FreightSimSilent Calculation Model

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1. Introduction

FreightSimSilent was created to facilitate the retrofitting of freight trains with quieter braking systems and enables users to analyse retrofitting scenarios. Calculations are aimed at evaluating costs incurred by the operator and the reduction of noise emissions.

FreightSimSilent comprises two parts:

An Excel workbook that is used as the calculation module and an Access application that is used to save the various retrofitting scenarios.
This document describes the way the Excel calculation module works; it does not address the Access application.

1.1. Target group of the Excel calculation module documentation

This documentation provides an explanation of the calculation model that is used by FreightSimSilent.
Basic familiarity with the application's content and functionality is assumed.
Information on how to use FreightSimSilent's Access interface can be found in "FreightSimSilent Quick Reference Guide".

1.2. Formatting conventions

Bold, cursive text indicates cells or cell ranges in the Excel application. Values are often given as vectors for the fixed calculation period of 20 years.
Example: ***N_LL_A(j)*** stands for the number of new vehicles with LL brake blocks that are purchased each year in the years 1-20.

Text contained in square brackets, for example ***[Calculation!co_ci_r]***, indicates named ranges in Excel. This example refers to the cells AM5:AM24 in the "Calculation" worksheet.

Please note:
- You can select named ranges in Excel using F5.
- The appendix contains a list of named ranges and what they stand for.

<u>Underlined text</u> indicates routines in Visual Basic for Applications code, hereafter referred to as VBA code.

2. Excel workbooks

There are two Excel workbooks used by the Access application FreightSimSilent. They are listed in the Access application on the first tab, named "Control Factors."
A file called "Excel file for input" in the Access application serves as the calculation module. This file is opened in write-protected mode in the Access application.
A file called "Excel file for output" in the Access application is created by clicking on the "Calculate" button. This file can be used by experienced users to enter and manipulate scenario values more quickly in Excel and to analyse errors.

The calculation module is implemented for the most part in VBA. A small part of the calculations is based on Excel formulas located in the "Calculation" worksheet in the cell range ***[Calculation!A1:BA26]***. Both parts are needed to identify break-even points, whose calculation also requires Excel's Solver Add-in.

Please note:

- Further information on embedding the Excel Solver can be found in the document titled "Embedding Solver."

2.1. Description of individual worksheets

2.1.1. "Introduction" worksheet

The "Introduction" worksheet contains a brief introduction to the calculation module. Calculations are performed by clicking on the "Calculate" button.

2.1.2. "Input" worksheet

The "Input" worksheet contains all the input fields required to perform a calculation. They are grouped in tables according to subject:

- **Table 1** contains 37 technical and financial parameters for the current retrofitting scenario.
- **Tables 2a, 2b and 2c** contain vehicle numbers for individual years. Blue-coloured cells are input fields; values in the yellow-coloured cells are calculated when the button "Refresh vehicle numbers" is clicked. If the user wants **Table 2b** to contain the same values for each of the 20 years, the input process can be automated by clicking the "Transfer" button.
  Table 2c shows the waiting period in years after which retrofitted, funded vehicles receive noise-related track access discounts.
  Table 2d contains track access discounts and surcharges (dependent on noise emissions). It is also possible to enter direct funding of vehicle retrofitting for every year.
- **Table 3** contains the control factors for the calculation. In particular, the following can be entered:
  - Type of brake block replacement
  - Number of axles (***nox_ax***) and brake blocks per wheel (***bb_con***)
  - Parameter used to calculate the break-even point and run parameter

2.1.3. "Calculation" worksheet

The "Calculation" worksheet is used exclusively to determine the break-even points. These break-even points can then be displayed in tables and diagrams.

2.1.4. Additional worksheets: "Output" and "Noise emission"

The "Output" worksheet contains the results of the costs calculation. Costs are calculated using a routine in the VBA code called "Berechnung_fuer_aktuellen_parametersatz."

The results incorporate changes in vehicle fleet size as well as development in costs over time. If the calculation was performed using run parameters, results are shown for every parameter value.
Results are displayed in tables and diagrams.

The "Noise emission" worksheet displays the number of vehicles from the "Input" worksheet and noise emissions in clearly organized diagrams and tables.

3. Types of calculation

The Excel application supports five different types of calculation:

1) Simple calculation

The application calculates, for years 1 – 20, the difference in costs between the current retrofitting scenario and the status quo (i.e. the vehicles retain their CI brake blocks).
In addition, the change in noise emissions is calculated.

2) Calculation with a run parameter

In this calculation, one of parameters 1 – 37 in Table 1 of the "Input" worksheet is selected. Values contained in the "Run parameter value" columns are then inserted successively and the difference in costs between the current retrofitting scenarios and the status quo is calculated for years 1 – 20.
In addition, the change in noise emissions is calculated.

3) Calculation of the break-even point

One of parameters 1 – 37 from Table 1 is selected for use as a variable parameter. This parameter is then varied by Excel Solver with the aim of creating a retrofitting scenario that is cost-neutral for the operator.

Please note:

- It is not possible to determine a break-even point for all combinations of values.
- The Excel Solver calculation is not implemented for all 37 parameters.

4) Calculation with a run parameter and determination of the break-even point

This type of calculation combines (2) and (3). The calculation described in (3) is performed for every value of the run parameter.

5) Brake block replacement methods

K or LL brake blocks can be replaced stochastically or periodically. In the stochastic process, brake block replacement is spread out over the service life period, i.e. equal numbers of brake blocks are replaced gradually over time until they have all been replaced when the end of service life is reached. Periodic means that the brake blocks are replaced all at once in the year in which service life expires.
The periodic (or all-at-once) method is more cost-effective than the stochastic (or gradual) method. It cannot be implemented in practice, however, when a large number of new vehicles is purchased at once. Thus the default setting is "stochastic."
The replacement of CI brake blocks and of wheelsets is always calculated based on the stochastic method.

3.1. Cost factors

The following costs, and any changes in them, are factored into the calculation:

- Retrofitting costs for CI vehicles and external funding of retrofitting
- Replacement of brake blocks due to wear
- Reprofiling and replacement of wheelsets
- Noise-related track access discounts and surcharges

4. Vehicle fleet

4.1. Vehicle numbers

The basis of all calculations is the number of same-type vehicles equipped with CI, LL and K brake blocks. There is no difference in the way vehicles with K and LL brake blocks are handled in the calculations; the same formulas are used for both vehicles.
The calculation period is fixed at 20 years. It cannot be extended.
It is possible to shorten this period by setting the number of vehicles to 0 after a certain year.

