Wheel profile optimization for the iron ore wagons on Malmbanan

Project introduction

2012-10-24

-Johan Öberg & Peter Hartwig-

Project assigned by

LKAB

MiW Konsult AB

Motivation

- RCF issues on iron ore wagon wheels:

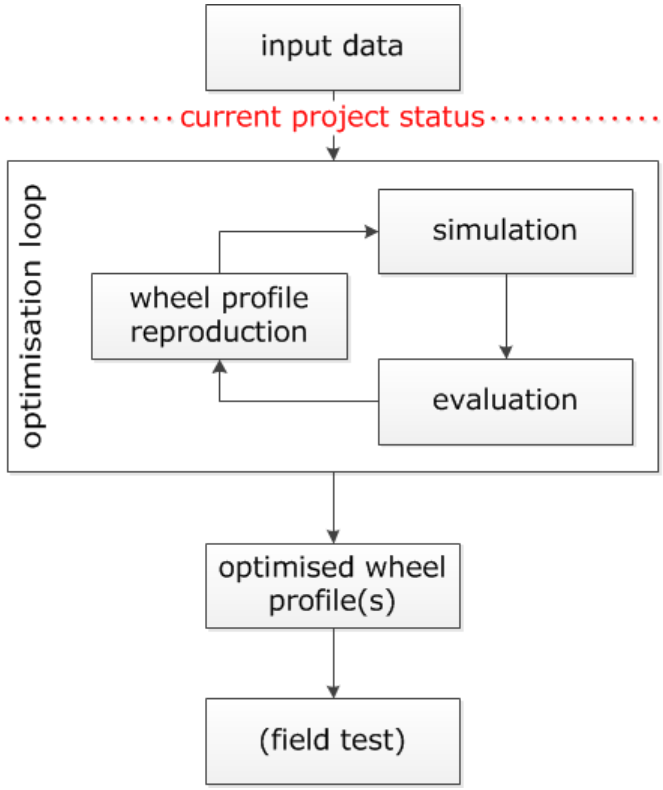
driven by e.g.:
- high axle loads
- environmental conditions
- wheel/rail interaction
- vehicle dynamics

affecting e.g.:
- reprofiling costs
- idle wagon costs
- wheel life
- rail damage
- noise

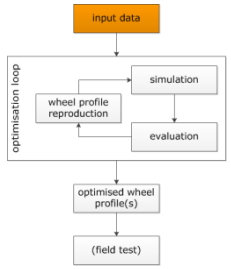
- substantial economic impact + unpredictable secondary damages

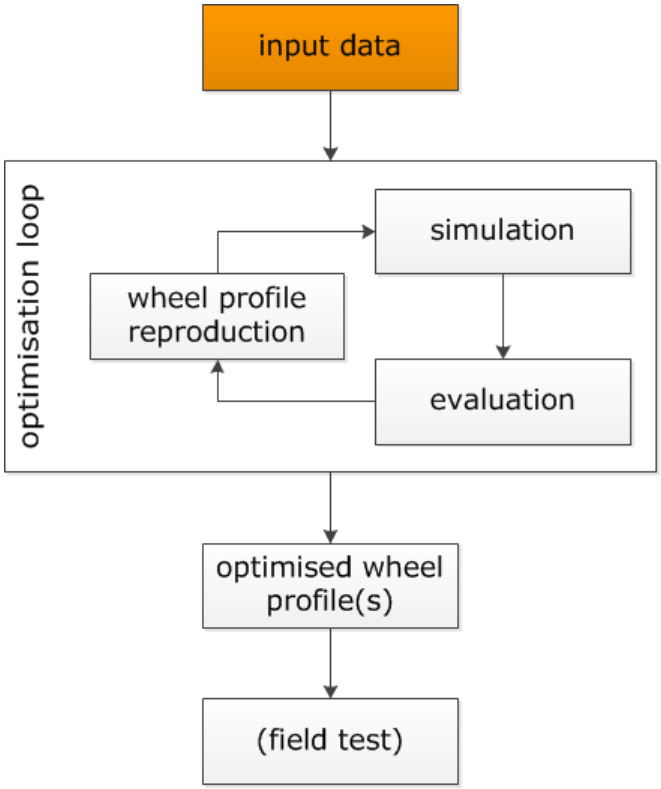
- assignment:
  find wheel profile(s) with minimised risk of RCF while keeping other characteristic functionalities in reasonable boundaries

