Gradient Index Profile
a novel idea for predicting equivalent conicity

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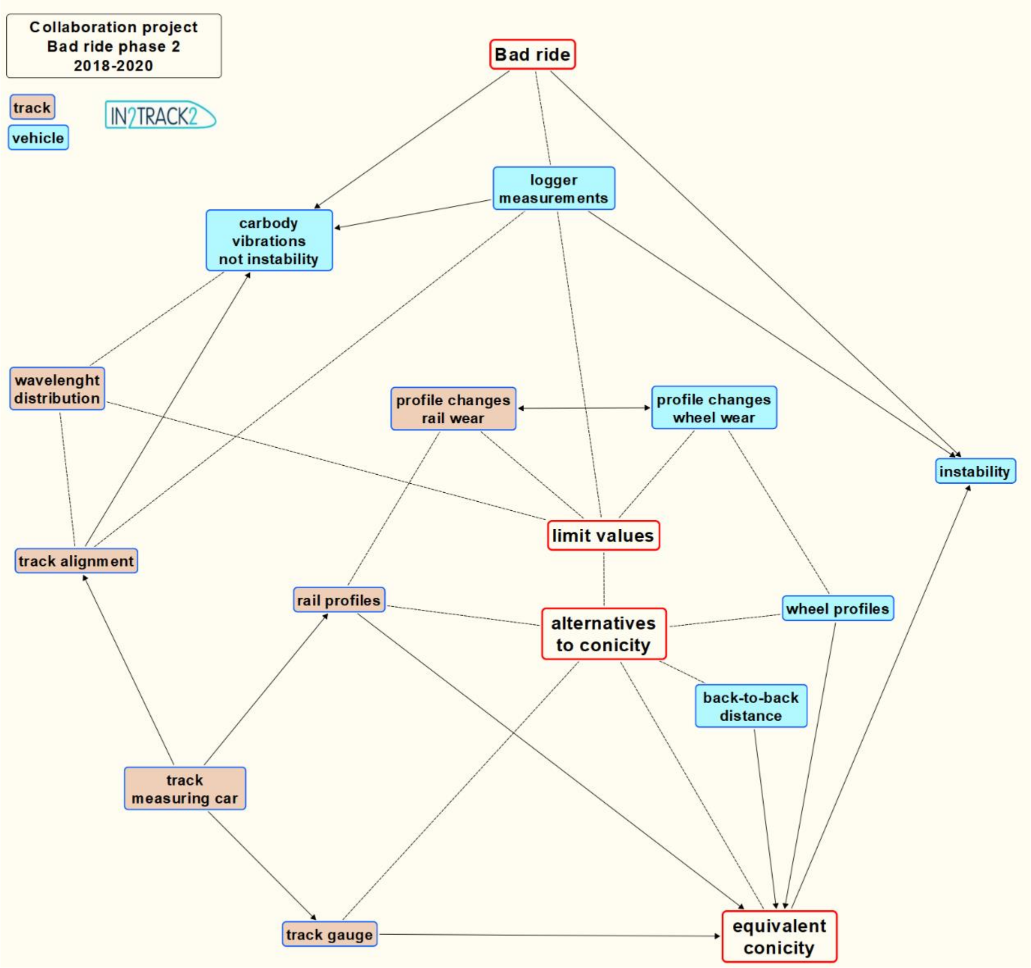
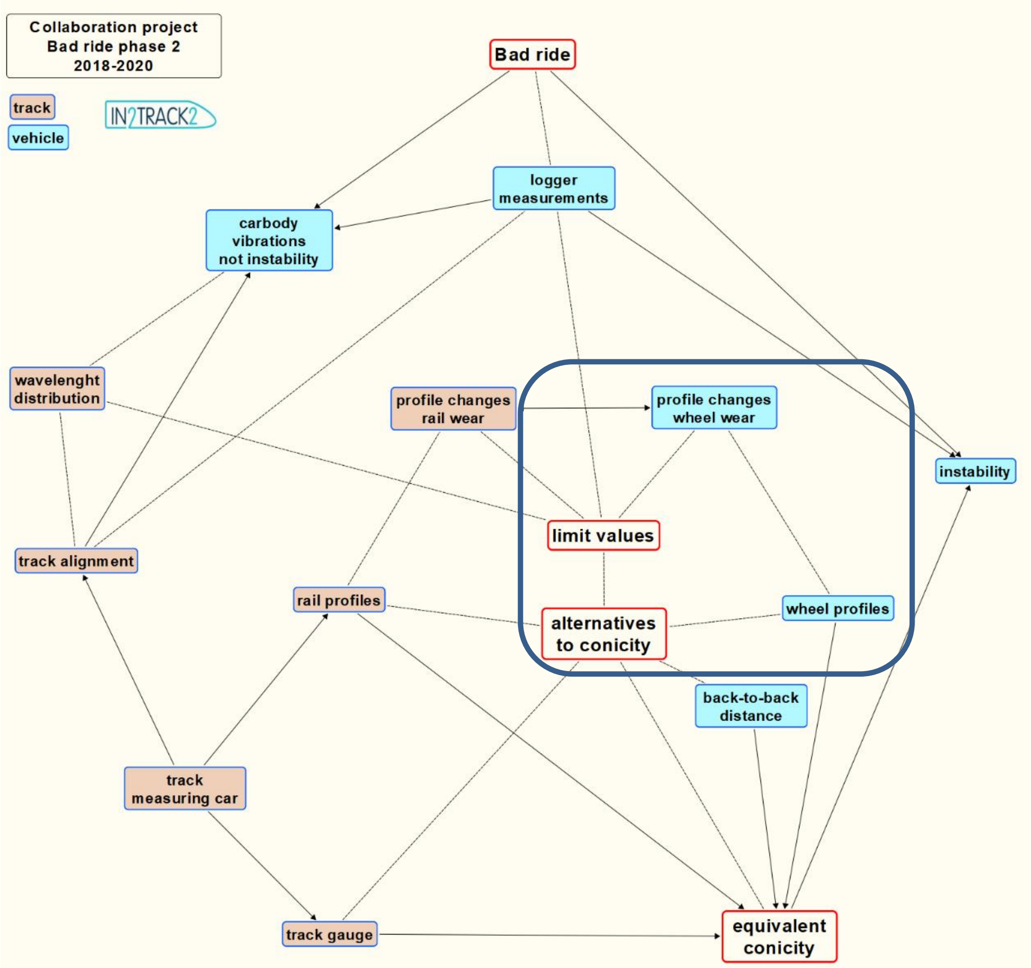