The vehicle fleet is described using the following parameters:

Formula variables	Excel variables	Description
$TN_{CI}(0)$, $TN_{LL}(0)$, $TN_K(0)$	***TN_CI_Start***, ***TN_LL_Start***, ***TN_K_Start***	Number of vehicles with CI, LL and K brake blocks in Year 0 of the calculation period
$SC_{CI}(j)$, $SC_{LL}(j)$, $SC_K(j)$	***SC_CI_A(j)***, ***SC_LL_A(j)***, ***SC_K_A(j)***	Number of vehicles with CI, LL and K brake blocks that were scrapped in Year j
$N_{LL}(j)$, $N_K(j)$	***N_LL_A(j)***, ***N_K_A(j)***	Number of new vehicles with LL and K brake blocks that were purchased in Year j
$RF_{LL}(j)$, $RF_K(j)$	***RF_LL_A(j)***, ***RF_K_A(j)***	Number of vehicles retrofitted with LL and K brake blocks in Year j

Vehicles numbers for years 1 – 20 are calculated based on the values of the above parameters. Because of different funding modalities for vehicles equipped with K or LL brake blocks, a distinction is made between retrofitted and newly purchased vehicles.

To prevent negative numbers appearing in calculation results, the calculation is stopped when there are 0 vehicles. In this case, only as many vehicles as actually exist are retrofitted or scrapped.

Calculations for determining vehicle numbers for every year are performed in the following sequence:

- Scrapping of LL vehicles with the following priority: scrapping of retrofitted LL vehicles according to age, followed by scrapping of LL vehicles purchased new.
- Scrapping of K vehicles with the following priority: scrapping of retrofitted K vehicles according to age, followed by scrapping of K vehicles purchased new.
- Retrofitting of CI vehicles with K brake blocks
- Retrofitting of CI vehicles with LL brake blocks

- Scrapping of CI vehicles
- Purchase of new K and LL vehicles

The following vehicle numbers are calculated:

Formula variables	Excel variables	Description
$tn_v(j)$	***tn_v_y(j)***	Total number of vehicles in Year j
$tn_{ci}(j)$, $tn_{ll}(j)$, $tn_k(j)$	***tn_ci_y(j)***, ***tn_ll_y(j)***, ***tn_k_y(j)***	Total number of vehicles with CI/LL/K brake blocks in Year j
$nr_{ll}(j)$, $nr_k(j)$	***nr_ll_y(i)***, ***nr_k_y(j)***	Number of vehicles actually retrofitted with LL or K brake blocks in Year j
$tn\_nv_{ll}(j)$, $tn\_nv_k(j)$	***tn_nv_ll(y)***, ***tn_nv_k(y)***	Total number of new vehicles with LL or K brake blocks in Year j
$tpa_{ll}(j)$, $tpa_k(j)$	***tpa_ll_y(j)***, ***tpa_k_y(j)***	Number of LL/K vehicles that receive noise-related track access discounts (see Section 6.3.8) in Year j

Please note:

- The calculation of vehicle numbers is implemented entirely in VBA using the routines "FahrzeugZahlen_aktualiseren" in the "Fahrzeugzahlen" module and in the routines "Fahrzeugspalte_einlesen_und_kopieren" and "Fahrzeugspalte_einlesen" in the "Berechnung" module.

4.1.1. Brake blocks and wheelsets per vehicle

The number of wheelsets (an axle with 2 wheels) is determined by the parameter ***no_ax***. The number of brake blocks per wheel (not per wheelset!) is determined by the parameter ***bb_con***.

Thus the formula for calculating the number of brake blocks per vehicle (tn_{bb}^{v}) is: [***Calculation!tn_bb_v***]:

$$tn_{bb}^{v} = 2 \cdot no\_ax \cdot bb\_con$$

$$TN\_V(j)$$

5. Calculation of noise emissions

Noise emissions, measured in dBA at a distance of 7.5 meters, are calculated for every year using the following formula:

$$LEMI(j) = 10 \cdot \log 10 \frac{TN_{CI}(j) \cdot 10^{\frac{1}{10}LEQU_{CI}} + TN_{LL}(j) \cdot 10^{\frac{1}{10}LEQU_{LL}} + TN_K(j) \cdot 10^{\frac{1}{10}LEQU_K}}{TN\_V(j)}$$

LEMI (j)	***LEMI (j)***	Noise emissions, measured in *dBA* at a distance of 7.5 m in Year j
$TN_{CI}(j)$, $TN_{LL}(j)$, $TN_K(j)$	***TN_CI_A(j)***, ***TN_LL_A(j)***, ***TN_K_A(j)***	Total number of vehicles with CI, LL and K brake blocks in Year j (There is no distinction made between retrofitted and new K/LL vehicles.)
$LEQU_{CI}$, $LEQU_{LL}$, $LEQU_K$	***LEQU_CI***, ***LEQU_LL,*** ***LEQU_K***	Noise equivalent for a vehicle with CI, LL or K brake blocks, measured in *dBA* at a distance of 7.5 m
$TN\_V(j)$	***TN_V(j)***	Total number of vehicles in Year j

6. Calculation of costs

In addition to changes in noise emissions due to new brake blocks, the application calculates increases or reductions in cost that result for operators participating in the retrofitting program.

6.1. Yearly cost increases / reductions

For every year, the difference $\Delta_{v\_gg(j)}$ is calculated between the cost of the retrofitting scenario $co_r(j)$ and the cost of maintaining the status quo with continued use of CI brake blocks $co_{stqo}(j)$.

Breakdown of total costs for the retrofitting scenario $co_r(j)$:

- Breakdown of total costs for vehicles with CI brake blocks $co_{ci}(j)$:
  - Cost of regularly replaced brake blocks (see Sections 6.3.1 to 6.3.5)
  - Cost of reprofiling and replacement of wheelsets (see Section 6.3.6)
  - Noise-related track access surcharges (see Section 6.3.8)
- Breakdown of total costs for vehicles with LL brake blocks $co_{LL}(j)$:
  - Cost of retrofitting CI vehicles with LL brake blocks (see Section 6.3.7)
  - Cost of regularly replaced brake blocks (see Sections 6.3.1 to 6.3.5)
  - Cost of reprofiling wheelsets (see Section 6.3.6)
  - Noise-related track access discounts or surcharges (see Section 6.3.8)
  - Direct funding for retrofitting CI vehicles with LL brake blocks (see Section 6.3.7)
- Breakdown of total costs for vehicles with K brake blocks $co_K(j)$:
  - Cost of retrofitting CI vehicles wit K brake blocks (see Section 6.3.7)
  - Cost of regularly replaced brake blocks (see Sections 6.3.1 to 6.3.5)

  - Cost of reprofiling wheelsets (see Section 6.3.6)
  - Noise-related track access discounts or surcharges (see Section 6.3.8)
  - Direct funding for retrofitting CI vehicles with K brake blocks (see Section 6.3.7)

The cost of maintaining the status quo $co_{stqo}(j)$ is broken down as follows:

- Cost of regularly replaced brake blocks (see Sections 6.3.1 to 6.3.5)
- Cost of reprofiling wheelsets (see Section 6.3.6)
- Noise-related track access surcharges (see Section 6.3.8)

$\Delta_{v\_gg(j)}$	***delta_v_gg(j)***	Difference in cost between retrofitting scenario and status quo in Year j ***[Calculation!AT5:AT24]***
$co_r(j)$	***t_co_r(j)***	Cost of retrofitting scenario in Year j ***[Calculation!AS5:AS24]***
$co_{stqo(j)}$	***co_ci_stqo(j)***	Cost of status quo in Year j ***[Calculation!AN5:AN24]***
$co_{ci}(j)$, $co_{LL}(j)$, $co_K(j)$	***co_ci_r(j), co_v_r(j), co_k_r(j)***	Costs of retrofitting CI, LL and K vehicles in Year j ***[Calculation!AM5:AM24], [Calculation!AO5:AO24], [Calculation!AQ5:AQ24]***

6.2. Calculation of net present value

The difference in costs (the cost of the retrofitting scenario minus the cost of maintaining the status quo) is calculated in "net present values" for each year.
Net present value is defined as the net cash flow of an investment based on a discount rate. It measures, in present-value terms, the present-day value of future excess or shortfall of cash flows (in this case the difference in cost per year between the retrofitting scenario and the continued use of CI brake blocks).
The net present value serves the operator as a measure of whether retrofitting with LL or K brake blocks is financially advantageous, or at least cost-neutral.
A total of 20 net present values $npv_{\Delta}(j)$ are calculated at an internal rate of return (*Ri*) for the calculation period.

