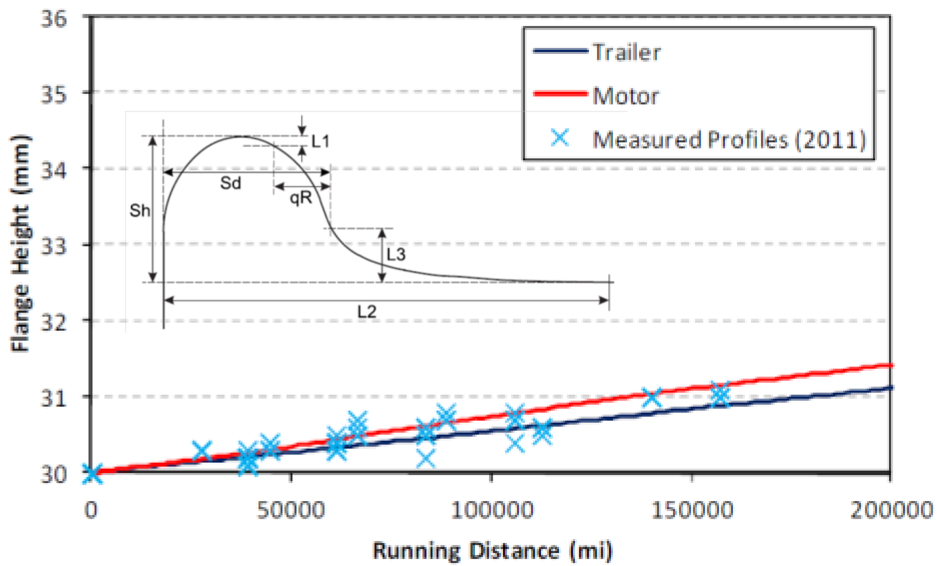
Damage Rates

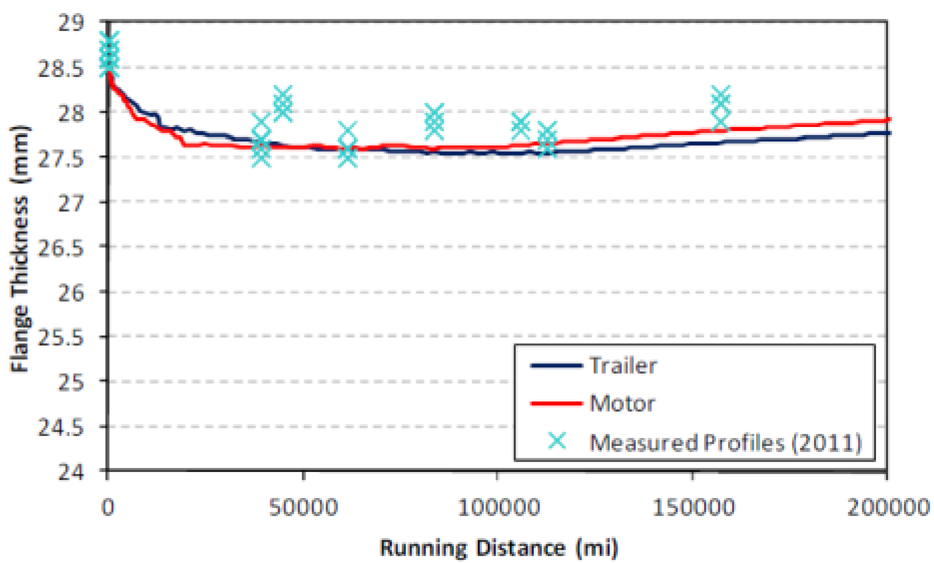
- Rates of damage are included to describe how the attributes of the wheel deteriorate over time
  - Tread/flange wear
  - Change in conicity
  - RCF damage
  - Probability of flats
- Compared with pre-defined limits - trigger maintenance or renewal activity
- This information can be obtained from observation data
- Alternatively, the WPDM can be used to predict the damage rates

