



AEROSOFT®

ZUSI 3

AEROSOFT EDITION



MANUAL

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Zusi 3

Aerosoft Edition

Manual

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Content

1 Introduction and basic principles 7

1.1 What is Zusi?.....	7
1.1.1 Track plan editor	9
1.1.2 3D editor	10
1.1.3 Rolling stock editor	11
1.1.4 Driver's cab editor.....	12
1.1.5 Management	13
1.2 Languages.....	13
1.4 Directory structure	14
1.4.1 Program installation	14
1.4.2 Data installation	15
1.4.3 Data sub-directories	15
1.5 Introduction to the creation of Zusi accessories.....	19
1.5.1 3D object construction	19
1.5.2 Route construction.....	20
1.5.3 Timetable creation	20
1.5.4 Rolling stock construction.....	21
1.6 Incorporating your own documentation.....	22
1.6.1 Organisation	22
1.6.2 File format	22
1.6.3 Uniform appearance.....	23
1.6.4 Images/graphics	23
1.7 File information	24
1.8 Formula symbols.....	26

2 Driving simulator..... 27

2.1 "Simulation" menu	27
2.1.1 Starting the Simulator	27
2.1.2 Fast forward.....	29
2.1.3 Pause	30
2.1.4 Autopilot	30
2.1.5 Time leap	31
2.2 "Configuration" menu	32
2.2.1 Settings.....	32
2.2.2 Input Devices	41

2.2.3 Manual device assignment	46
2.2.4 Automatic device assignment.....	47
2.2.5 Network.....	48
2.2.6 Show cab view.....	50
2.2.7 Show additional info in cab.....	50
2.2.8 Show train data window	50
2.2.9 Show cheat sheet.....	50
2.2.10 Hide menu	51
2.2.11 Set window size to cab view size	51
2.3 "Navigation" menu	51
2.3.1 Take over different train... ..	51
2.3.2 Train locations	52
2.3.3 Viewpoint trackside location	53
2.4 "Timetable creation" menu	53
2.4.1 Timetable file	53
2.4.2 Train Editor.....	60
2.5 "Help" menu	87
2.5.1 Debugging	87
2.5.1.13.1 Name.....	91
2.5.1.13.2 Status (in square brackets).....	91
2.5.1.13.3 Position.....	92
2.5.1.13.4 Visibility	92
2.5.1.13.5 Distances	92
2.5.2 Show message window.....	92
2.5.3 Show last order	93
2.5.4 Updates, add-ons.....	93
2.6 Evaluation at end of trip	94
2.7 Operation during the trip.....	97
2.7.1 Braking	97
2.7.2 Driving	100
2.7.3 Doors.....	102
2.7.4 Safety systems.....	106
2.8 Railway operation.....	106
2.8.1 Germany.....	106
2.8.2 All clear to depart.....	121
2.9 Drive Technology	121
2.9.1 Electric Series-Wound Motor Drive	121
2.9.2 Electric Drive (Three-Phase Current).....	122



2.9.3 Diesel-Hydraulic Drive.....	122
2.10 Braking technology.....	123
2.10.1 Introduction	123
2.10.2 Braking efficiency.....	123
2.10.3 Air brake	124
2.10.4 Wear-resistant brakes	127
2.10.5 Magnetic brake	128
2.11 Signals.....	129
2.11.1 Germany.....	129
2.12 Train protection	145
2.12.1 Europe-wide systems.....	146
2.12.2 ETCS.....	148
2.12.3 Germany.....	156
2.12.4 Austria	201

1 Introduction and basic principles

Welcome to the world of the virtual railway! Zusi is a highly complex topic – and no less so than the real railway. Consequently, this documentation is extremely comprehensive.

However, a very few users will want to understand the full breadth of the subject. Those who only wish to drive the train probably need only to read the Introduction and Chapter 2 at most. The content is divided so that everything that applies to virtual train driving can be found there. The remaining chapters are intended only for users who wish to create their own routes, rolling stock etc.