This work is part of a collaboration project between infrastructure managers, operators and external partners in Sweden:

Workgroup: A systematic approach to improve passenger ride comfort

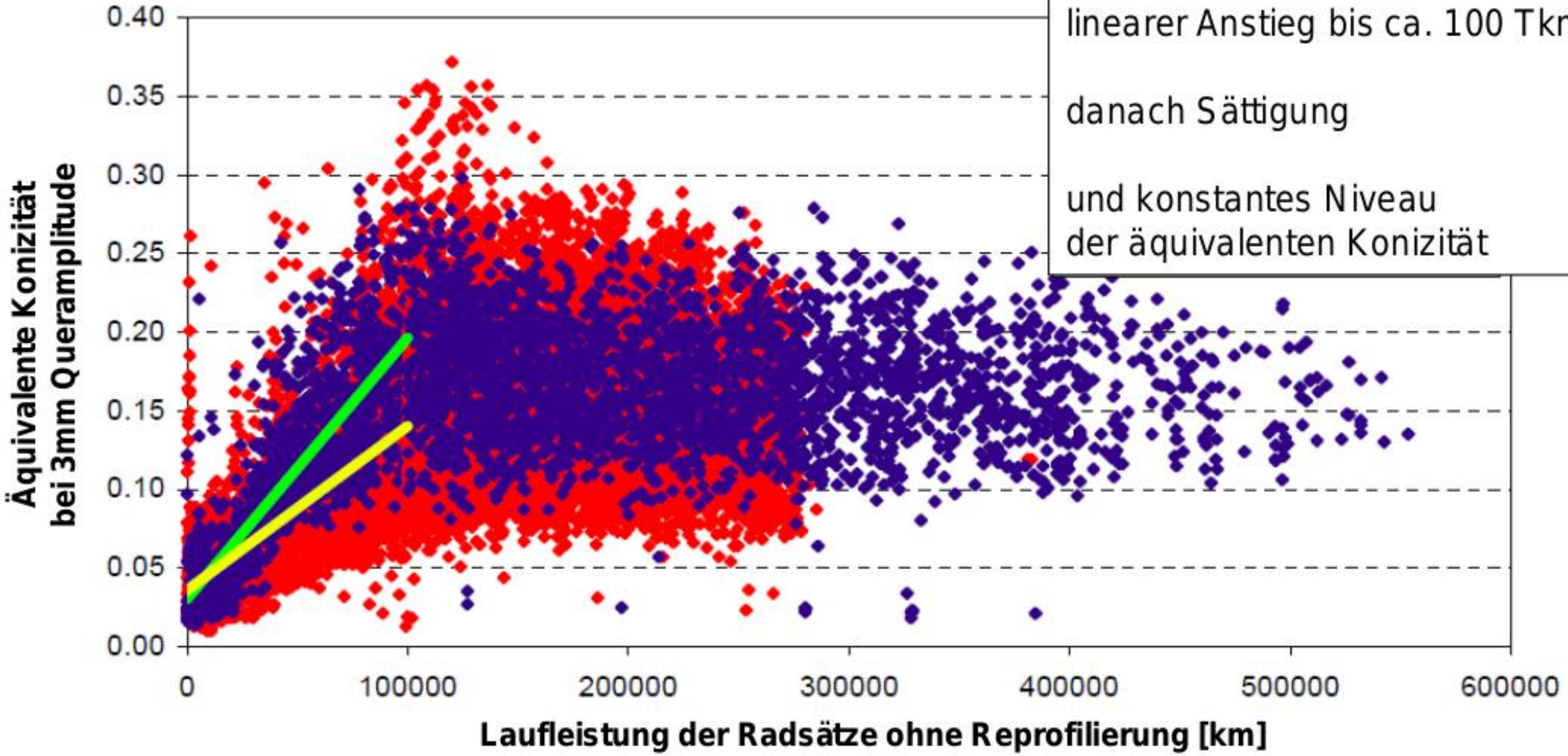
The project has received funding from EU initiatives In2Track2 and In2Track3.



In the current presentation today I will focus on the following:

- Why S1002 is no longer a typical worn-in wheel profile
- The available ”equivalent conicity budget” needs to be shared between infrastructure manager and train operator – how?