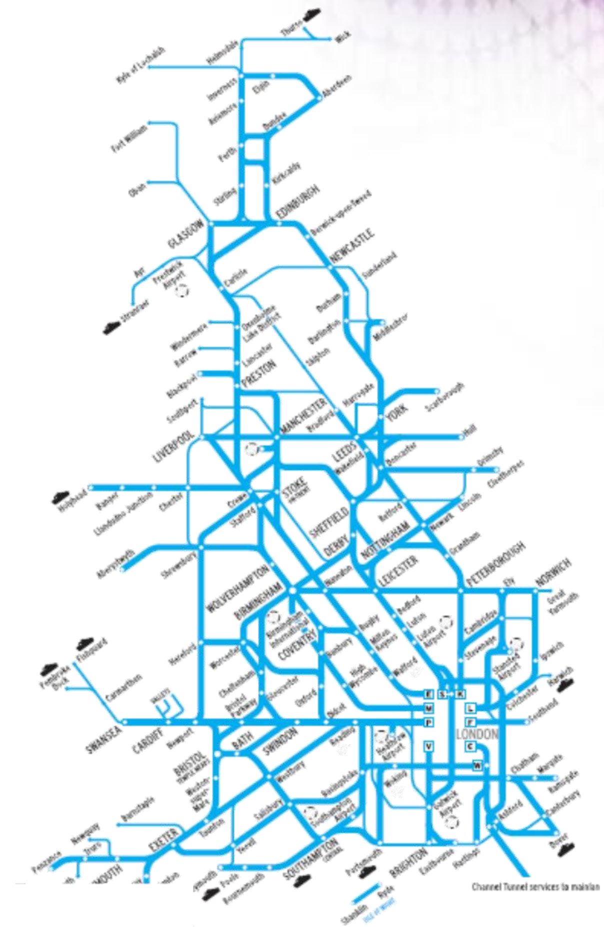
WPDM

- Wheel Profile Damage Model (WPDM) is a standalone tool for the prediction of deterioration rates of the wheel tread
- Uses VAMPIRE vehicle dynamics simulation software to predict wear and RCF damage
- WPDM methodology
  - Characterises a vehicle's route diagram in terms of parameters which influence wheel damage
  - Predicts wheel-rail forces for the chosen route conditions using vehicle dynamics simulations
  - Post-process the calculated wheel-rail forces to predict the formation of wear (Archard model) and RCF (Tγ-damage model) on the wheel
  - Plot and save the results for use within VTISM and WMM

Predicted Wheel Wear







Analysis Scenarios

- Mileage-based turning regime (Base Case)
  - Turning interval set to 140,000 miles to represent current practice
- Reduced mileage-based turning interval
  - Turning interval reduced to 100,000 miles to represent a 'little and often' turning regime
- Condition-based turning regime
  - Turning triggered by the condition of the wheelset only
- Lubrication strategy
  - Coefficient of friction at the flange contact was reduced to $\mu=0.1$
  - Inspection and maintenance of the lubrication system included
  - Includes modified wear and RCF damage rates for all wheelset types
- Modified primary yaw stiffness
  - Includes modified wear and RCF damage rates for all wheelset types