Optimisation process

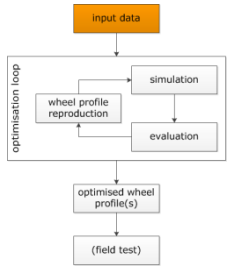


Input data

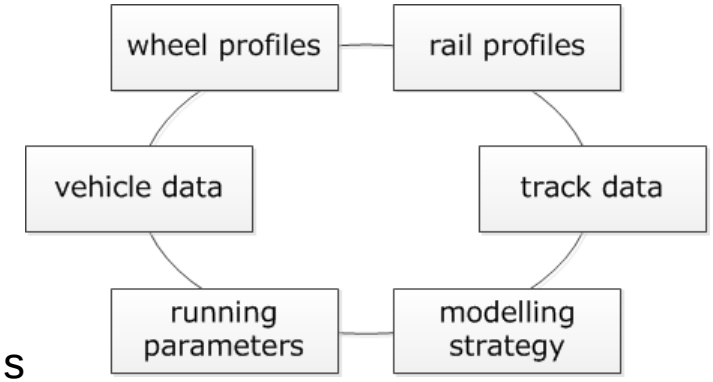

input data
optimisation loop
simulation
wheel profile reproduction
evaluation
optimised wheel profile(s)
(field test)


input data
optimisation loop
simulation
wheel profile reproduction
evaluation
optimised wheel profile(s)
(field test)

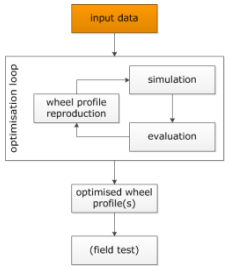
Input data



- vehicle data
  - Fanoo type wagon
  - model revised and validated by KTH
  - block brake still to be modelled
- track data
  - selection of representative track sections
  - tight curves, transitions, narrow gauge
  - (switches disregarded)
- running parameters
  - velocity profile
    - option A: track-defined operational speed (max. 60 km/h)
    - option B: speed profile from CATO (computer-aided train operation)
    - option C: STEC (simulated train energy consumption) program output developed by KTH and MiW
  - braking regime