If you would like to immerse yourself more deeply in Zusi and create your own works, turn to the chapter “Introduction to the creation of Zusi accessories” below. It provides an overview of the various tasks as well as initial introductions to the various topics.

1.1 What is Zusi?

Zusi is a highly authentic PC-based 3D railway simulation, and accordingly the main focus is on virtual train driving. The objective of the “mission” is the punctual and safe driving of a train as per the timetable, while observing all the permitted speeds. Zusi creates entire timetable scenarios potentially several hundred trains. Technically, these trains are all of equal standing, and are automatically guided along the network in accordance with their timetable data. The user can select one of the trains and either drive it manually or have it driven by the autopilot and spectate from the perspective of the train driver. Trains can be changed at any time during the current simulation. At the end of the journey a graphical evaluation and rating is shown. The editors required for creating the user’s own routes and rolling stock are included in the package.

Zusi has an open and fully documented structure and uses data formats that match the usual standards as far as possible. All Zusi



data (rolling stock, driver's cab, route data etc.) are saved in the xml format. The x format (Microsoft DirectX) is also supported for the 3D objects. So Zusi can either use .x files directly or import them into the Zusi format, which offers additional options. All the usual 3D editors such as 3D StudioMax, 3DCanvas or the extremely powerful but free Blender can be used to construct objects. Textures in any format supported by DirectX (tga, bmp, dds, jpg, png, dib) can be used.

The user does not need to have any programming or scripting experience. All that is required for the normal construction of routes and accessories is provided in standard Windows interfaces. As Zusi is designed throughout for authentic railway operation, almost anything that is required for a good simulation can be configured with ease. There is also the option of using plug-ins to create your own functions that go beyond the standard scope of Zusi. However, you will need to have some programming experience to do that.

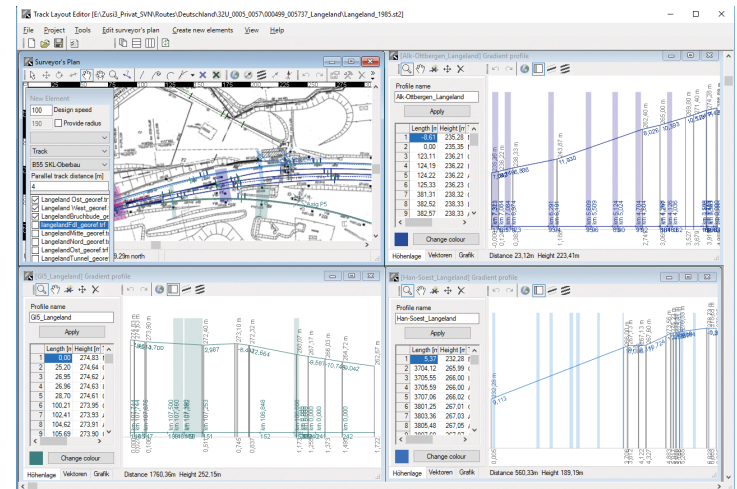
Zusi 3 is not a continuation of the previous version 2.4, but entirely new software. The last versions of the Zusi 2 editors contain export functions that can convert Zusi 2 files into the Zusi 3 format. Those who are already familiar with Zusi 2 will find a section in the appendix specifically for users with background knowledge of Zusi 2. This documentation does not otherwise address Zusi 2, and does not require any prior knowledge of Zusi 2.

In addition to the driving simulator, Zusi consists of five other programs, all of which are briefly explained here.

1.1.1 Track plan editor

The track plan editor is used to create the route geometry in a two-dimensional space, so it is the first program that is used for the construction of a new route. An extremely precise and realistic construction method can be achieved using authentic draft elements (arcs, straights, clothoids, switch modules). The track elements are easy to position using the mouse, and automatically click onto existing elements so you can create even complex routes, for example, in next to no time. The editor supports the use of geo-referenced bitmaps (track plans, topographic maps and similar) as background images so that routes can easily be constructed in authentic geographic locations.

The height information is determined for each branch or height level in a separate height profile.