Wheelset Whole Life Costs

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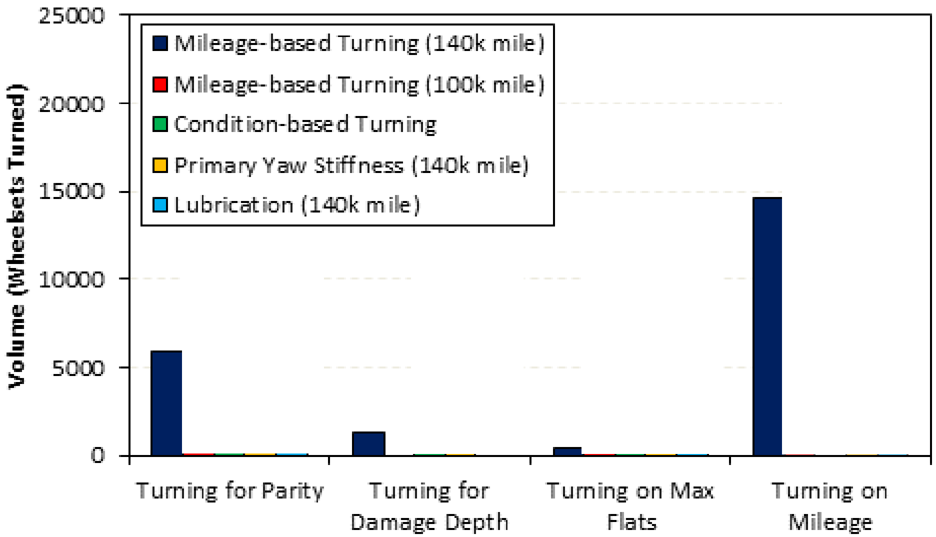
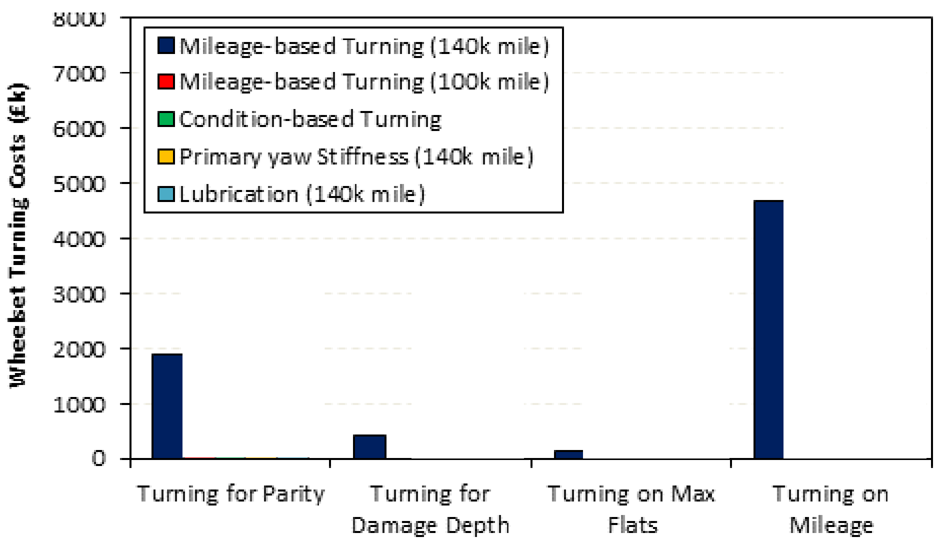
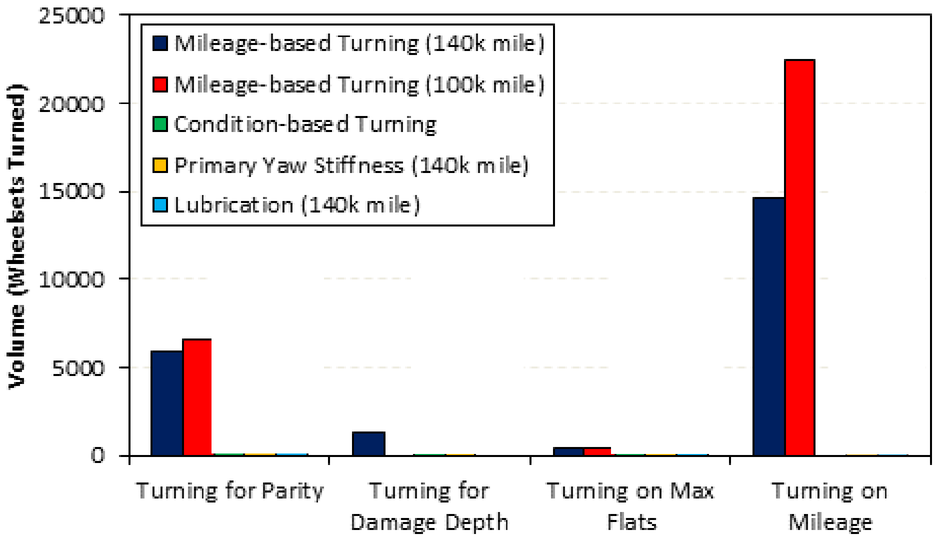
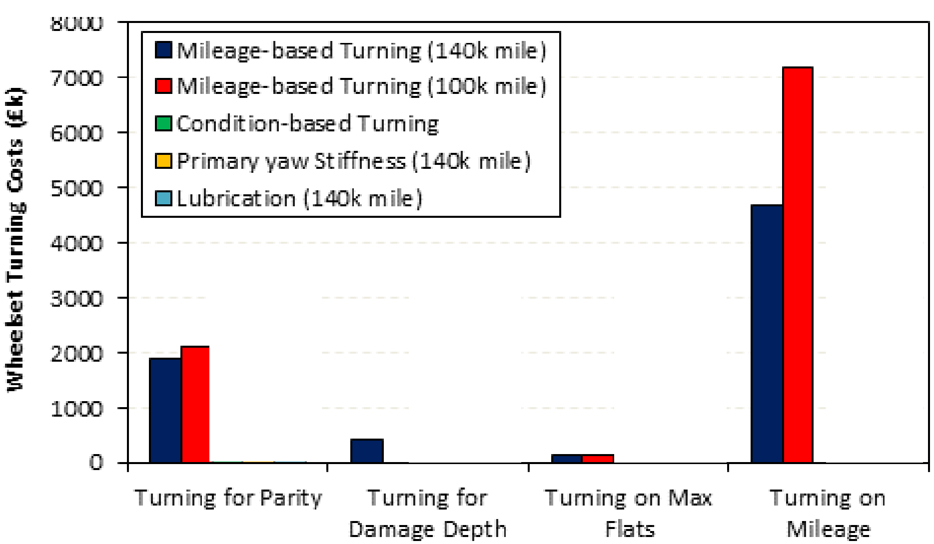