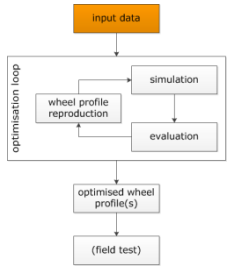


Input data: modelling strategy

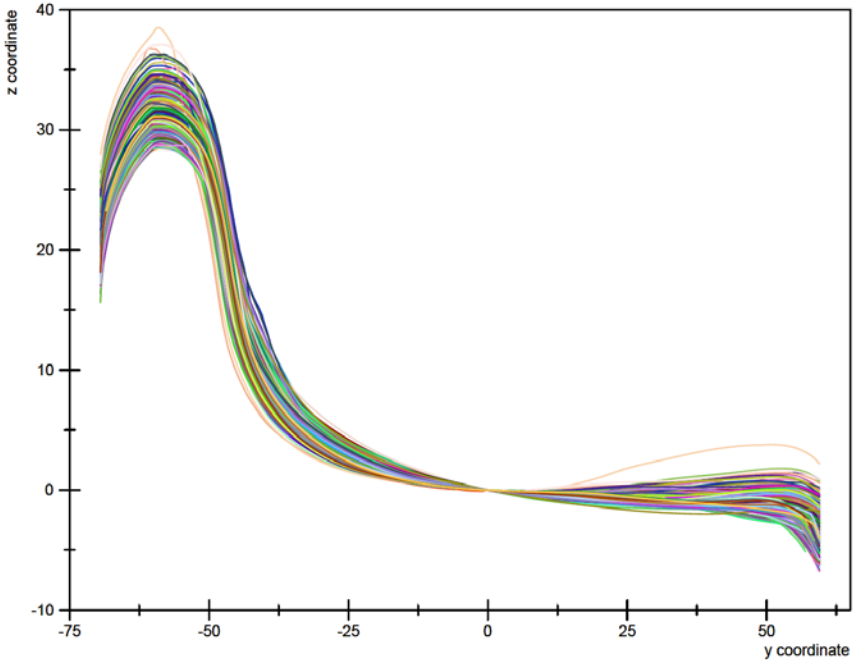


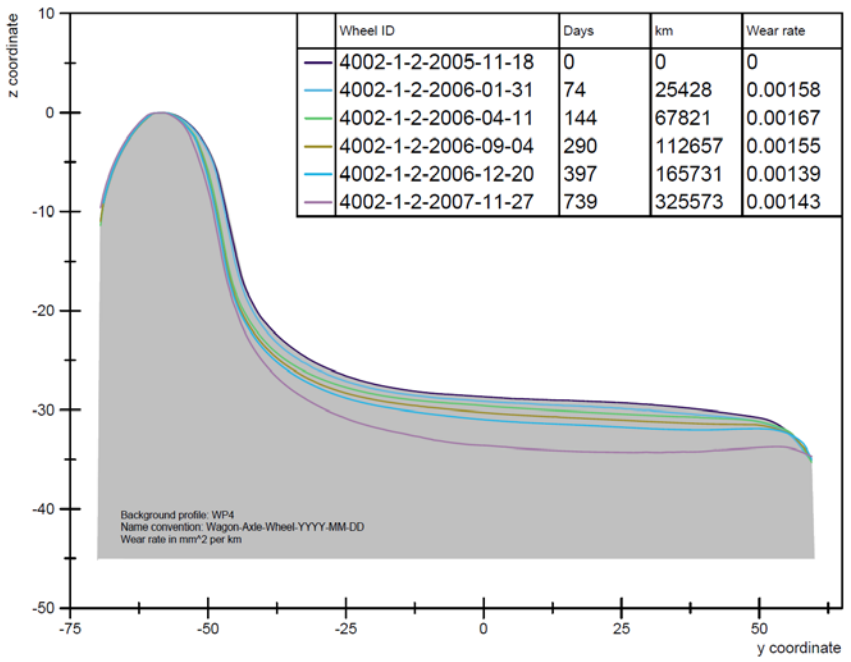
- contact:
  - *Hertz* (as implemented in Gensys©)
  - fast and conservative
  - use of other contact models will be considered upon first results
- friction:
  - can vary between 0.2 and 0.7
  - nominal friction will be set to 0.4
- RCF:
  - shakedown map with fatigue indexes (SI model)
- wear:
  - T_γ as indicator
  - *Archard*‘s model for comprehensive analysis
- simulation strategy

Input data: wheel profiles



- evaluation of 586 MiniProf WP4 measurement files (2005-2009)
- follow up on wear development
- wheel tread: 1 mm material loss every 55,000..85,000 km
- comparison basis for subsequent simulation

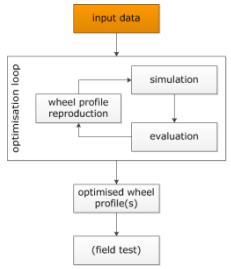




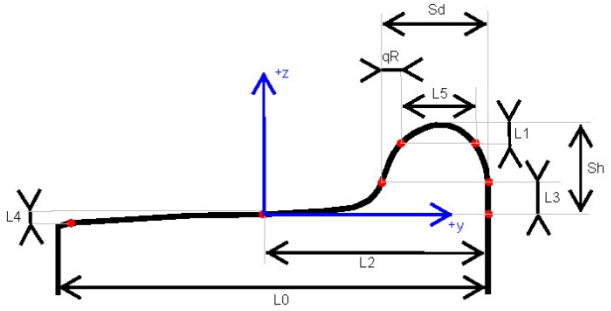
Wheel ID	Days	km	Wear rate
4002-1-2-2005-11-18	0	0	0
4002-1-2-2006-01-31	74	25428	0.00158
4002-1-2-2006-04-11	144	67821	0.00167
4002-1-2-2006-09-04	290	112657	0.00155
4002-1-2-2006-12-20	397	165731	0.00139
4002-1-2-2007-11-27	739	325573	0.00143