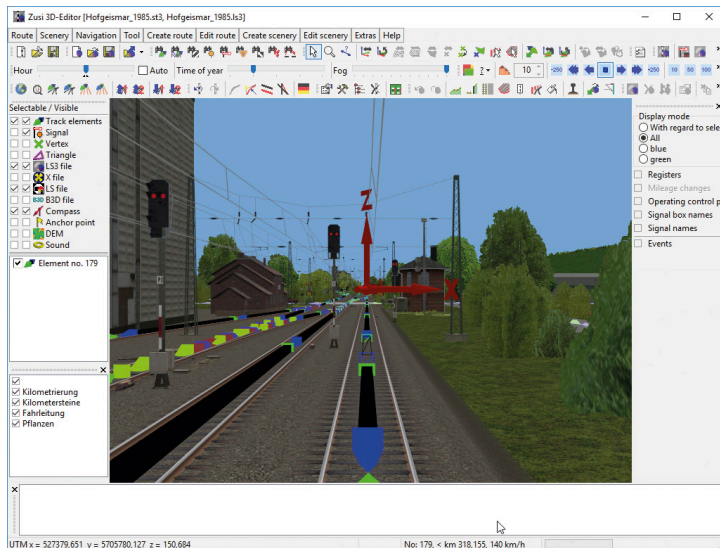


1.1.2 3D editor

At the end of the route construction in the track plan editor, the route is exported into the actual 3D route format and built in the 3D editor. So the landscape and functions of the route are designed there, with the landscape looking exactly as it will later on in the driving simulator. The usual steps in the development of a route are: Setting up the signals, including signal box functions; creating the track ballast; construction of track-related objects (platforms, supporting walls, embankments, cuttings, overhead lines etc.); creating the terrain with the terrain shaper; the placement of items such as houses and trees on the terrain.

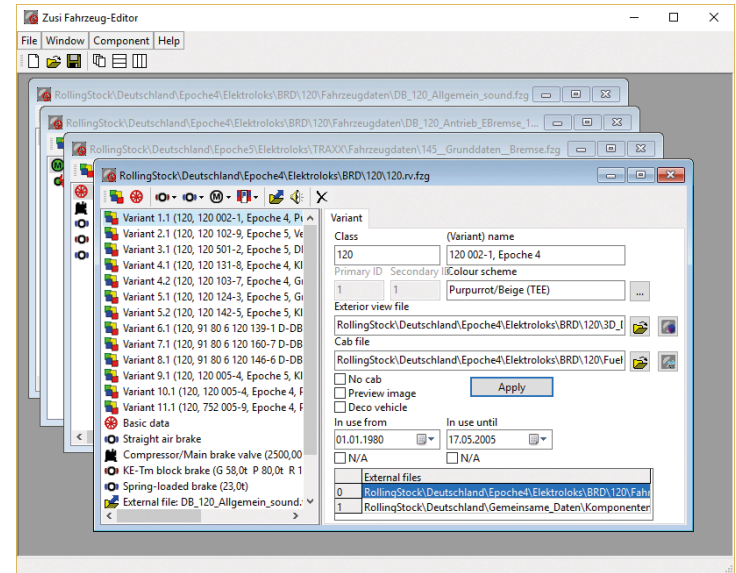
It is also possible to design a route entirely in 3D, i.e. without using the track plan editor. However, it is then more difficult to insert curved switches and give the arcs and clothoids the precise authentic geometries and height positions.

The 3D editor is also used for the construction and configuration of 3D objects and libraries.



1.1.3 Rolling stock editor

The rolling stock editor is used to set up the technical properties of the engines and carriages. Various modules (basic rolling stock data, brake, drive, driver's cab etc.) are available for use in making up the rolling stock. The choice of modules determines the rolling stock function (engine, carriage, control car etc.).