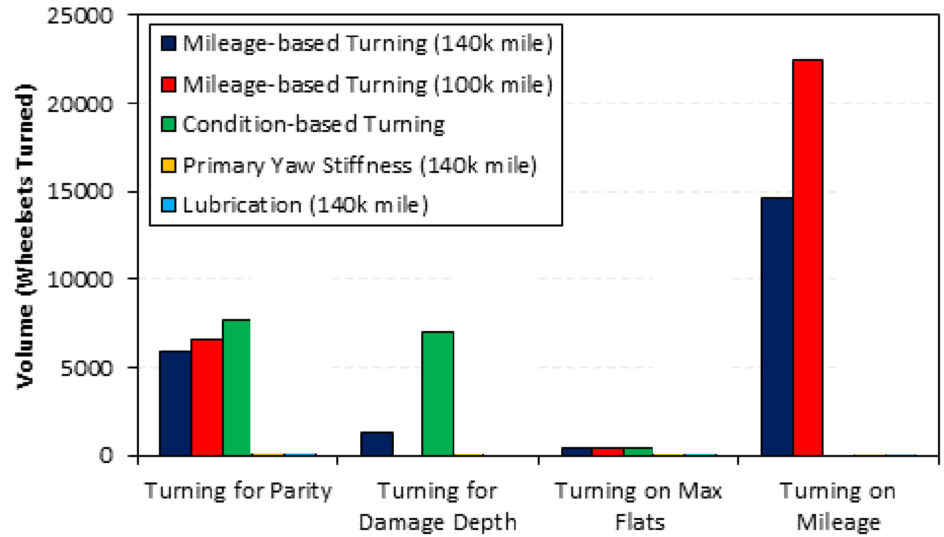
Wheelset Whole Life Costs

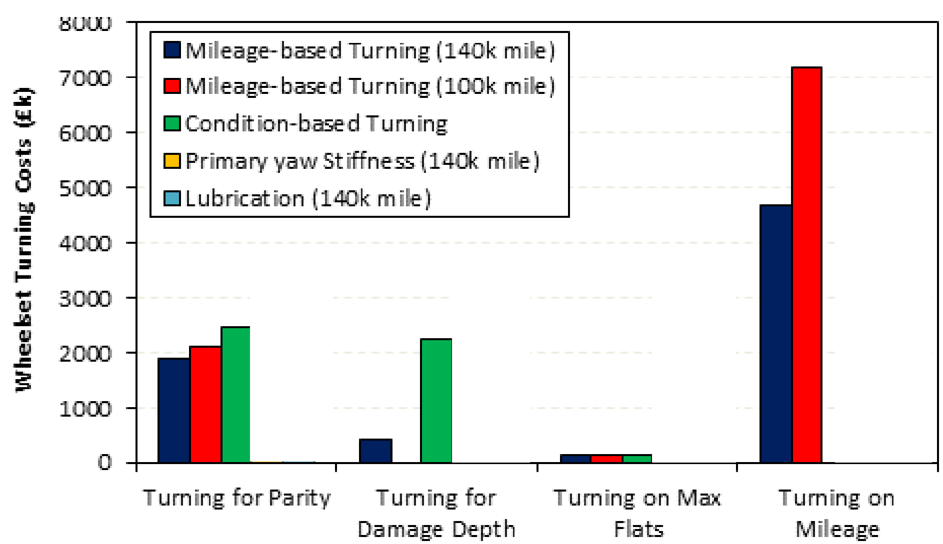




- **Reduced Turning Interval**
  - Increase in mileage-based turning
  - Reduction in turning for damage

Wheelset Whole Life Costs





- Reduced Turning Interval
  - Increase in mileage-based turning
  - Reduction in turning for damage
- **Condition-based Turning**
  - Increase in turning for damage and parity
  - No mileage-based turning