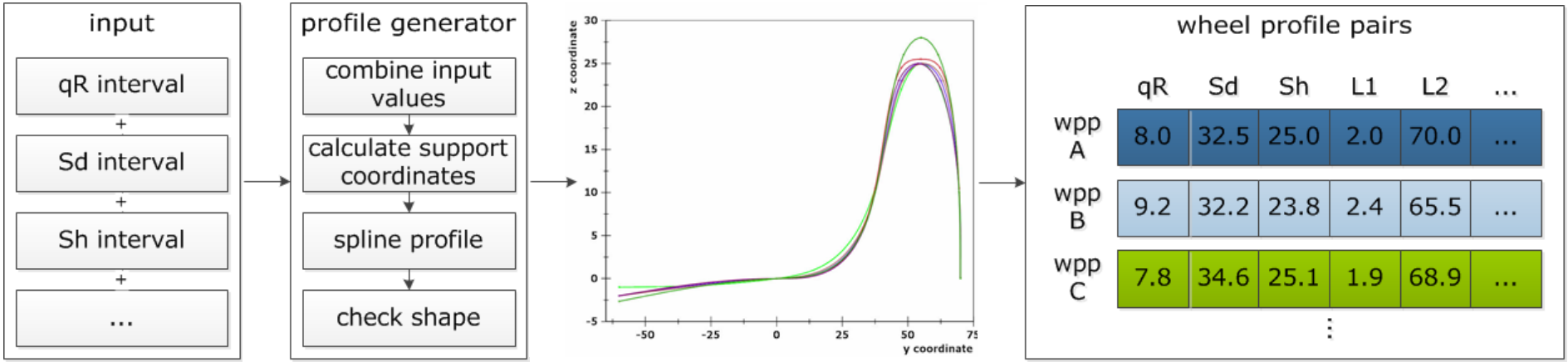
MiW Konsult AB

Input data: wheel profiles



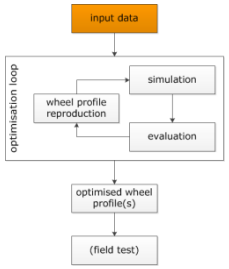
- define a start population for optimisation process
  - reference profile(s), e.g. WP4, S1002
  - measured worn profiles
  - random profiles
- wheel profile generator
  - reverse engineering approach
  - creates wheel profiles from characteristic values



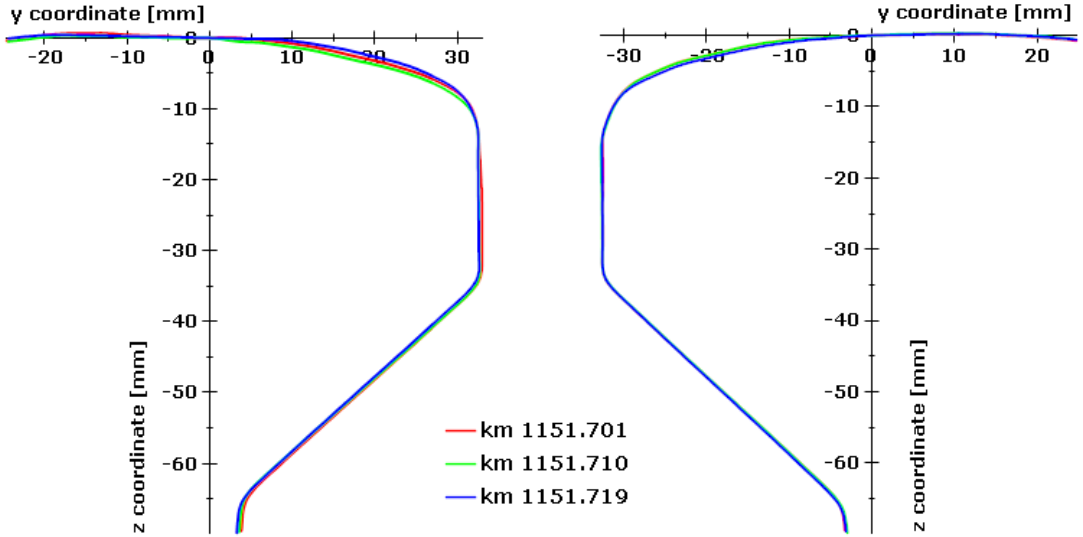


MiW Konsult AB

Input data: rail profiles

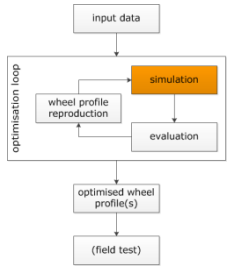


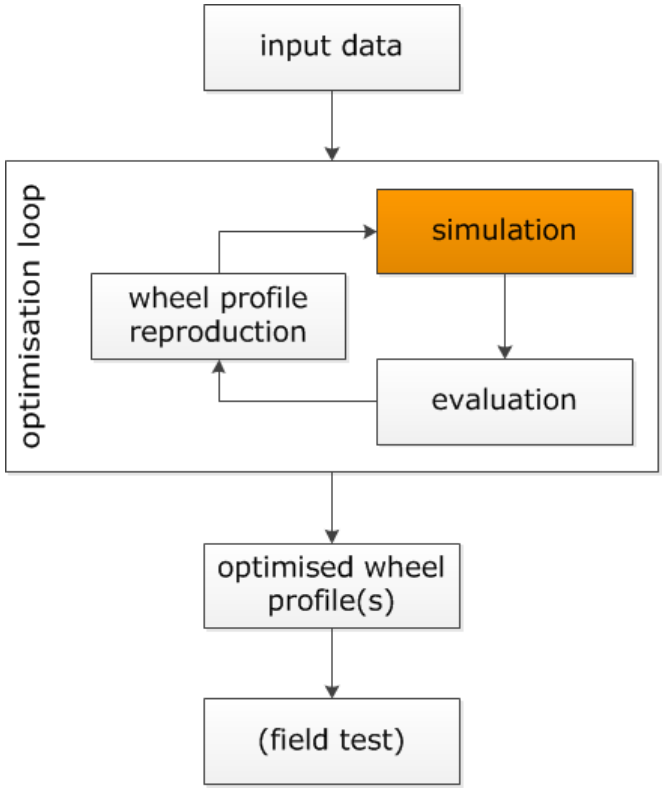
- evaluation of measured rail profiles (2011, 2012)
- compare and classify profiles on:
  - original profile type (MB1, UIC60, MB4, MB1asym)
  - shape similarity -> define class tolerances
  - create profile clusters
- map profiles to geographical position on track