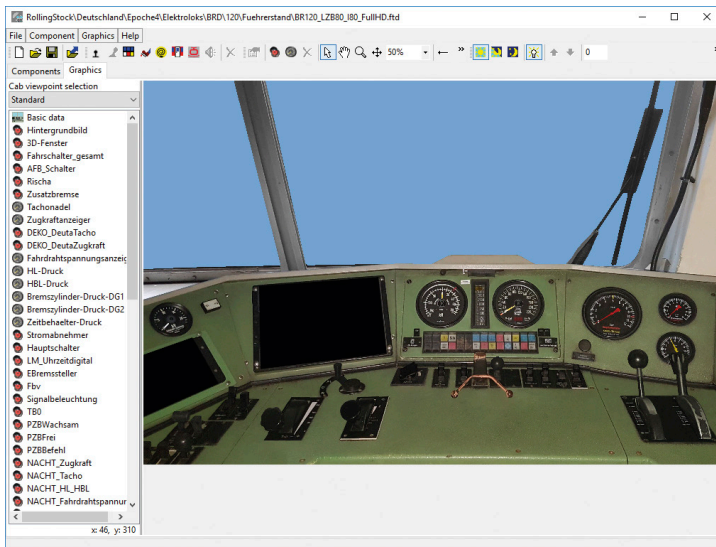




1.1.4 Driver's cab editor

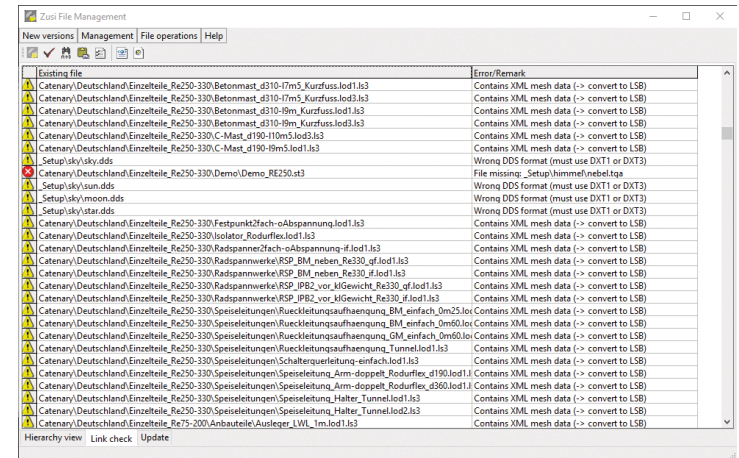
The technology and looks of the driver's cab are created in the driver's cab editor. The graphic is composed of a background bitmap and a bitmap for each switch setting. The bitmaps are created using standard picture editing programs and then loaded into the driver's cab editor for the final cropping. There, the bitmap sequences only need to be cut/positioned and assigned to the operating functions. The entire representation is produced using the DirectX functions that are also used in the driving simulator, so the driver's cab can be tested easily in the editor, including night view.

The technical elements in the driver's cab, such as the train control systems, types of driver's brake valves etc. are also defined in the driver's cab editor.



1.1.5 Management

This program helps to manage the files. It can install and package new add-ons, check the database for incorrect links, and provide other assistance with data maintenance.



1.2 Languages

All of the texts in the windows, messages or other elements that are visible to the end user are in German as standard, but can also be translated into other languages using a text file. The directory %Zusi-Programm%_InstSetup\language contains a sub-directory for each language with the name of the particular language, e.g. "Deutsch", "English" or "Francais". This directory contains the two files text.txt and GleisplanEditor.txt with the translations for the track plan editor and the other programs. The user can select the language directory that is to be used for all the Zusi programs in the Zusi file management (Chapter 8.2.9).

The language directory "Test" is also available for translators, and contains a raw file as the basis for a new translation. This raw file uses



the internal identifiers for all texts as plain text, so it is easy to see the identifier for a particular text in the window interfaces. New languages should only be introduced after prior discussion (carsten.hoelscher@zusi.de).

1.4 Directory structure

1.4.1 Program installation

You must be logged in as administrator and need to be connected to the internet to install ZUSI 3, otherwise the installation will not work.