The calculation is performed using the following formula (definition of net present value):

$$npv_{\Delta}(j) = \sum_{i=1}^{j} \frac{\Delta_{v\_gg}(i)}{(1+Ri)^{i}}$$

Retrofitting scenarios are evaluated with regard to profitability and noise control on the basis of net present values $npv_{\Delta}(j)$ and noise emission values $LEMI(j)$.

$npv_{\Delta}(j)$	***npv_delta(j)***	Net present value of the difference in cost for Years 1 to j ***[Calculation!AW5:AW24]***
Ri	***RI***	Internal rate of return

6.3. Detailed description of individual costs

The following section gives an overview of how the individual costs listed in Section 6.1 are calculated.

6.3.1. Costs of regular replacement of brake blocks

These are the costs incurred by the regular, wear-related replacement of brake blocks. Brake block replacements that are made due to the retrofitting of braking systems are not included here.

6.3.2. Service life (with regard to brake block replacement)

Service life is a measurement used in reference to the wear-related replacement of brake blocks. Service life defines the time (in years) that it takes for a brake block to be worn down from its initial thickness when fitted to the lowest acceptable thickness, assuming that the vehicle is operated under average conditions, i.e. that it is driven the average number of kilometres per year. The service life of a brake block varies substantially among the three materials under consideration, as wear per kilometre and lowest acceptable thickness depend in part on the material.

Service life of the three materials is thus calculated as follows:

Service life of CI brake blocks in years: $ny_{ci} = 100{,}000 \frac{SI_{CI} - SL_{CI}}{RW_{CI}} AM_{V}$

Service life of LL brake blocks in years: $ny_{LL} = 100{,}000 \frac{SI_{LL} - SL_{LL}}{RW_{LL}} AM_{V}$

Service life of K brake blocks in years: $ny_{K} = 100{,}000 \frac{SI_{K} - SL_{K}}{RW_{K}} AM_{V}$

SI_{ci}, SI_{LL} and SI_K indicate thickness of the brake block when fitted for the respective types; SL_{ci}, SL_{LL} and SL_K indicate minimal thickness (measured in mm).
AM_V stands for the average mileage of a vehicle (measured in kilometres per year). RW_{ci}, RW_{LL} and RW_K stand for the wear of a brake block (measured in millimetres per 100,000 kilometres of use).

ny_{ci}, ny_{LL}, ny_K	***NY_GG_BB_Y***, ***NY_LL_BB_Y***, ***NY_K_BB_Y***	Service life of CI, LL, and K brake blocks
SI_{ci}, SI_{LL}, SI_K	***SI_GG***, ***SI_LL***,***SI_K***	Thickness of brake blocks when fitted [mm]
SL_{ci}, SL_{LL}, SL_K	***SL_GG***, ***SL_LL***,***SL_K***	Minimal thickness [mm]
RW_{ci}, RW_{LL}, RW_K	***RW_CI***, ***RW_LL***, ***RW_K***	Wear in $\left[\frac{mm}{100{,}000km}\right]$
AM_V	***AM_V***	Average annual mileage of a vehicle [km]

6.3.3. Cost of a single brake block

The cost (in Euros) of a single brake block in the first year are calculated using the parameters CP_{CI}^0, CP_{LL}^0 and CP_K^0.
As CI brake blocks have been in use for several years, there is not expected to be a significant drop in their unit price. This is not the case with composite brake blocks; it is expected that prices will drop due to mass production being introduced as a result of the large numbers of operators expected to switch to quieter composite brake blocks. To account for this in the calculations, the parameters CHL_{LL} and CHL_K can be used to specify a "half-life" for the price of brake blocks, as measured in years.

Thus the price of a brake block in Year j is calculated as follows:

CI brake blocks: $CP_{CI}(j) = CP_{CI}^0$

LL brake blocks: $$CP_{LL}(j) = \begin{cases} (j <= I_{LL}) \vee (CHL_{LL} = 0): & CP_{LL}^0 \\ (j > I_{LL}) \wedge (CHL_{LL} \neq 0): & CP_{LL} \cdot e^{-\log(2)\frac{j-I_{LL}}{CHL_{LL}}} \end{cases}$$

K brake blocks: $$CP_K(j) = \begin{cases} (j = 1) \vee (CHL_K = 0): & CP_K^0 \\ (j > 1) \wedge (CHL_K \neq 0): & CP_K^0 \cdot e^{-\log(2)\frac{j-1}{CHL_K}} \end{cases}$$

Please note:
- If CHL_{LL} or CHL_K are set to zero, there will be no drop in their unit price.
- In the case of LL brake blocks, the reduced price is not factored into the calculation until the year in which retrofitting is started.

CP_{CI}^0, CP_{LL}^0, CP_K^0	***CP_CI***, ***CP_LL***, ***CP_K***	Initial cost of CI, LL, or K brake block. Parameters 5 to 7 in Table 1 of the "Input"

		worksheet
$CP_{CI}(j)$, $CP_{LL}(j)$, $CP_K(j)$	***CP_CI_Y(j)***, ***CP_LL_Y(j)***, ***CP_K_Y(j)***	Cost of CI, LL, or K brake block in Year j. Ranges [***P5:P24***], [***Q5:Q24***] and [***R5:R24***] in the "Calculation" worksheet
CHL_{LL}, CHL_K	***CHL_LL***, ***CHL_K***	Half-life for the price of an LL or K brake block. Parameters 8 and 9 in the "Input" worksheet
I_{LL}	***Y_LL***	Year in which retrofitting with LL brake blocks begins. Parameter 19 in the "Input" worksheet

6.3.4. Cost of replacing all brake blocks on a vehicle

It is assumed that a vehicle's brake blocks are always all replaced at the same time.