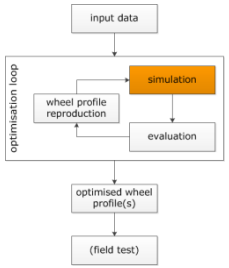
MiW Konsult AB

Simulation

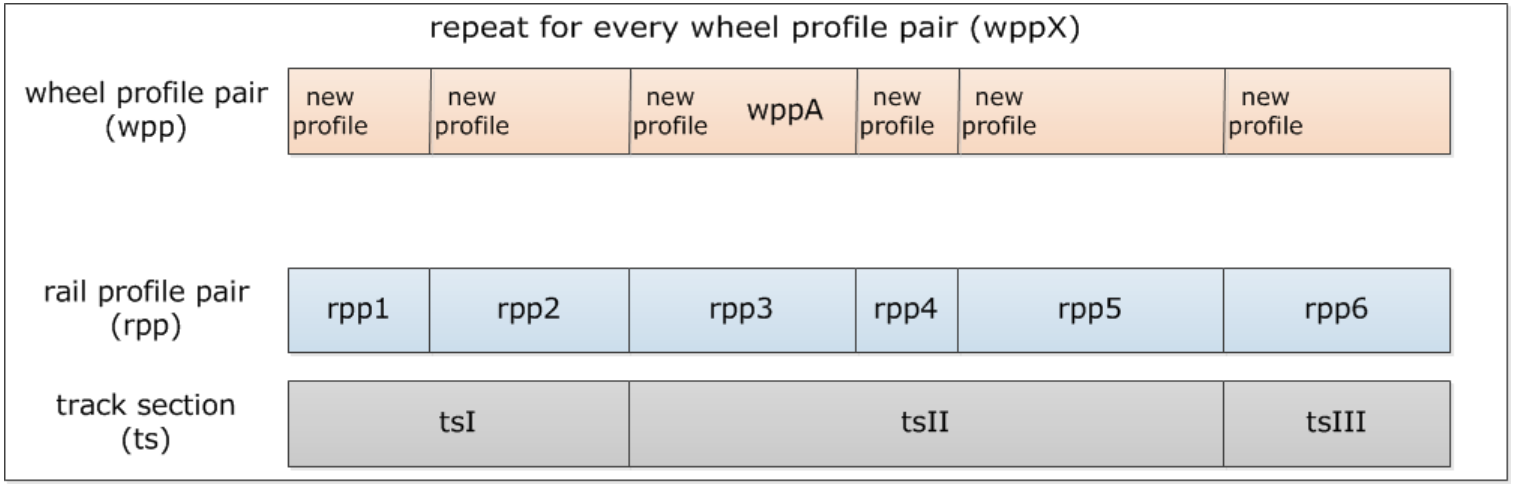

input data
optimisation loop
simulation
wheel profile reproduction
evaluation
optimised wheel profile(s)
(field test)


input data
optimisation loop
simulation
wheel profile reproduction
evaluation
optimised wheel profile(s)
(field test)

Simulation

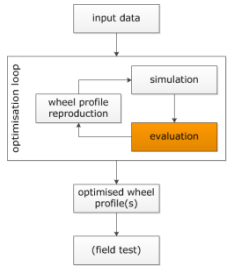


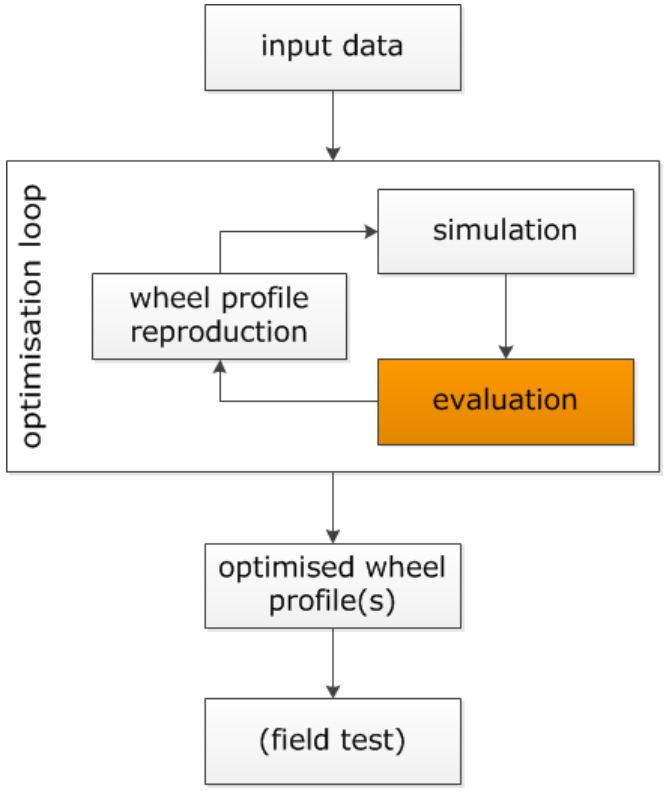
- Gensys® multi-body simulation software
- challenge: create a simple and fast simulation environment
  - same simulation boundary conditions for all wheel profile pairs
  - reduce overall track distance to a minimum
  - wheel/rail profile wear update neglected
  - constant friction & velocity
  - simplified block brake model