1. Insert the DVD of ZUSI 3 into your DVD drive. Follow the installation instructions presented on the screen. If the installation does not start automatically:
 - Click “Start” in the taskbar and then on “Computer”.
 - Double click on the corresponding DVD-ROM drive.
 - Double click the “setup.exe” icon.
2. Steam will be installed first if it is not already installed on your system. Any necessary updates will be installed.
3. You may create a new Steam account or use an existing one. Enter the required information.
4. When prompted, enter the activation code you can find in your game box.
5. ZUSI 3 will be installed from the DVD. Any required updates will be downloaded from the Internet.
6. After installing the game, a ZUSI 3 icon will appear on your desktop. Double click it to start the game.
7. If you see an error “Access denied”, please repeat the installation

After the installation you can find the ZUSI 3 files under ...\\Program Files\\Steam\\Steamapps\\common\\ZUSI3.

The installation paths are displayed for information purposes in the Zusi programs under “Help → Info”.

1.4.2 Data installation

The core program (exe and dll files, documentation and accessory files) is installed in the write-protected Windows program folder as standard.

All the accessories (routes, rolling stock etc.) and thus the bulk of the Zusi data in terms of volume are contained in two separate data directories. One contains everything officially supplied with Zusi, and is not changed by the user.

It can be found in the sub-directory `_Zusidata` beneath the exe files. There is also a data directory for the user’s own files, for which the user must have read and write permissions. This directory is queried separately during installation, and all the files that the user creates are stored in this directory. When opening a file, if both file directories contain a file of the same name, then the one in the user directory will be used. So as the user, you can, for example, save a personally modified version of a file, which is always given preference over the version in the official inventory and is not overwritten during installations.

It is generally also possible to install the program and data in the same directory, although this is not in accordance with the Windows standard and is not recommended.

The two data paths are displayed for information purposes in the Zusi programs under “Help | Info”. If they are changed, the general Zusi settings in Zusi file management must also be adjusted. After changing this entry, the Zusi programs will search for the data in the newly listed directory following the next restart.

No data may be saved outside the basic data directories as it is not always possible to ensure that the file links are correctly interpreted.

1.4.3 Data sub-directories

In order to share works by various accessory creators, it is essential to have a uniform directory structure that is compulsory for all users. To this end, the data directory contains the following sub-directories:



_Setup:	Program accessories files such as sky textures, dll accessories etc.
Catenary:	Overhead catenary systems
PermanentWay:	Tracks, superstructures, switches, junctions, turntables etc.
RailwayObjects:	All 3D track accessories such as railway bridges, tunnels, platform equipment, telegraph poles etc.
RollingStock:	Railway vehicles
Routes:	Route modules including 3D models (houses etc.)
Signals:	Signal systems
Temp:	Temporary directory used by Zusi for storing files that are only required temporarily
Terrain:	All 3D accessories that are not rail-specific, e.g. plants, rolling stock, road equipment including rail crossing elements etc.
Timetables:	Timetables and train information

Directories that start with an underscore do not contain any user data for normal use.

1.4.3.1 Country directory and language

The next level always contains a country file in the respective language, e.g. "Deutschland" or "Nederland". The "General" directory is used for universal items such as plants.

In country-specific directories, file names can be used in the particular language; English file names are to be used in all other directories.

1.4.3.2 Rolling stock structure

Great care is required when creating the rolling stock structure, as vast quantities of data will accumulate over time, and managing and maintaining them will require a sensible structure. Due to the various development stories and historic and political developments, it is not possible to define a single true and absolutely perfect data structure. However, the rules stated in the following do have the advantage that

all of the rolling stock's relevant data is contained clearly in an area of the structure (which is a fundamental requirement of proper data management), and is so easy that it can easily be applied to almost any piece of rolling stock, making it easy to establish the expected location of the files at any time.

1.4.3.2.1 Basic rule

Basic rule: The rolling stock and all of its derivative models are always sorted to where the basic rolling stock first appeared.