The following costs are incurred per vehicle:

- Labour costs for the brake block replacement: CL_{CI}, CL_{LL}, CL_K
- Cost of downtime during brake block replacement: *CU*
- Other costs: CO_{CI}, CO_{LL} and CO_K

The following costs are incurred for every brake block:

- Purchase price of brake block in Year j: $CP_{CI}(j)$, $CP_{LL}(j)$, $CP_K(j)$
- Disposal costs for the old brake block: CD_{CI}, CD_{LL} and CD_K

Thus the costs for replacing all of a vehicle's brake blocks in Year j are as follows:

For CI vehicles:

$$co_{ci}^{bex}(j) = CL_{CI} + tn_{bb}^{v}(CP_{CI}(j) + CD_{CI}) + CU + CO_{CI}$$

For LL vehicles:

$$co_{ll}^{bex}(j) = CL_{LL} + tn_{bb}^{v}(CP_{LL}(j) + CD_{LL}) + CU + CO_{LL}$$

For K vehicles:

$$co_{k}^{bex}(j) = CL_{K} + tn_{bb}^{v}(CP_{K}(j) + CD_{K}) + CU + CO_{K}$$

CL_{CI}, CL_{LL}, CL_K	***CL_CI***, ***CL_LL***, ***CL_K***	Labour costs for replacing all of a vehicle's brake blocks (CI, LL or K brake blocks). Parameters 27 to 29 in Table 1 of the "Input" worksheet
CU	***CU***	Cost of downtime during brake block replacement. Parameter 4 in Table 1 of the "Input" worksheet
CO_{CI}, CO_{LL} and CO_K	***CO_CI***, ***CO_LL***, ***CO_K***	Other costs associated with replacing all of a vehicle's brake blocks (CI, LL or K

		brake blocks). Parameters 30 to 32 in Table 1 of the "Input" worksheet
CD_{CI} , CD_{LL} and CD_K	***CD_CI_Y***, ***CD_LL_Y***, ***CD_K_Y***	Disposal costs for a CI, LL or K brake block. Parameters 24 to 26 in Table 1 of the "Input" worksheet
$co_{CI}^{bex}(j)$, $co_{LL}^{bex}(j)$, $co_{k}^{bex}(j)$	***co_bex_ci(j)***, ***co_bex_ll(j)***, ***co_bex_k(j)***,	Total costs for replacing all of a vehicle's brake blocks (CI, LL or K brake blocks) in Year j. Ranges ***V5:V24***, ***X5:X25***, ***Z5:Z24*** in the "Calculation" worksheet

6.3.5. Brake block replacement models

As described above, the calculation uses two different models for the replacement of brake blocks on vehicles with LL or K blocks: the stochastic replacement of brake blocks and the periodic replacement of brake blocks once service life has expired. The replacement of CI brake blocks is always calculated based on the stochastic model.

In the **stochastic model**, brake block replacement is spread out over the service life period, i.e. equal numbers of brake blocks are replaced gradually over time until they have all been replaced when the end of service life is reached.
The age of the vehicles and the age of the brake blocks is not taken into consideration in this model.

Costs for the regular, stochastic replacement of brake blocks are calculated as follows for a given retrofitting scenario:

$$tco_{BEX,Stoch}^{R}(j) = tn_{CI}(j)\frac{co_{CI}^{bex}(j)}{ny_{CI}} + tn_{LL}(j)\frac{co_{LL}^{bex}(j)}{ny_{LL}} + tn_{K}(j)\frac{co_{K}^{bex}(j)}{ny_{K}}$$

The status quo (i.e. the continued use of CI brake blocks on all vehicles) is calculated as follows:

$$tco_{BEX}^{SQ}(j) = tn_{v}(j)\frac{co_{CI}^{bex}(j)}{ny_{CI}}$$

In the model "**periodic replacement of brake blocks upon expiration of service life**", the brake blocks of every vehicle with K or LL blocks are replaced all at once after their service life has expired.
The brake blocks' service life is rounded to whole years.
The calculation model is located in the routine " Berechnung_fuer_aktuellen_parametersatz" in Line 663 of the VBA code.

The total number of K or LL vehicles whose brake blocks have to be replaced in Year j is designated as $nex_{ll}^{bs}(j)$ or $nex_{K}^{bs}(j)$.

Costs for the regular, periodic replacement of brake blocks for a given retrofitting scenario are calculated as follows:

$$tco_{BEX,Per}^{SQ}(j) = tn_{CI}(j)\frac{co_{CI}^{bex}(j)}{ny_{CI}} + nex_{ll}^{bs}(j)\cdot co_{LL}^{bex}(j) + nex_{K}^{bs}(j)\cdot co_{K}^{bex}(j)$$

$nex_{ll}^{bs}(j)$	***nex_w_ll(j)***	Number of LL vehicles whose brake blocks are replaced in Year j, using the periodic method ***[Calculation!N5:N24]***
$nex_{K}^{bs}(j)$	***nex_w_k(j)***	Number of K vehicles whose brake blocks are replaced in Year j, using the periodic method ***[Calculation!O5:O24]***
$tco_{BEX,Stoch}^{R}(j)$		Cost of regular stochastic replacement of brake blocks in a given retrofitting scenario
$tco_{BEX,Per}^{R}(j)$		Cost of regular periodic replacement of brake blocks in a given retrofitting scenario
$tco_{BEX}^{SQ}(j)$		Cost of regular replacement of brake blocks when CI brake blocks continue to be used. Please note: the stochastic model is always used for the replacement of CI brake blocks.

6.3.6. Cost model for the reprofiling and replacement of wheelsets

Total costs factor in, among other things, the costs of reprofiling and replacing wheelsets. These costs vary depending on the type of brake block used, as there are significant variations in wear per kilometre.

The cost model for the reprofiling and replacement of wheelsets can be divided into three parts:

1) Basic costs (CL_{WS}): The operator maintains stocks of new or reprofiled wheelsets. These stocks create costs in the form of storage, maintenance, security (e.g. guards), etc. The operator also maintains facilities for the replacement and maintenance of wheelsets. These costs are summarised as "basic costs". In this calculation model, they are distributed equally across all vehicles regardless of mileage or number of axles.

2) Cost of wheelset replacement per vehicle (CB_{WS}): Labour costs, etc. can be entered here.

   Please note:
   If brake blocks and wheelsets are replaced at the same time, costs associated with the transportation of the vehicle to the maintenance facility and the corresponding downtime are not included here. These

costs are included among costs for the brake block replacement.

3) Costs for wheelset replacement per axle (CO_{WS}): Costs entered here include expenses for newly installed wheelsets, a percentage of labour costs, etc.

The service life of the wheelsets, which varies depending on the braking system, is represented in the model by the parameters WL_{CI}, WL_{LL} and WL_{K}. These parameters determine the number of kilometres driven, and when the wheelsets (with CI, LL or K brake blocks) are replaced or reprofiled.