Veränderungen am Partner Rad – Situation bis ca. 2005

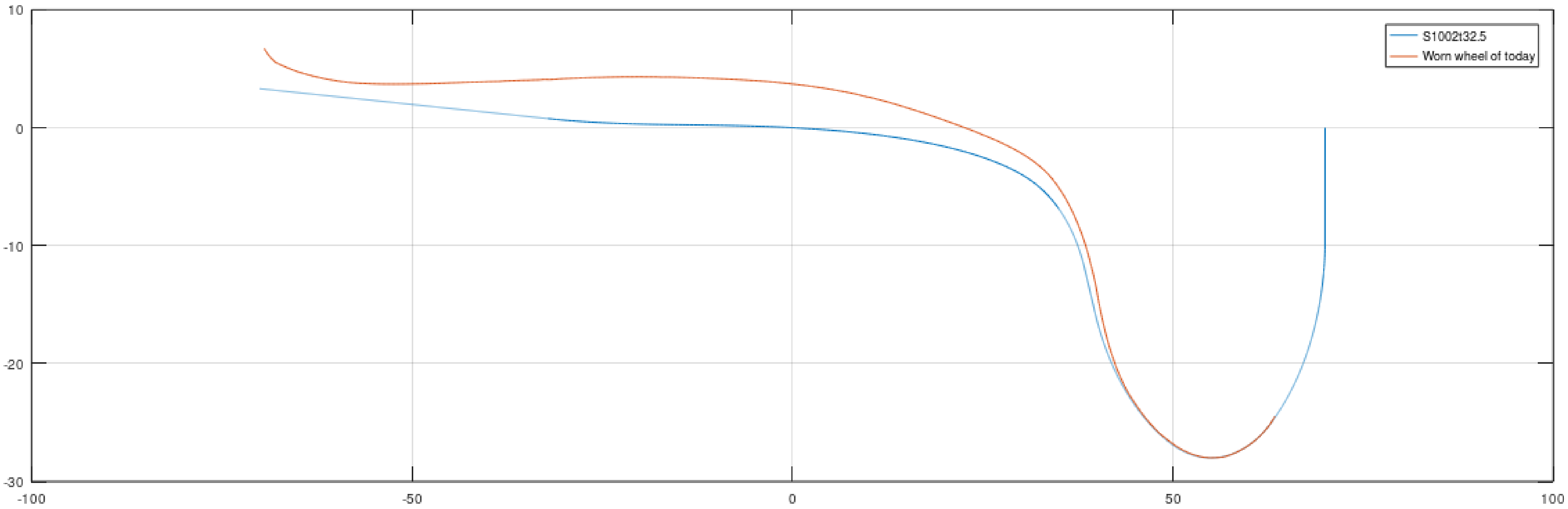


linearer Anstieg bis ca. 100 Tkm

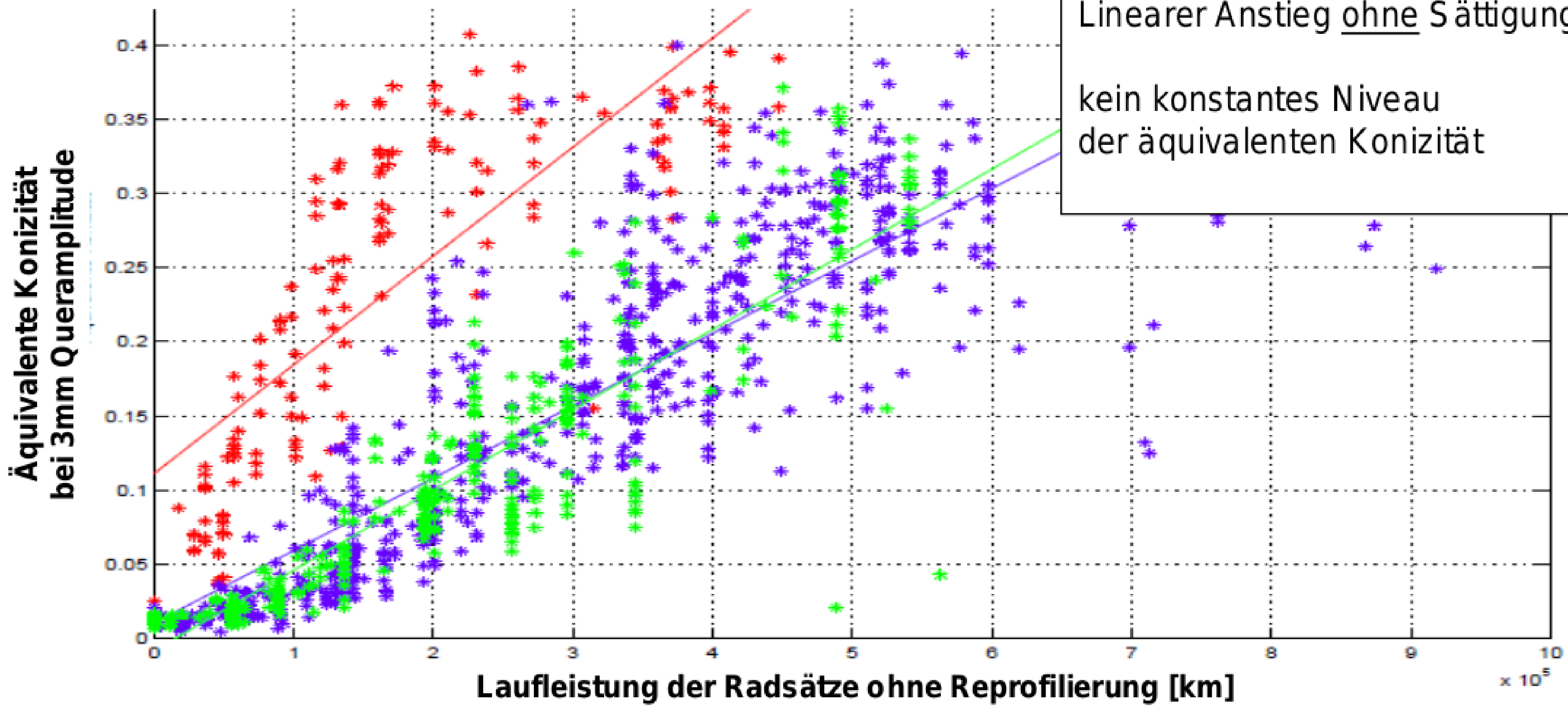
danach Sättigung

und konstantes Niveau
der äquivalenten Konizität

Comparison of S1002 with a worn wheel profile of today



Veränderungen am Partner Rad – Situation ab ca. 2014



Linearer Anstieg <u>ohne</u> Sättigung