Wheelset Whole Life Costs

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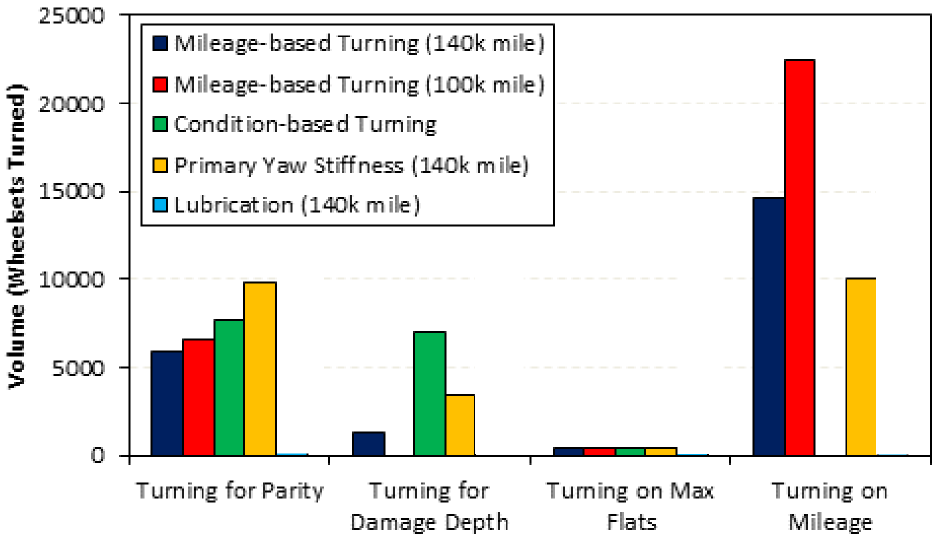
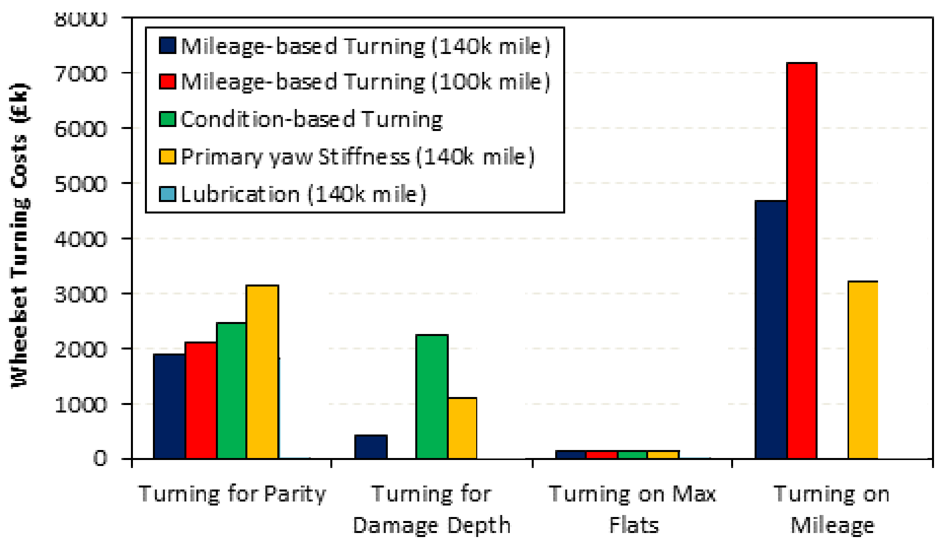
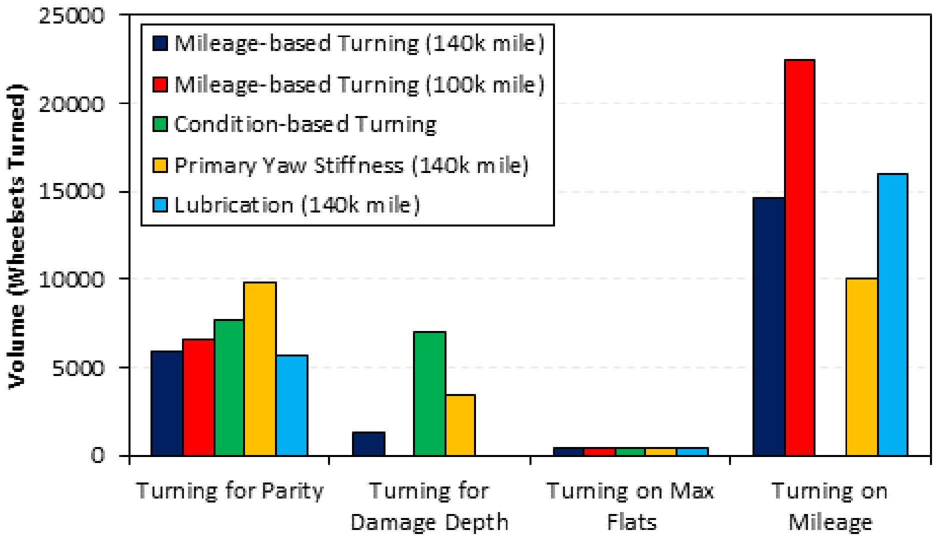
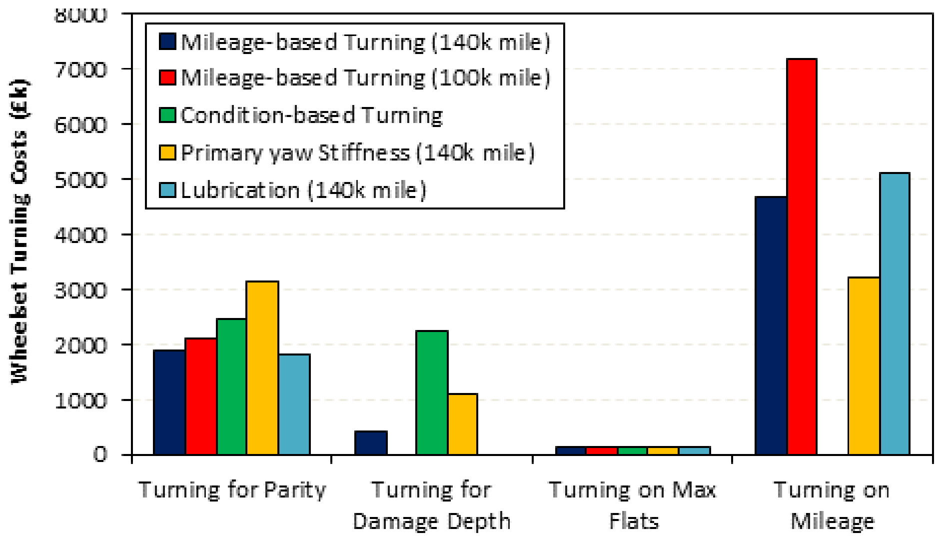




- Reduced Turning Interval
  - Increase in mileage-based turning
  - Reduction in turning for damage
- Condition-based Turning
  - Increase in turning for damage and parity
  - No mileage-based turning
- **Primary Yaw Stiffness**
  - Increase rates of damage
  - Increase in turning for damage