The cost of wheelset replacement for a given retrofitting scenario is calculated using the following formula:

$$tco_{WS}^{R}(j) = (CB_{WS} + no\_ax \cdot CO_{WS}) \cdot \left(\frac{AM_V}{WL_{CI}} tn_{CI}(j) + \frac{AM_V}{WL_{LL}} tn_{LL}(j) + \frac{AM_V}{WL_K} tn_K(j) \right) + tn_V(j) \cdot CL_{WS}$$

The cost of wheelset replacement for the status quo is calculated using the following formula:

$$tco_{WS}^{SQ}(j) = (CB_{WS} + no\_ax \cdot CO_{WS}) \frac{AM_V}{WL_{CI}} tn_V(j) + tn_V(j) \cdot CL_{WS}$$

CL_{WS}	***CL_WS***	Basic cost of wheelset replacement. Parameter 33 in Table 1 of the "Input" worksheet
CB_{WS}	***CB_WS***	Cost of wheelset replacement per vehicle. Parameter 34 in Table 1 of the "Input" worksheet
CO_{WS}	***CO_WS***	Cost of wheelset replacement per axle. Parameter 35 in Table 1 of the "Input" worksheet
WL_{CI} , WL_{LL} , WL_{K}	***WL_CI***, ***WL_LL***, ***WL_K***	Distance [km] after which wheelsets must be replaced or reprofiled
LS_{V}	***LS_V***	Vehicle service life. Parameter 2 in Table 1 of the "Input" worksheet
$tco_{WS}^{R}(j)$		Cost of wheelset replacement in Year j of retrofitting scenario
$tco_{WS}^{SQ}(j)$		Costs of wheelset replacement in Year j if CI brake blocks continue to be used.

6.3.7. Retrofitting costs and direct funding

Retrofitting of CI vehicles with K or LL brake blocks entails high one-time costs. These costs are incurred in the year in which the retrofitting is performed (the "retrofitting year") and are designated as CR_{LL} or CR_{K}.
Potential direct funding is factored into the calculation in the retrofitting year. It is designated as $af_{LL}(j)$ or $af_{K}(j)$.

A complete new set of brake blocks is fitted as part of the retrofitting procedure; it is calculated separately from the actual retrofitting costs, however.

This results in the following formula for calculating retrofitting costs:

$$tco^{R}_{AF,CR}(j) = nr_{LL}(j)\cdot(CR_{LL} + af_{LL}(j) + tn^{bb}_{v}\cdot CP_{LL}(j)) + nr_{K}(j)\cdot(CR_{K} + af_{K}(j) + tn^{bb}_{v}\cdot CP_{K}(j))$$

Please note: Funding can be entered in three ways:
1) Using parameters 20, 21, 36 and 37 in Table 1 of the "Input" worksheet
2) For each year in Table 2d of the "Input" worksheet
3) For each year as the sum total of (1) and (2)

CR_{LL}, CR_{K}	***CR_LL, CR_K***	Cost of retrofitting a CI vehicle with LL or K brake blocks. Parameters 22 and 23 in Table 1 of the "Input" worksheet
$af_{LL}(j)$, $af_{K}(j)$	***af_ll_y(j), af_k_y(j)***	Funding for retrofitting a vehicle with LL or K brake blocks in Year j
$tco^{R}_{AF,CR}(j)$		The sum total of direct funding and cost of retrofitting in Year j

6.3.8. Noise-related track access charges

It is possible to factor a noise-related track access discount or surcharge into the total costs (see Section 6.1). The amount is entered for each year in €/km. The three brake block materials that are used are designated as $TP_{CI}(j)$, $TP_{LL}(j)$ and $TP_{K}(j)$.
Noise-related track access discounts and surcharges are another way of promoting low-noise freight trains (in addition to direct funding of retrofitting).
To prevent duplicate funding, i.e. vehicles receiving both direct funding and a track access discount, it is possible to define a waiting period.
During this period, a vehicle that receives direct funding does not qualify for a track access discount in the calculation. Thus the calculation model takes into account that duplicate funding may be prohibited by law in the future.
The waiting period after which vehicles whose retrofitting is directly funded can receive noise-related track access discounts is represented in the calculation as KZ_{LL} or KZ_{K} for LL and K brake blocks respectively.
The number of LL/K vehicles that receive noise-related track access discounts is calculated in the VBA code[1] and displayed as $tpa_{ll}(j)$ or $tpa_{k}(j)$ in the table.
The cost of the noise-related track access discounts in the retrofitting scenario is calculated using the following formula:

[1] For details, see the routine "FahrzeugZahlen_aktualiseren" in the VBA code, starting in Line 119

$$tco_{TP}^{R}(j) = AM_{V}\left(TP_{CI}(j)\cdot tn_{CI}(j) + TP_{LL}(j)\cdot tpa_{LL}(j) + TP_{K}(j)\cdot tpa_{K}(j)\right)$$

The cost of the noise-related track access surcharges for the status quo is calculated using the following formula:

$$tco_{TP}^{SQ}(j) = AM_{V}\left(TP_{CI}(j)\cdot tn_{V}(j)\right)$$

KZ_{LL}, KZ_{K}	***KZ_LL, KZ_K***	Waiting period after which vehicles whose retrofitting with LL or K brake blocks was directly funded can receive noise-related track access discounts. Table 2c in the "Input" worksheet
$TP_{CI}(j)$, $TP_{LL}(j)$, $TP_{K}(j)$	***TP_CI_A(j)***, ***TP_K_A(j)***, ***TP_K_A(j)***,	Track access surcharge / discount in $\left[\frac{€}{km}\right]$ for CI, LL and K vehicles in Year j. Columns 1 to 3 in Table 2d of the "Input" worksheet
$tco_{TP}^{R}(j)$		Cost of noise-related track access discounts in Year j of retrofitting scenario
$tco_{TP}^{SQ}(j)$		Cost of noise-related track access surcharges levied in Year j on vehicles which continue to use CI brake blocks

7. Calculation of break-even points

To determine the break-even point, one of parameters 1 – 37 from Table 1 of the "Input" worksheet is varied until retrofitting with K / LL brake blocks is cost-neutral for the operator.

The application defines cost neutrality using the following formula:

$$\underbrace{\sum_{j=1}^{20} npv_{\Delta}(j)}_{\text{Cell[Calculation!AR26]}} = \sum_{j=1}^{20}\sum_{i=1}^{j}\frac{\Delta_{v\_gg}(i)}{(1+RI)^{i}} = \sum_{j=1}^{20}\frac{\Delta_{v\_gg}(j)}{(1+RI)^{j}}(21-j) = 0$$

Differences in costs for the individual years, calculated in net present values, must add up to zero (0).

The calculation is performed using Excel's "Solver Add-in."

Calculation of a break-even point is currently implemented for the following parameters:

Number in Table 1	Name/Meaning	Comment
1	Rate of return	
3	Average annual mileage per vehicle in km/year	
6	Initial cost of a CI brake block	
7	Initial cost of a K brake block	
11	Wear for LL brake block, measured in mm/100,000km	
12	Wear for K brake block, measured in mm/100,000km	
14	Distance [km] after which the wheelsets on LL vehicles have to be replaced or reprofiled	
15	Distance [km] after which the wheelsets on K vehicles have to be replaced or reprofiled	
20	Funding for retrofitting of a CI vehicle with K brake blocks	Calculates remaining funding needs for all K vehicles
22	One-time costs for retrofitting with LL brake blocks	
23	One-time costs for retrofitting with K brake blocks	
34	Cost of wheelset replacement (cost per vehicle)	
36	Funding for retrofitting of CI vehicles with LL brake blocks	Calculates remaining funding needs for all LL vehicles

It is not possible to find a break-even point for all combinations of values. An error message is displayed if the calculation does not converge.
The initial parameter values are among the factors that determine whether a Solver run converges or not.
It is therefore recommended that you use run parameters to calculate reasonable initial values before you calculate the break-even point.
In some cases, the Solver may find a break-even point which makes no sense (for example, a negative purchase price for a brake block).