kein konstantes Niveau
der äquivalenten Konizität

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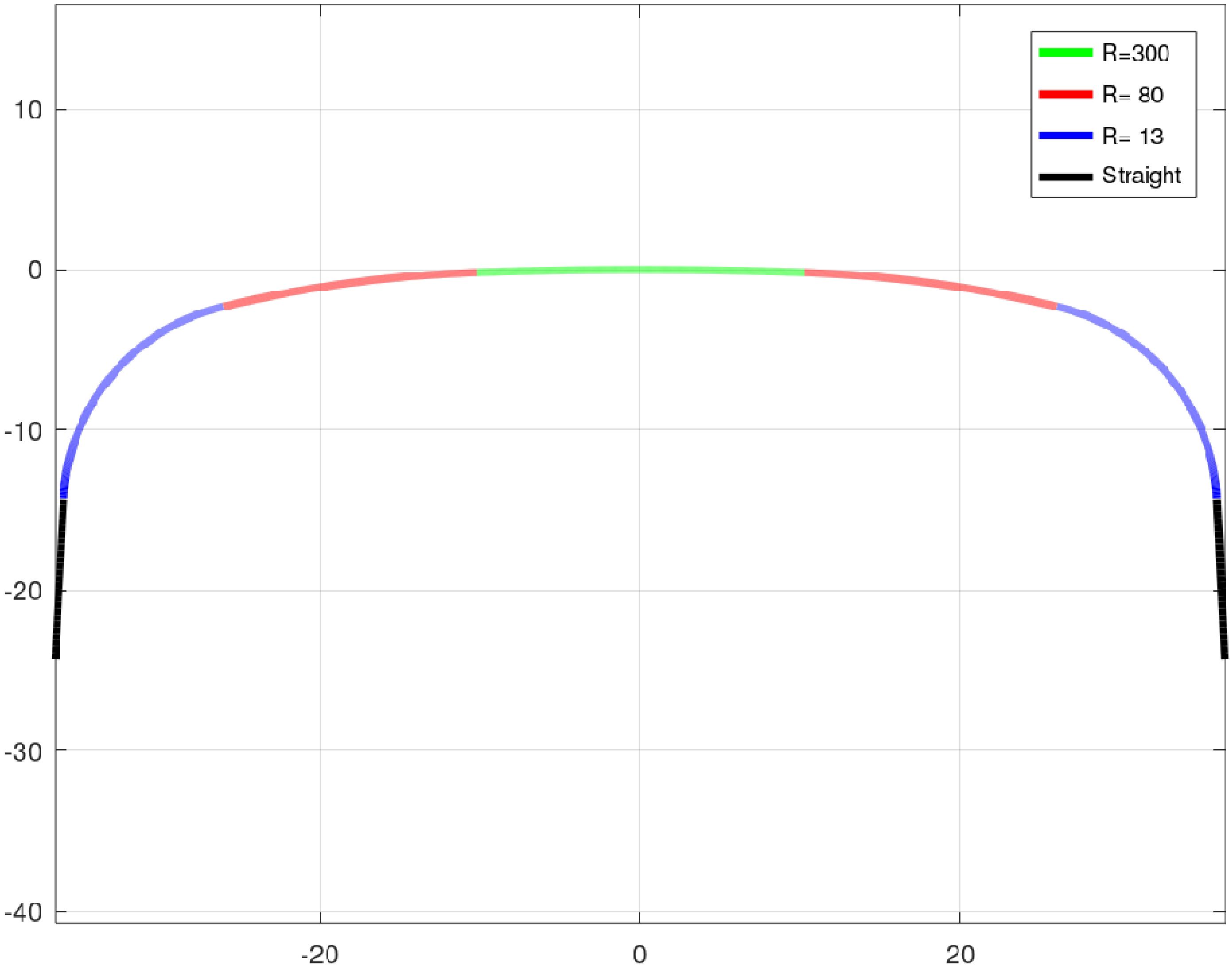
EN13674 60E1



IN2TRACK

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Current tolerances on wheel profiles are:

- Thickness of wheel ring
- Flange thickness
- Flange height
- Flange slope

but no requirements or tolerances on the shape of the tread

Current tolerances on rail profiles are:

- Wear on top of rail
- Wear on the sides of the rails measured at 14mm under top of rail
- Combined top of rail wear and side wear according to H= h + s/2

but there are no specific requirements or tolerances on the rail shoulders

- If a vehicle runs unstable, we have no guidance in any standard.