1.4.3.2.2 Example

The Taurus family by Siemens was first used by the ÖBB (Austrian Federal Railways). So there would be a directory RollingStock\Oesterreich\...\Taurus containing all the variants, including all rolling stock, 3D, sound and driver's cab files. So the detailed directory structure could look like this:

```
RollingStock\Oesterreich\...\Taurus\Fahrzeugdaten\ RollingStock\
Oesterreich\...\Taurus\Fuehrerstand\ RollingStock\Oesterreich\...\
Taurus\Sound\ RollingStock\Oesterreich\...\Taurus\OeBB1116\ Rolling-
Stock\Oesterreich\...\Taurus\DB182\ RollingStock\Oesterreich\...\
Taurus\TX\ RollingStock\Oesterreich\...\Taurus\<other company>\
```

All future Taurus derivations will also be organised (exclusively) in this Taurus directory. So with regard to the Zusi application, rolling stock is to be considered independent when it no longer shares any components with the original rolling stock. Thus, for instance, the Taurus, for example, would be independent rolling stock because it does not share the driver's cab, the locomotive body construction or sound and drive data with the Eurosprinter prototype (series 127).

1.4.3.2.3 Quick access

In order to provide rolling stock creators with quick access, links to a directory may be put in all other directories. So for instance, the German electric engines could have a link to the ...\Oesterreich\...\Taurus\DB182 directory in order to give the creators of German timetables direct access to the German Taurus derivative. A file ending in .link.txt is created for this that contains a line with the link to the new directory (e.g. file name DB182.link.txt with the content



RollingStock\Oesterreich\...\Taurus\DB182). The file selection dialogues also contain a filter for these link.txt files.

1.4.3.2.4 Detailed classification

Depending on the variety of a country's rolling stock, it might be necessary to classify it in more detail. The scheme used will generally be country-specific. As rolling stock can also be constructed in modules, ideally all of the variants should be kept in a basic file of rolling stock with one variant for each derivative. The system described in the following chapter is an example for Germany.

1.4.3.2.4.1 Detailed classification for Germany

The Germany directory contains the era as is also used with model railways:

- Era1: Länderbahn period 1835-1920
- Era2: Reichsbahn period 1920-1949
- Era3: Post-war period until the introduction of IT numbers 1949-1968 (DB) and 1970 (DR)
- Era4: Divided Germany 1968/1970-1990
- Era5: Unification and railway reform 1990-2007
- Era6: New UIC numbers from 2007

The type of the rolling stock (electric engines, diesel engines, passenger carriages etc.) is entered in the next level. With regard to Eras 3 and 4, because of the completely separate and not always clear designations, items have been divided into DDR (GDR) and BRD (FRG).

This is followed by the folders of the various engine types and families.

The standard engines (E41, E10, E40, E50), for instance, would all be organised under RollingStock\Deutschland\Epoche3\Elektroloks\BRD\Einheitsloks. This also applies to the traffic red versions of Era 5. Depending on the extent of the derivatives, the main folder should be sub-divided further.

For the E10 it would be sufficient to set up a basic file E10.rv.fzg containing a sufficiently large number of variants of the different

options with regard to colour, driver's cab and locomotive body (e.g. E10, 110, 115). Variants with different drive and brake parameters can also be created as a variant within a central rolling stock file (for instance, the series E10.12, 112, 113 could also go in the E10.rv.fzg folder).

1.5 Introduction to the creation of Zusi accessories

A number of tasks need to be completed in order to create a scenario complete with accessories. Experience shows that many creators of accessories choose certain focal points. The following section contains a brief description of the typical tasks with the specific requirements, and some information on getting started on a particular topic.

1.5.1 3D object construction

3D models are used for various purposes such as the external model of the rolling stock, objects for designing the landscape such as houses, trees etc., and for signal systems. Route builders also need to understand the principles of 3D model construction in order to design the landscape.

To construct 3D objects, they need to know how to use a 3D program such as Blender and an image editing program such as Photoshop. The Zusi editors are then used afterwards simply to define animations etc. The appendix contains a tutorial as an introduction for the complete construction of a basic house. For further instructions, please refer to the respective 3D and image processing programs.