7.1. Calculation of remaining funding needs

If Parameter 20 or Parameter 36 is selected as a variable parameter, the break-even point calculation does not identify funding needs for the retrofitting of each individual vehicle, but the remaining funding needs per K vehicle (co_K^{Δ}) or LL vehicle (co_{LL}^{Δ}) for each year.
There is no distinction made in this case between vehicles that are retrofitted and those that are purchased new.
Total remaining funding needs (tco_{K-LL}^{Δ}) are calculated for every year based on funding needs for K and LL vehicles.
Based in turn on total remaining funding needs, a noise-related track access surcharge for CI vehicles $tp_{CI}^{\Delta}(j)$ and a track access discount for K and LL vehicles $tp_{K,LL}^{\Delta}(j)$ is calculated.

The user can specify the amount of external funding (q_{Oeff}).

To ensure that the change-over is cost-neutral for the operator, the track access surcharge for CI vehicles in Year j is calculated as follows:

$$tp_{CI}^{\Delta}(j) = -tco_{K-LL}^{\Delta} \cdot (1 - q_{Oeff}) \frac{AM_V}{tn_{CI}(j)}$$

The track access discount for K / LL vehicles is calculated using the following formula:

$$tp_{K,LL}^{\Delta}(j) = tco_{K-LL}^{\Delta} \cdot (1 - q_{Oeff}) \frac{AM_V}{tn_{LL}(j) + tn_K(j)}$$

co_K^{Δ} , co_{LL}^{Δ}	***co_diff_k (j)***, ***co_diff_ll(j)***	Remaining funding needs for every K or LL vehicle in Year j. ***[Calculation!AW5:AW24]***, ***[Calculation!AX5:AX24]***
tco_{K-LL}^{Δ}	***tco_diff_k_ll(j)***	Remaining funding needs for all K or LL vehicles in Year j. ***[Calculation!AY5:AY24]***
q_{Oeff}	***ProzentSatzOeffentlicheFoerderung***	Amount of direct funding (used for calculation of track access discount/surcharge) ***[Calculation!BF34]***
$tp_{CI}^{\Delta}(j)$	***[Calculation!BA5:BA24]***	Track access surcharge in $\left[\frac{€}{km}\right]$ for all CI vehicles (in order to achieve cost neutrality)
$tp_{K,LL}^{\Delta}(j)$	***[Calculation!AZ5:AZ24]***	Track access discount in $\left[\frac{€}{km}\right]$ for all K and LL vehicles (in order to achieve cost neutrality)

8. Appendix

8.1. Formula variables and cell ranges

Excel variables	**Formula variables**	**Unit**	**English description**	**German description**
CP_LL	CP_{LL}^0	€/block	Initial material costs (LL)	Anfangs-Materialkosten LL
CP_K	CP_K^0	€/block	Initial material costs (K)	Anfangs-Materialkosten K
TN_CI_Start	$TN_{CI}(0)$		Initial number, GG vehicles	Anfangszahl GG-Sohlen-Fahrzeuge

TN_K_Start	$TN_K(0)$		Initial number, K vehicles	Anfangszahl K-Sohlenfahrzeuge
TN_LL_Start	$TN_{LL}(0)$		Initial number, LL vehicles	Anfangszahl LL-Sohlen-Fahrzeuge
no_ax	*no_ax*		Number of axles	Anzahl Achsen
LEQ_CI	$LEQU_{CI}$	dBA	Coefficient for noise calculation (CI brake blocks)	äquivalenter Dauerschallpegel (Lärmkoeffizient) GG-Sohle
LEQ_K	$LEQU_K$	dBA	Coefficient for noise calculation (K brake blocks)	äquivalenter Dauerschallpegel (Lärmkoeffizient) K-Sohle
LEQ_LL	$LEQU_{LL}$	dBA	Coefficient for noise calculation (LL brake blocks)	äquivalenter Dauerschallpegel (Lärmkoeffizient) LL-Sohle
RF_K_A	$RF_{LL}(j)$		Vehicles retrofitted with K brake blocks (year)	Auf K-Sohlen umgerüstete Fahrzeuge (Jahr)
nr_k_y	$nr_k(j)$		Vehicles retrofitted with K brake blocks (year)	Auf K-Sohlen umgerüstete Fahrzeuge (Jahr)
RF_LL_A	$RF_K(j)$		Vehicles retrofitted with LL brake blocks (year)	Auf LL-Sohlen umgerüstete Fahrzeuge (Jahr)
nr_ll_y	$nr_{ll}(j)$		Vehicles retrofitted with LL brake blocks (year)	Auf LL-Sohlen umgerüstete Fahrzeuge (Jahr)
nex_w_k	$nex_K^{bs}(j)$		Number of K brake block replacements due to wear (year)	Austausch K-Sohlen wegen Abnutzung (Jahr)
nex_w_ll	$nex_{ll}^{bs}(j)$		Number of LL brake block replacements due to wear (year)	Austausch LL-Sohlen wegen Abnutzung (Jahr)
CP_CI_Y	$CP_{CI}(j)$	€/block	Material costs for CI brake block (year)	Materialkosten pro GG-Sohle (Jahr)
CP_K_Y	$CP_K(j)$	€/block	Material costs for K brake block (year)	Materialkosten pro K-Sohle (Jahr)
CP_LL_Y	$CP_{LL}(j)$	€/block	Material costs for LL brake block (year)	Materialkosten pro LL-Sohle (Jahr)
bb_con, bb_veh_k, bb_veh_ll	*bb_con*		Configuration of brake block	Bremsanordnung
NY_FK		a	Duration of funding for retrofitting with K	Dauer der Förderung
NY_FLL		a	Duration of funding for retrofitting with LL	Dauer der Förderung LL
CHL_K	CHL_K	A	Cost degression for K brake blocks (half-life)	Degression Kosten K-Sohle (Halbwertszeit)
CHL_LL	CHL_{LL}	A	Cost degression for LL brake blocks (half-life)	Degression Kosten LL-Sohle (Halbwertszeit)
delta_v_gg	$\Delta_{v\_gg(j)}$	€	Cost difference between status quo	Differenz der Gesamtkosten zwischen Status quo (KEINE