Wheelset Whole Life Costs

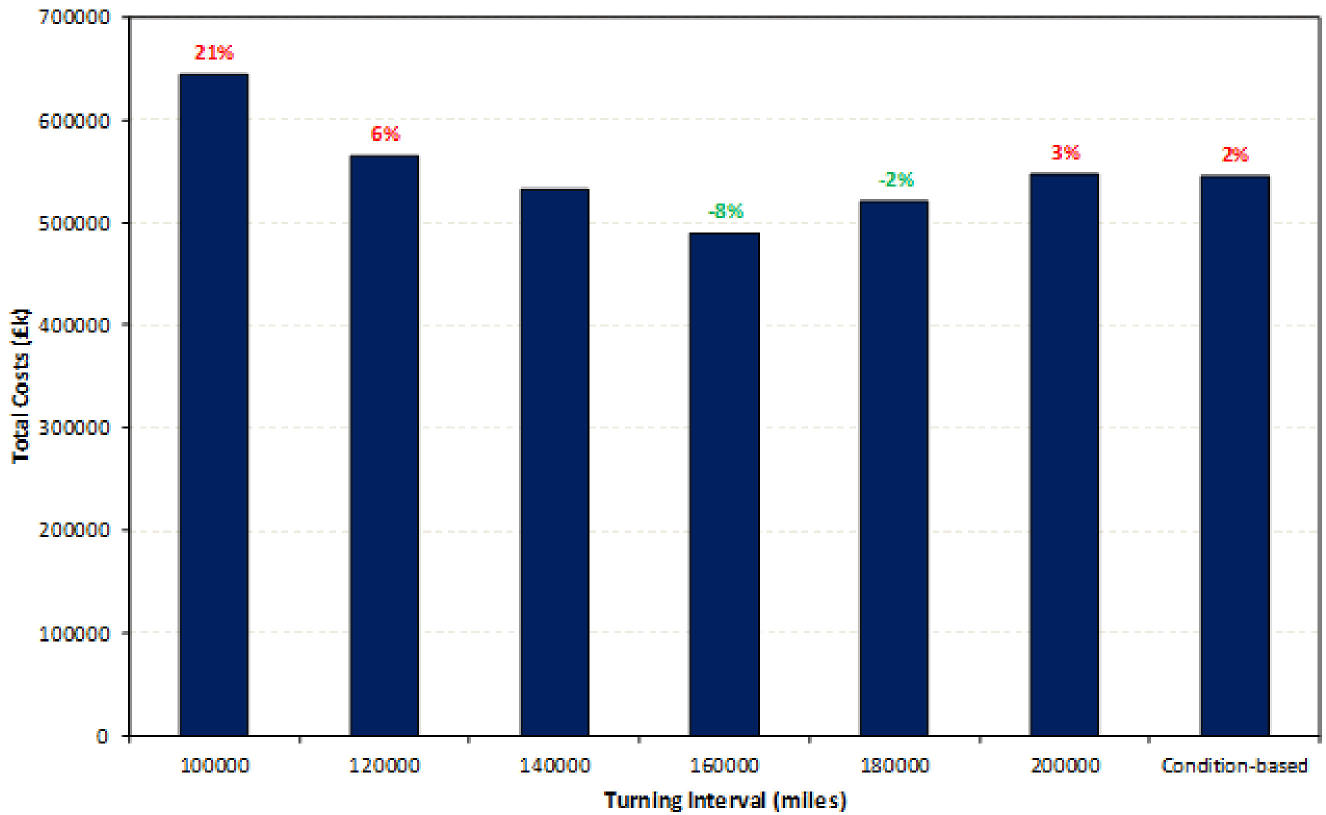




- Reduced Turning Interval
  - Increase in mileage-based turning
  - Reduction in turning for damage
- Condition-based Turning
  - Increase in turning for damage and parity
  - No mileage-based turning
- Primary Yaw Stiffness
  - Increase rates of damage
  - Increase in turning for damage
- **Lubrication**
  - Reduction in damage rates
  - Increase in number of wheelsets achieving mileage-based turning