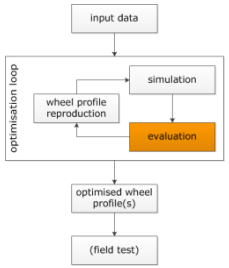
MiW Konsult AB

Evaluation


input data
optimisation loop
simulation
wheel profile reproduction
evaluation
optimised wheel profile(s)
(field test)

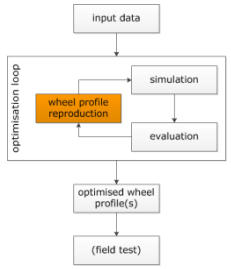

input data
optimisation loop
simulation
wheel profile reproduction
evaluation
optimised wheel profile(s)
(field test)

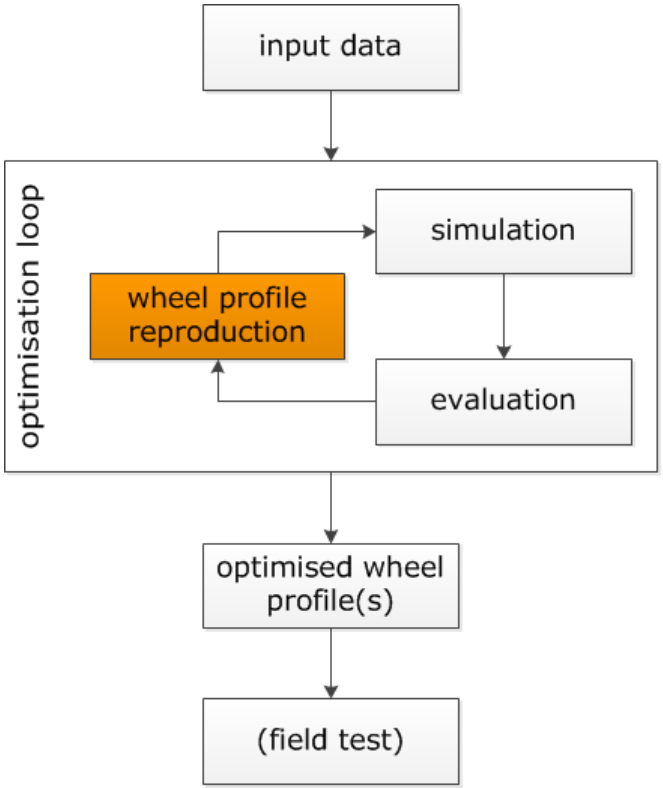
Evaluation



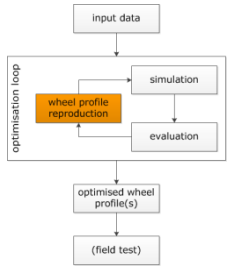
- select appropriate “fitness” measures
  - RCF
  - wear rate
  - radial steering index
  - Y/Q
  - …
- decide on ranking of fitness values
- define evaluation procedures
- formulate an overall fitness function
- each simulated profile will be assigned an individual fitness value