			(continued use of CI) and retrofitting vehicles with LL or K brake blocks	Umrüstung) und Umrüstungsszenario
DA_K_A		€/veh	Direct funding for replacement of CI with K brake blocks	Direktförderung für die Umrüstung von GG-Fahrzeugen auf K Sohlen
DA_LL_A		€/veh	Direct funding for replacement of CI with LL brake blocks	Direktförderung für die Umrüstung von GG-Fahrzeugen auf LL-Sohlen
npv_delta	$npv_{\Delta}(j)$	€	Discounted cost difference between status quo and retrofitting	Diskontierte Kostendifferenz zwischen Reprofilierung und Status quo
CR_K	CR_K	€/veh	One-time retrofitting costs for K	Einmalige Umrüstkosten auf K
CR_LL	CR_{LL}	€/veh	One-time retrofitting costs for LL	Einmalige Umrüstkosten auf LL
CD_CI	CD_{CI}	€/block	Disposal costs (CI)	Entsorgungskosten GG
CD_K	CD_K	€/block	Disposal costs (K)	Entsorgungskosten K
CD_LL	CD_{LL}	€/block	Disposal costs (LL)	Entsorgungskosten LL
CL_WS	CL_{WS}	€/veh	Fixed costs for wheelset stocks per vehicle and year	Fixe Kosten Radsatzpool pro Fahrzeug und Jahr
af_k_y	$af_K(j)$	€/veh	Public funding for retrofitting with K brake blocks (year)	Fördersumme pro auf K-Sohlen umgerüstetes Fahrzeug (Jahr)
af_ll_y	$af_{LL}(j)$	€/veh	Public funding for retrofitting with LL brake blocks (year)	Fördersumme pro auf LL-Sohlen umgerüstetes Fahrzeug (Jahr)
tco_diff_k_ll	tco^{Δ}_{K-LL}	€	Total remaining funding needs for all K/LL vehicles	Gesamter zusätzlicher Förderbedarf für alle K- und LL-Sohlen Fahrzeuge
t_co_r	$co_r(j)$	€	Total cost of all brake blocks (with retrofitting)	Gesamtkosten für alle Bremsschuhe (mit Umrüstung)
TN_RF_K_A			Total number of vehicles retrofitted with K brake blocks (year)	Gesamtzahl der auf K-Sohlen umgerüsteten Fahrzeuge (Jahr)
tn_k_y	$tn_k(j)$		Total number of vehicles retrofitted with K brake blocks (year)	Gesamtzahl der auf K-Sohlen umgerüsteten Fahrzeuge (Jahr)
TN_RF_LL_A			Total number of vehicles retrofitted with LL brake blocks (year)	Gesamtzahl der auf LL-Sohlen umgerüsteten Fahrzeuge (Jahr)
tn_ll_y			Total number of vehicles retrofitted with L brake blocks (year)	Gesamtzahl der auf LL-Sohlen umgerüsteten Fahrzeuge (Jahr)
tpa_k_y	$tpa_k(j)$		Total number of K	Gesamtzahl der K-

			vehicles that receive a track access discount (year)	Fahrzeuge, die am lärmabhängigen Trassenpreissystem teilnehmen (Jahr)
tpa_ll_y	$tpa_{ll}(j)$		Total number of LL vehicles that receive a track access discount (year)	Gesamtzahl der LL-Fahrzeuge, die am lärmabhängigen Trassenpreissystem teilnehmen (Jahr)
TNV			Total number of vehicles (CI, LL and K)	Gesamtzahl Fahrzeuge (GG,LL und K)
tn_v_y	$tn_v(j)$		Total number of vehicles (year)	Gesamtzahl Fahrzeuge (Jahr)
tn_ci_y			Total number of vehicles with CI brake blocks (year)	Gesamtzahl Fahrzeuge mit GG-Sohlen (Jahr)
TN_CI_A	$tn_{ci}(j)$		Total number of CI vehicles (year)	Gesamtzahl GG-Sohlen-Fahrzeuge (Jahr)
TN_K_A			Total number of K vehicles (year)	Gesamtzahl K-Sohlen Fahrzeuge (Jahr)
TN_LL_A	$tn_{ll}(j)$		Total number of LL vehicles (year)	Gesamtzahl LL-Sohlen-Fahrzeuge (Jahr)
tn_nv_K	$tn\_nv_K(j)$		Total number of vehicles acquired with K brake blocks (year)	Gesamtzahl neu beschaffter Fahrzeuge mit K-Sohlen (Jahr)
tn_nv_LL	$tn\_nv_{ll}(j)$		Total number of vehicles acquired with LL brake blocks (year)	Gesamtzahl neu beschaffter Fahrzeuge mit LL-Sohlen (Jahr)
TN_N_K_A			Total number of vehicles acquired with K brake blocks (year)	Gesamtzahl neu beschaffter K-Sohlen Fahrzeuge (Jahr)
TN_N_LL_A			Total number of vehicles acquired with LL brake blocks (year)	Gesamtzahl neu beschaffter LL-Sohlen Fahrzeuge (Jahr)
tn_bb_v	tn_{bb}^v		Total number of brake blocks per vehicle	Gesamtzahl Sohlen pro Fahrzeug
SL_CI	SL_{ci}	mm	Tolerance of CI brake blocks [mm]:	Grenzmaß GG-Sohle
SL_K	SL_K	mm	Tolerance of K brake blocks [mm]:	Grenzmaß K-Sohle
SL_LL	SL_{LL}	mm	Tolerance of LL brake blocks [mm]:	Grenzmaß LL-Sohle
y			Year	Jahr
Y_LL	I_{LL}		Start (year) of retrofitting with LL brake blocks	Jahr, in dem die Umrüstung auf LL-Sohlen beginnt
KZ_K	KZ_K	a	Waiting period (in years) after which retrofitted, funded K vehicles receive track access discount	Wartezeit für umgerüstete K-Fahrzeuge bis zur Teilnahme am nach Lärm gestaffelten Trassenpreis

KZ_LL	KZ_{LL}	a	Waiting period (in years) after which retrofitted, funded LL vehicles receive track access discount	Wartezeit für umgerüstete LL-Fahrzeuge bis zur Teilnahme am nach Lärm gestaffelten Trassenpreis
CU	*CU*	€/veh	Cost of downtime due to retrofitting	Kosten des Nutzungsentzugs während Sohlenwechsel
CO_WS	CO_{WS}	€/wheelset	Costs for wheelset replacement per axle	Kosten für einen Radsatzwechsel pro Achse
CB_WS	CB_{WS}	€/veh	Costs for wheelset replacement per vehicle	Kosten für einen Radsatzwechsel pro Fahrzeug
co_ci_r	$co_{ci}(j)$	€	Cost of CI brake blocks (year) (incl. retrofitting with K or LL brake blocks)	Kosten GG-Sohlen (Jahr) (mit Umrüstung)
co_ci_stqo	$co_{stqo(j)}$	€	Cost of CI brake blocks (year) (not incl. retrofitting with K or LL brake blocks)	Kosten GG-Sohlen (Jahr) (ohne Umrüstung)
co_k_r	$co_K(j)$	€	Cost of K brake blocks per year (incl. retrofitting)	Kosten K-Sohlen (Jahr) (mit Umrüstung)
co_v_r	$co_{LL}(j)$	€	Cost of LL brake blocks (year) (incl. retrofitting)	Kosten LL-Sohlen (Jahr) (mit Umrüstung)
co_wsex_ci		€	Cost of wheel set replacement per vehicle (CI)	Kosten Radsatztausch pro GG-Sohlen-Fahrzeug
co_wsex_k		€	Cost of wheel set replacement per vehicle (K)	Kosten Radsatztausch pro K-Sohlen-Fahrzeug
co_wsex_ll		€	Cost of wheel set replacement per vehicle (LL)	Kosten Radsatztausch pro LL-Sohlen-Fahrzeug
co_bex_ci	$co_{CI}^{bex}(j)$	€	Cost of brake block replacement per vehicle (CI) (year)	Kosten Sohlenwechsel pro Fahrzeug mit GG-Sohlen (Jahr)
co_bex_k	$co_k^{bex}(j)$	€	Cost of brake block replacement per vehicle (K) (year)	Kosten Sohlenwechsel pro K-Sohlen Fahrzeug (Jahr)
co_bex_ll	$co_{LL}^{bex}(j)$	€	Cost of brake block replacement per vehicle (LL) (year)	Kosten Sohlenwechsel pro LL-Sohlen-Fahrzeug (Jahr)
LEMI	*LEMI (j)*	dBA	Noise emissions at distance of 7.5m (year)	Lärmemission in 7,5m Entfernung (Jahr)
LS_V	LS_V	a	Service life of vehicle	Lebensdauer eines Fahrzeugs
CL_CI	CL_{CI}	€/veh	Labour costs for brake block replacement (CI)	Lohnkosten Sohlenwechsel GG
CL_K	CL_K	€/veh	Labour costs for brake block replacement (K)	Lohnkosten Sohlenwechsel K