- Vägledning för tillämpning av TSD Lok och passagerarfordon LOC&PAS (ERA/GUI/07-2011/INT) says:
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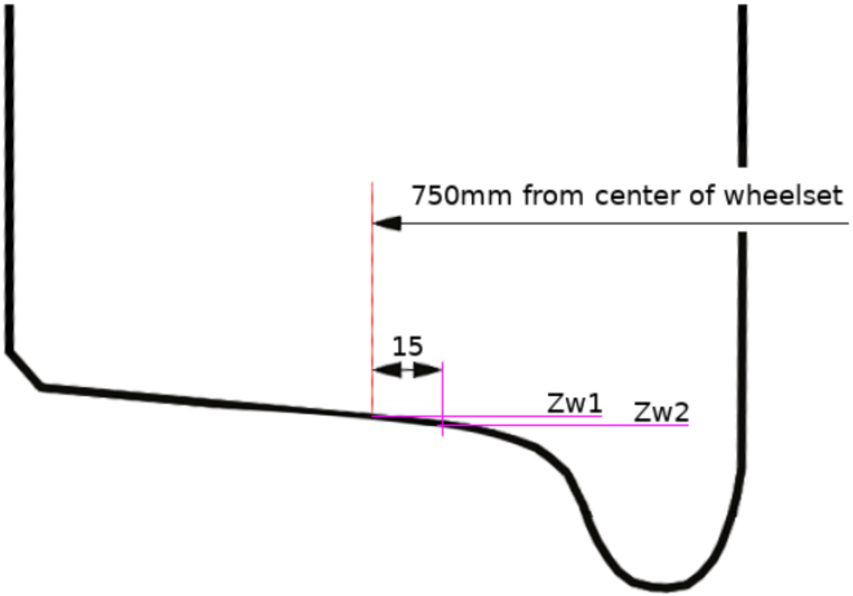
How can the ”equivalent conicity budget” be shared between infrastructure manager and train operator?

GIP
Gradient Index Profile

`GIPw_L=`	Gradient Index Profile	Wheel	Left
`GIPw_R=`	Gradient Index Profile	Wheel	Right
`GIPr_L=`	Gradient Index Profile	Rail	Left
`GIPr_R=`	Gradient Index Profile	Rail	Right

GIP
Gradient Index Profile



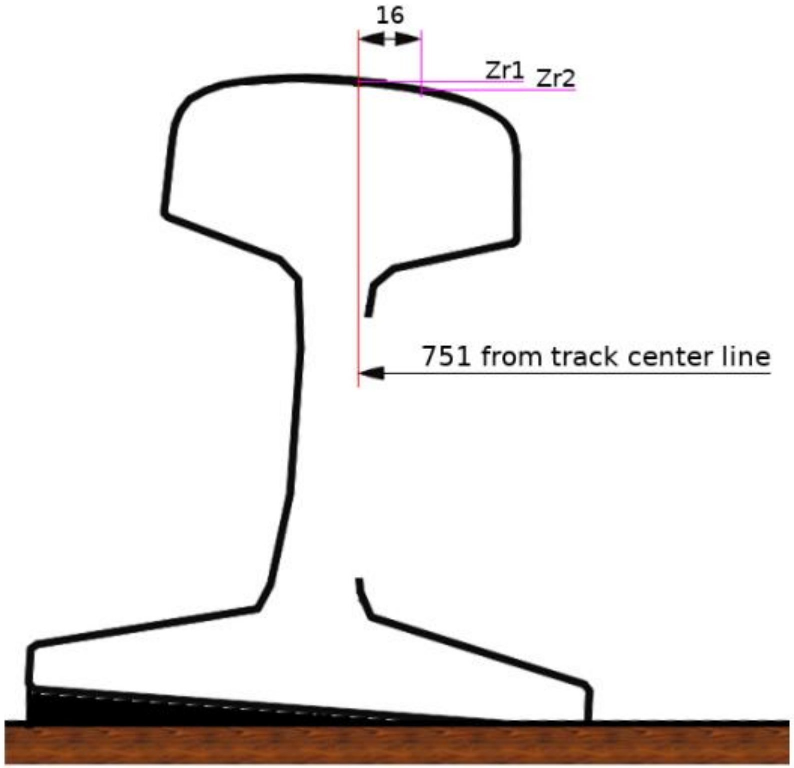
The gradient index for the wheel, GIPw:

$$GIPw = 100 \cdot \frac{Zw2 - Zw1}{15}$$

Note that the distances 750 mm and 15 mm differs from the calculation of GIPr. The differences are intentional, and are chosen to optimize the prediction power for equivalent conicity.

As for the rail profiles separate indexes are calculated for the left and right right side: GIPwL and GIPwR.

GIP
Gradient Index Profile



The gradient index for the rail, GIPr:

$$GIPr = 100 \cdot \frac{Zr2 - Zr1}{16}$$

Separate indexes are calculated for the left and right right profiles, and are denoted GIPrL and GIPrR, respectively.

GIP
Gradient Index Profile

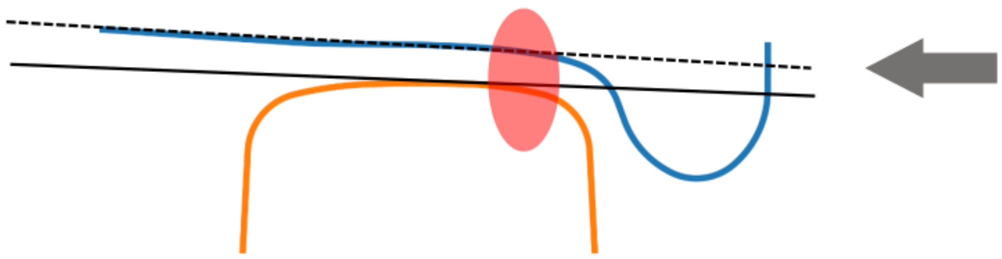
Single sided GIP:

$$\text{GIP\_\{LR\}} = \frac{GIPw - GIPr}{(GIPw + GIPr)/2}$$

For a wheelset:

$$GIP = \frac{\text{GIP\_L} + \text{GIP\_R}}{2}$$

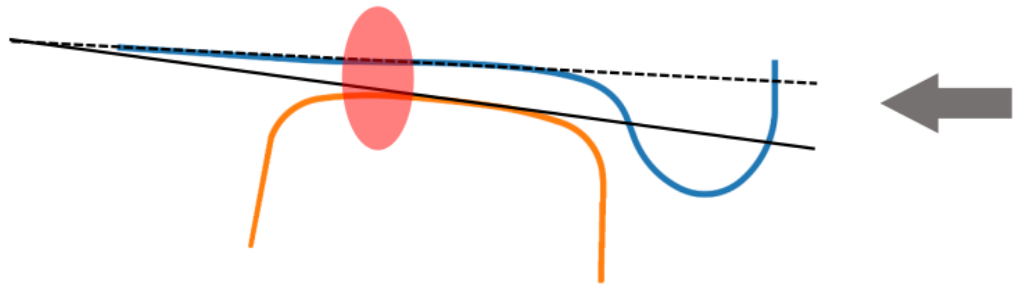
$$GIP = \frac{GIP_w - GIP_r}{(GIP_w + GIP_r)/2}$$



Here GIPw, the gradient of the wheel, is larger than GIPr, the gradient of the rail. Remember that the positive direction is downwards!

Thus in this case is GIP>0.

High conicity is associated with positive GIP values.