Optimised Wheel Turning Interval

- Total costs for varying wheel turning interval



Material Loss at Turning

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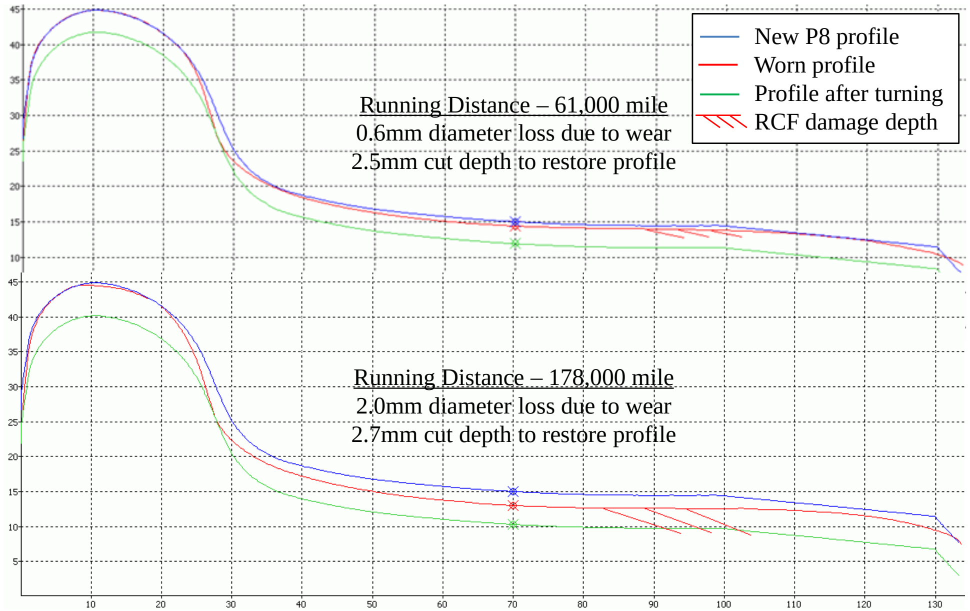
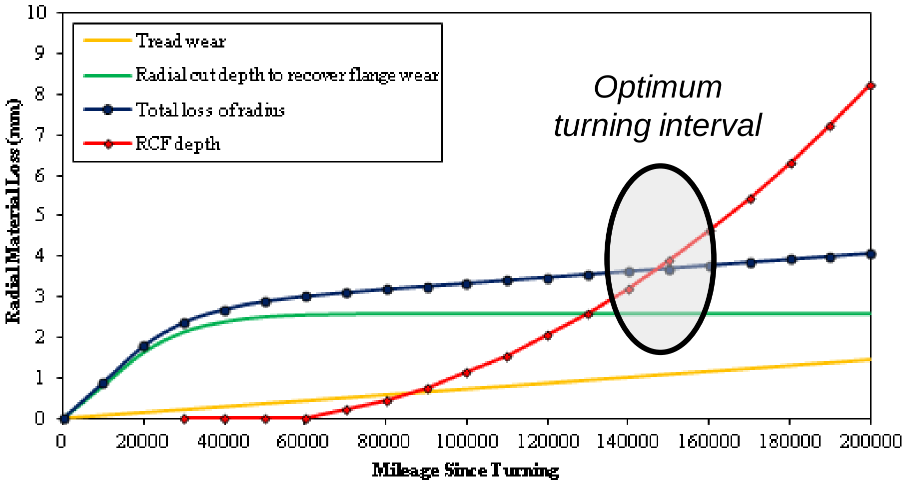
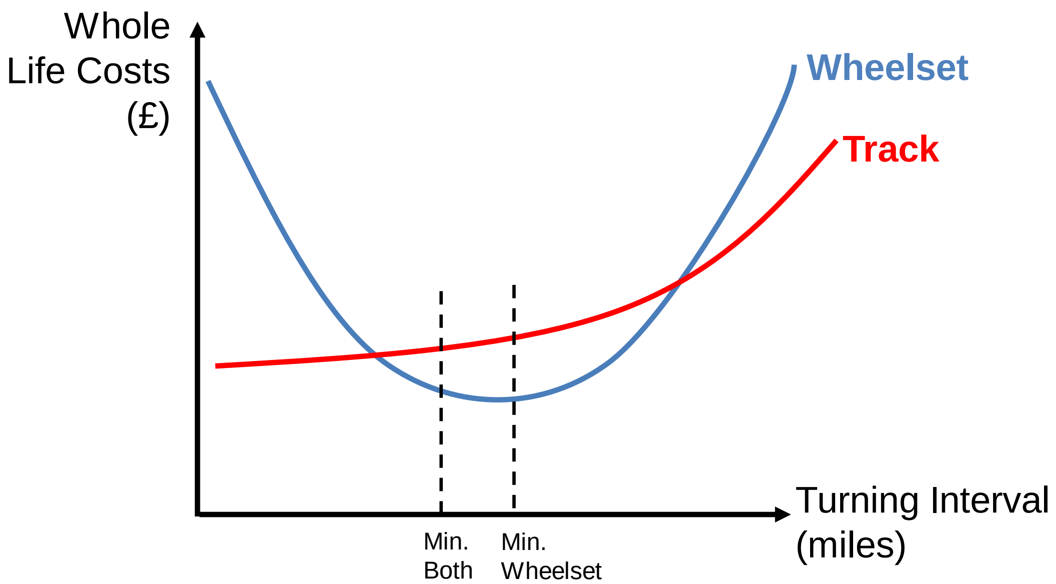
- Low mileages – cut depth is governed by the amount of material loss required to restore the profile shape
- Higher mileages – similar cut depth to restore profile, but additional material removed due to RCF damage