CL_LL	CL_{LL}	€/veh	Labour costs for brake block replacement (LL)	Lohnkosten Sohlenwechsel LL
CP_CI	CP_{CI}^{0}	€/block	Material costs (CI)	Materialkosten GG
AM_V	AM_V	km/a	Average annual vehicle mileage	mittlere Laufleistung eines Fahrzeugs pro Jahr
SI_CI	SI_{ci}	mm	Nominal size of CI brake block	Nennmaß GG-Sohle
SI_K	SI_K	mm	Nominal size of K brake block	Nennmaß K-Sohle
SI_LL	SI_{LL}	mm	Nominal size of LL brake block	Nennmaß LL-Sohle
n_nv_k_y			Number of new vehicles with K brake blocks (year)	Neu beschaffte Fahrzeuge mit K-Sohlen (Jahr)
N_K_A	$N_K(j)$		Number of new vehicles with K brake blocks	Neu beschaffte K-Sohlen Fahrzeuge
N_LL_A	$N_{LL}(j)$		Number of new vehicles with LL brake blocks	Neu beschaffte LL-Sohlen Fahrzeuge
ny_ci_ws_y		a	Replacement of wheelsets with CI brake blocks per year	Radsatzwechsel pro Jahr bei Verwendung von GG-Sohlen
ny_k_ws_y		a	Replacement of wheelsets with K brake blocks (year)	Radsatzwechsel bei Verwendung von K-Sohlen (Jahr)
ny_ll_ws_y		a	Replacement of wheelsets with LL brake blocks (year)	Radsatzwechsel bei Verwendung von LL-Sohlen (Jahr)
GT_K_A			See TPA_K_Y	Siehe TPA_K_Y
GT_LL_A			See TPA_LL_Y	Siehe TPA_LL_Y
CO_CI	CO_{CI}	€/veh	Other costs for brake block replacement (CI)	sonst. Kosten Sohlenwechsel GG
CO_K	CO_K	€/veh	Other costs for brake block replacement (K)	sonst. Kosten Sohlenwechsel K
CO_LL	CO_{LL}	€/veh	Other costs for brake block replacement (LL)	sonst. Kosten Sohlenwechsel LL
ny_ci_bb, ny_ci_bb_y	ny_{ci}	a	Service life of CI brake blocks in years	Standzeit GG-Sohlen in Jahren
ny_k_bb , ny_k_bb_y	ny_K	a	Service life of K brake blocks in years	Standzeit K-Sohlen in Jahren
ny_ll_bb, ny_ll_bb_y	ny_{LL}	a	Service life of LL brake blocks in years	Standzeit LL-Sohlen in Jahren
WL_CI	WL_{CI}	km	Mileage between two wheelset replacements, CI vehicles	Strecke zwischen zwei Radsatzwechseln für GG-Fahrzeuge
WL_K	WL_K	km	Mileage between two wheelset	Strecke zwischen zwei Radsatzwechseln für K-

			replacements, K vehicles	Fahrzeuge
WL_LL	WL_{LL}	km	Mileage between two wheelset replacements, LL vehicles	Strecke zwischen zwei Radsatzwechseln für LL-Fahrzeuge
AF_K		€/veh	Amount of funding for retrofitting with K	Summe Förderung Umrüstung K
AF_LL		€/veh	Amount of funding for retrofitting with LL	Summe Förderung Umrüstung LL
TP_CI_A	$TP_{CI}(j)$	€/km	Track access charge for CI veh. in €/km (year)	Trassenpreis für GG-Fahrzeuge €/km (Jahr)
TP_K_A	$TP_{K}(j)$	€/km	Track access charge for K veh. in €/km (year)	Trassenpreis für K-Fahrzeuge €/km (Jahr)
TP_LL_A	$TP_{LL}(j)$	€/km	Track access charge for LL veh. in €/km (year)	Trassenpreis für LL-Fahrzeuge €/km (Jahr)
RW_CI		mm/10,e+5 km	Characteristic wear (CI brake blocks)	Verschleißwert GG-Sohle
RW_K		mm/10,e+5 km	Characteristic wear (K brake blocks)	Verschleißwert K-Sohle
RW_LL		mm/10,e+5 km	Characteristic wear (LL brake blocks)	Verschleißwert LL-Sohle
SC_CI_A	$SC_{CI}(j)$		Scrapped CI vehicles (year)	Verschrottete GG-Sohlen Fahrzeuge (Jahr)
SC_K_A	$SC_{K}(j)$		Scrapped K vehicles (year)	Verschrottete K-Sohlen-Fahrzeuge (Jahr)
SC_LL_A	$SC_{LL}(j)$		Scrapped LL vehicles (year)	Verschrottete LL-Sohlen-Fahrzeuge (Jahr)
NR_CI			Number of possible wheelset reprofilings (CI)	Zahl möglicher Radsatzreprofilierungen GG
NR_K			Number of possible wheelset reprofilings (K)	Zahl möglicher Radsatzreprofilierungen K
NR_LL			Number of possible wheelset reprofilings (LL)	Zahl möglicher Radsatzreprofilierungen LL
RI	*Ri*		Rate of return	Zinssatz
co_diff_k	co_{K}^{Δ}	€/veh	Remaining funding needs per K vehicle	Zusätzlicher Förderbedarf für jedes K-Sohlen-Fahrzeug
co_diff_ll	co_{LL}^{Δ}	€/veh	Remaining funding needs per LL vehicle	Zusätzlicher Förderbedarf für jedes LL-Sohlen-Fahrzeug

Do you have any questions regarding the application?

Email us or pick up the phone and give us a call:

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