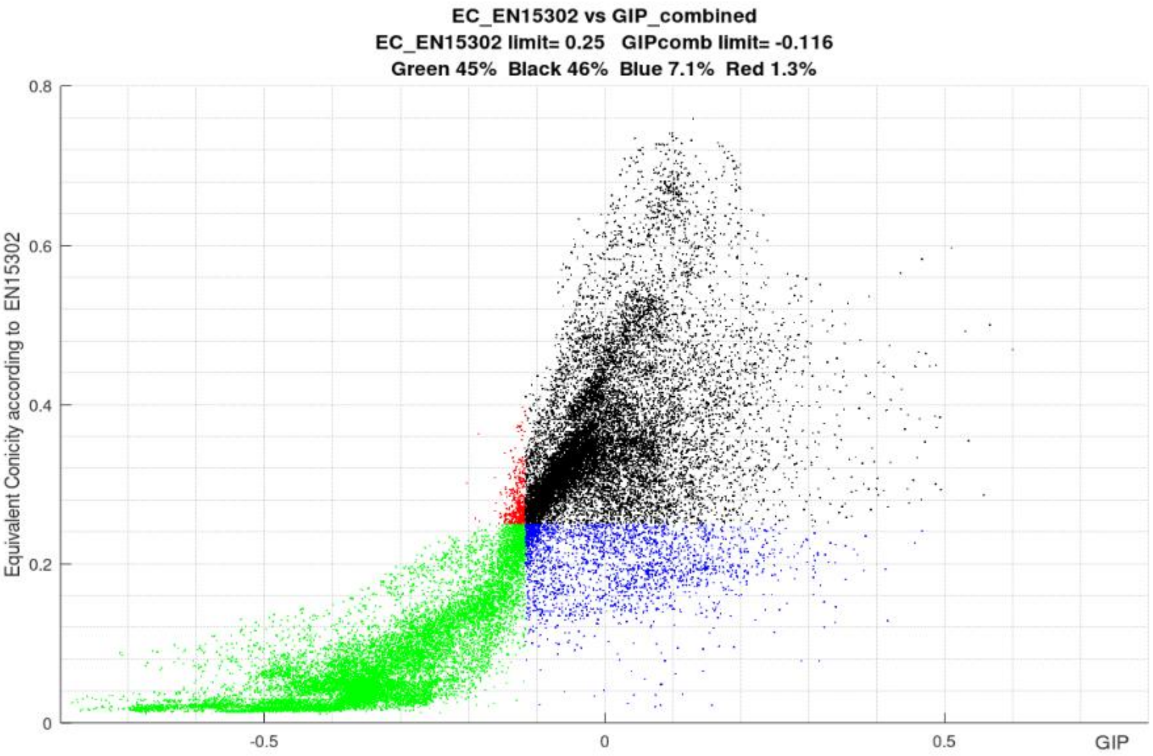


Here, on the other hand, is GIPr larger than GIPw. (remember, positive direction downwards)

Thus in this case is GIP<0.

Low conicity is associated with negative GIP values.

How well does GIP predict equivalent conicity?



Given a limit of conicity of 0.25 and limit of GIP of -0.116 the example shows:

- Green: 45 %
  GIP correctly predicts low EC.
- Black: 46 %
  GIP correctly predicts high EC.
- Blue: 7.3 %
  Error: GIP indicates high EC, but true value is low.
- Red: 1.3%
  Error: GIP indicates low EC, but true value is high.

Summary:

- GIP is a simple way of estimating conicity
- GIP can be calculated separately for wheel and rail
- Wheelsets with high GIP-values can be sent to the workshop before the problem gets acute
- Rails with low GIP-values can be reprofiled before the problem gets acute

Further work:

- Try to mitigate the problem that make wheels wears into a shape that leads to high conicities
- Finding limit values to GIPw and GIPr

Gradient Index Profile, a novel idea for predicting equivalent conicity

Ingemar Persson[1] and Lars-Ove Jönsson[2]

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Abstract. A novel idea for predicting the equivalent conicity is presented, based on the inclinations of the wheel thread at the running circle and the rail profile at top-of-rail.

Both the shape of the wheel profiles and the shape of the rail profiles can be acceptable in today's standards, but together the wheel/rail profile combination can lead to an unacceptable high value of the equivalent conicity, which can make the vehicle unstable. By introducing two gradient indices, one for the wheel and one for the rail, it is possible to separate the equivalent conicity into two parts, which also make it possible to put limit values on wheel and rail profiles separately. The indices are combined into a joint index, GIP. The new GIP index is compared to the equivalent conicity for a large number of worn rail and wheel profiles, and show promising results.

Keywords: equivalent conicity, instability, wheel-rail contact, wheel profile, rail profile, Gradient Index, Gradient Index Profile, GIP, GIPw, GIPr

The Gradient Index Profile was presented at IAVSD 2022, and a paper will be published in the proceedings by Springer:

Advances in Dynamics of Vehicles on Roads and Tracks II

Thank you for your attention