Wheel profile reproduction

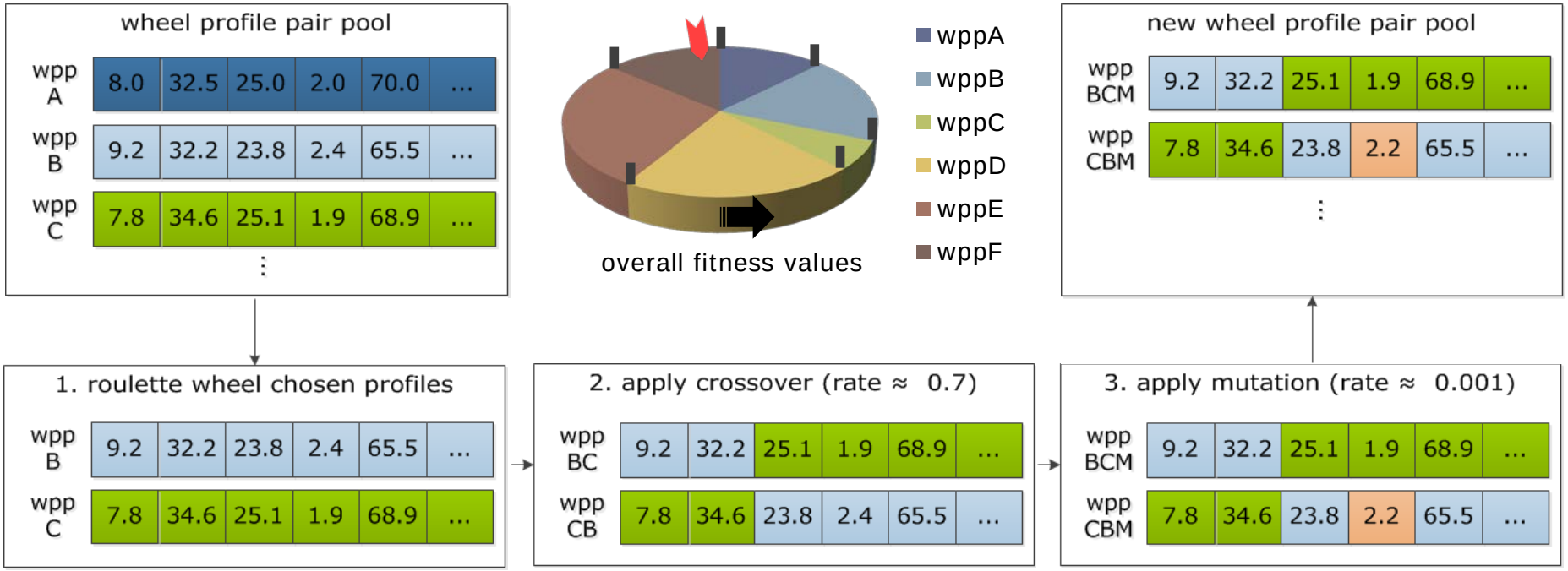




Wheel profile reproduction

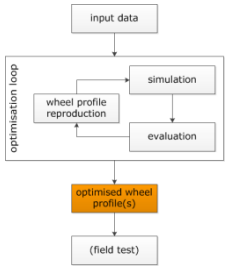


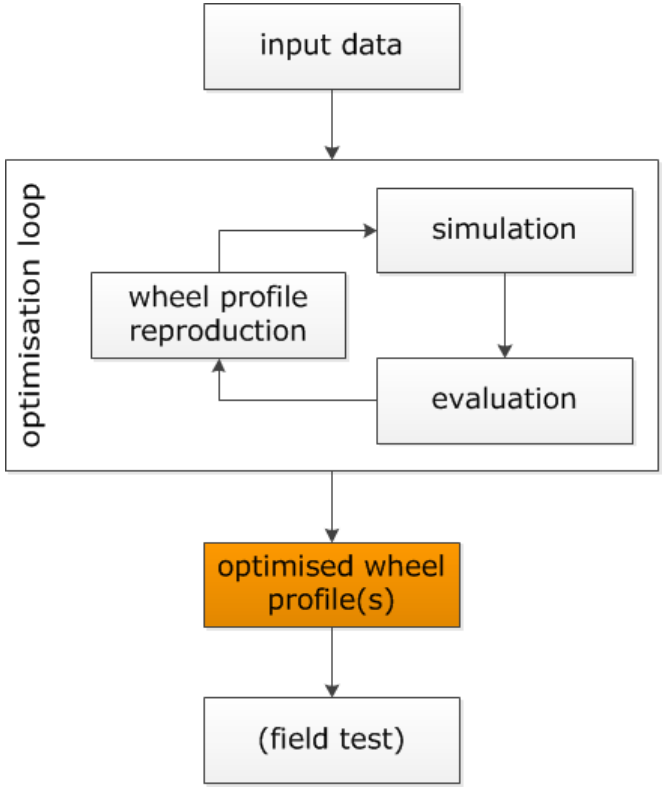
- reproduction process based on genetic algorithm features