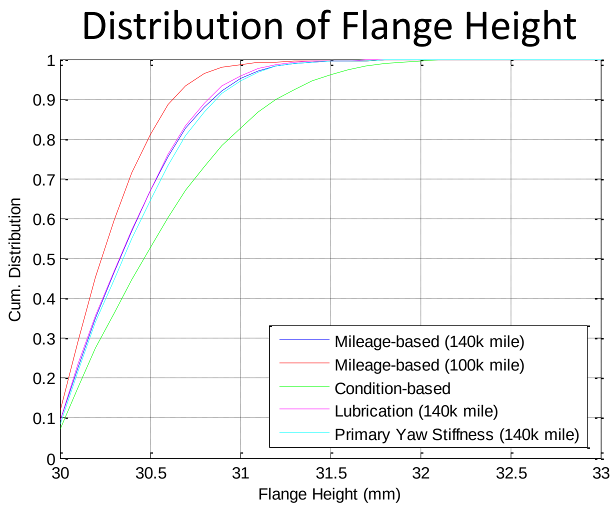


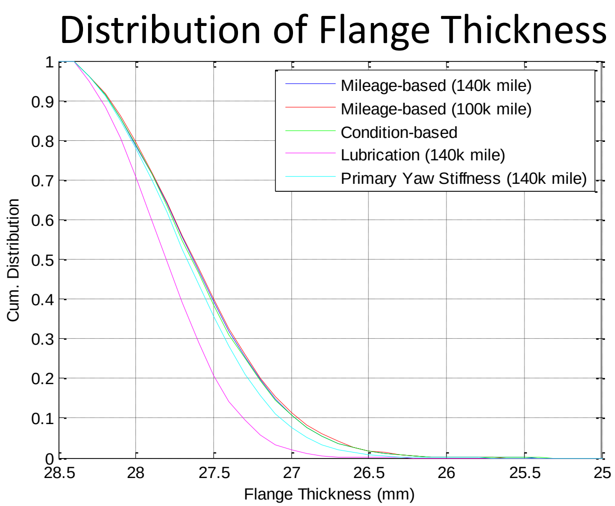
Whole System Costs

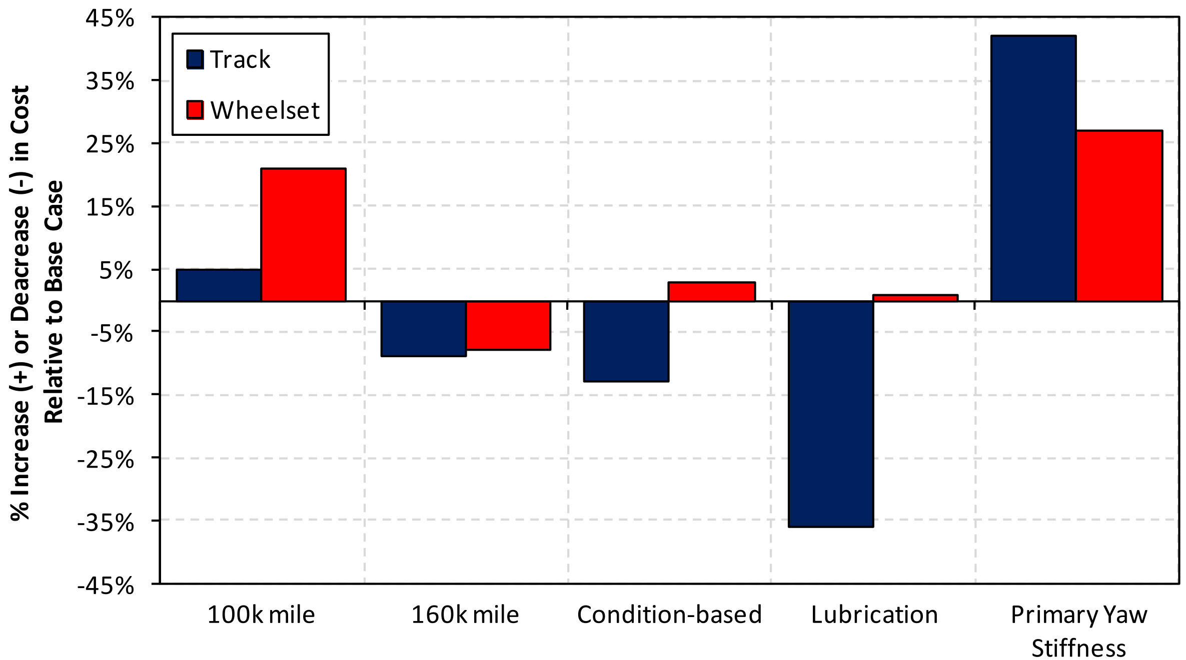
- Increased intervals between wheel turning may result in a cost benefit to vehicle operators/maintainers
- But increases in wheel/rail conformality may result ≈ increasing the probability of RCF damage on the track
- To reduce whole system costs (vehicle-track) it is therefore important to optimise both sides of the interface



Track-Wheelset Costs







Summary

- New tools have been developed which allow users to:
  - Evaluate wheelset whole life costs using fleet asset inventory data, deterioration rates and maintenance regimes
  - Determine annual inspection, maintenance and renewal costs
  - Optimise wheelset maintenance strategy
  - Carry out *'what if'* analysis
- Capabilities of these new tools have been demonstrated by predicting the whole life costs for a typical DMU fleet
  - Cost implications of number of scenarios presented
- Tools can be used to determine the impact of system changes on both vehicle and track costs ≈ potential for reducing whole system costs

Acknowledgements

- The results and findings presented were developed from the RSSB managed rail industry research programme, funded by the Department of Transport

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