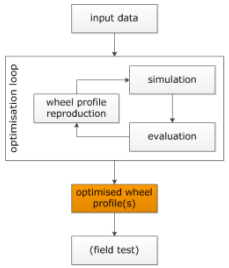
MiW Konsult AB

Optimised wheel profiles

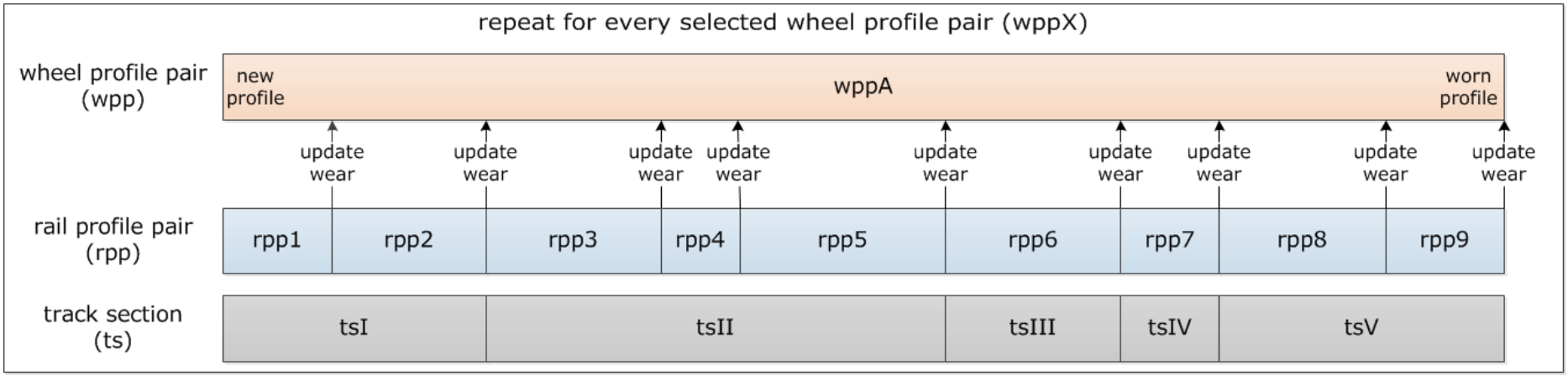




Optimised wheel profiles

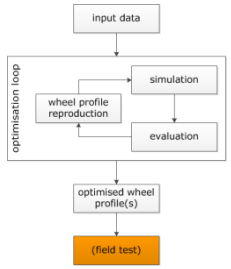


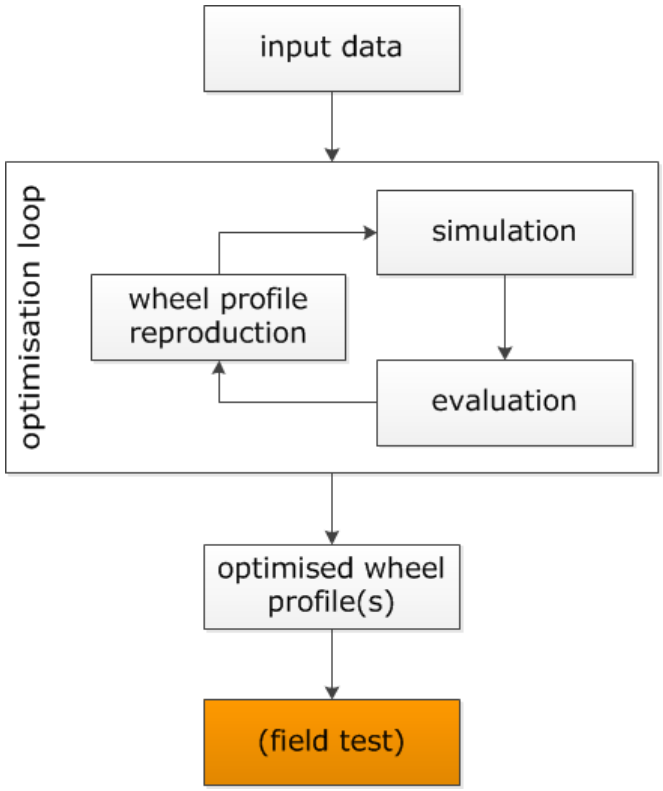
- repeat optimisation process until no further substantial changes
- select profile(s) with best overall fitness indexes
- compare candidates with WP4 profile along extended track section
  - inclusion of wheel profile wear update
  - consider different friction conditions
  - apply speed profile and refined brake model
- finally choose most promising profile(s) for testing



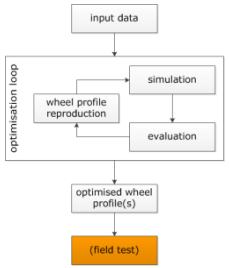
MiW Konsult AB

Field testing





Field testing



- selected profile(s) will be applied to limited number of wheels
- in-service shape monitoring with local track instrumentation
- random visual checks
- profile review and revision

Thank You !

Peter Hartwig
MiW Konsult AB
Fiskargatan 8
SE-116 20 Stockholm
Mobile: +46 (0)707 714 417
peter.hartwig@miw.se