Various technical 3D principles are also explained in the first sections of Chapter 5. These will give you a deeper understanding.



1.5.2 Route construction

Route construction takes place mainly in the Zusi track plan and 3D editors. Route constructors need to have an understanding of track construction, drafting, signal and catenary systems, and of the principles of 3D construction. The documentation of the Zusi editors is structured more as a reference book than as a methodical guide, so it mostly reflects the functions in the sequence of the menu options.

For a better introduction to route construction, there is a short video tutorial with the basic connections in the directory %Zusi-Programm%_docu\tutorial. It is divided into three sections. To view, click on the htm file. The browser must support JavaScript. The films were produced with versions of Zusi from the development phase, so some input interfaces may differ from the current program status, as may certain other details. This tutorial is not included in the standard setup, but needs to be selected manually and installed using the Zusi file management installation mechanism (tut0001_streckenbau.zao). It is not installed automatically.

For an even better understanding, Chapter 3 “Building a practice route” provides a methodical approach to explain the process using two route modules.

The main additional software when constructing models is “Transdem” by Roland Ziegler, which edits geodata for the Zusi editors (software and documentation are included).

1.5.3 Timetable creation

Timetables are drawn up using the timetable editor in the driving simulator. The creator needs to understand how a railway operates, in particular the operating procedures, brake settings, train formation, train control etc.

Chapter 3 ends with the construction of a simple timetable that is ideal as an introduction.

1.5.4 Rolling stock construction

The following tasks need to be completed in order to create rolling stock.

1.5.4.1 Rolling stock file

Knowledge of railway technology (drive, brakes etc.) in particular is required for the creation of a rolling stock file in the Zusi rolling stock editor. Chapter 6 describes all the functions with numerous tips for the correct dimensioning. However, detailed information on original vehicles is virtually essential for good results.

1.5.4.2 Driver’s cab construction

For the construction of driver’s cabs, knowledge on the fittings and operation of the originals is required, as well as knowledge of an image editing program such as Photoshop to create bitmaps. As an alternative to photos, the bitmaps can also be created from a driver’s cab as a 3D object (see above).

The final design is created in the Zusi driver’s cab editor. Chapter 7 explains the process.

1.5.4.3 3D object

See above for more on the 3D object as the representation of the exterior of the rolling stock.

1.5.4.4 Sound

Sounds need to be recorded for the soundscape, and the user must have experience in common sound editing programs such as Audacity. The final configuration is then created in the Zusi rolling stock editor. Chapter 6.8 explains the process.



1.6 Incorporating your own documentation

Those who wish to incorporate their own chapters, e.g. tutorials on certain topics or documentation on additional software, into this documentation are warmly invited to do so. The advantage of a complete work is the bundled summary of every topic in one document, which also makes it easier for the user to search for certain keywords. The author will be acknowledged below the chapter heading, of course. The following points are to be observed for the sake of clarity when creating the full documentation and to achieve a uniform look.

1.6.1 Organisation

- The project should first be discussed briefly with regard to meaningfulness, insertion into the structure of the documentation, file paths for images and graphics (important!) and the outline level of the first heading (Zusi forum or carsten.hoelscher@zusi.de).
- Headings may be allocated to a maximum of level 6. A sensible layout is to be desired.

1.6.2 File format

- The Zusi documentation is managed with XeLaTeX. This typesetting system has its own syntax, and not all authors can be expected to be familiar with it. An “editor” is therefore required in order to transfer supplied pieces of documentation into the TeX format. Those who are TeX-savvy are welcome to deliver in TeX, but are asked to agree this in advance due to formatting conventions.
- New documentation submissions should otherwise be sent in the OpenOffice Writer (.odt) file format. The OpenOffice package is available for free at <http://www.openoffice.org>. It can also read and write MS Office formats, although the formatting may not always be retained.

1.6.3 Uniform appearance

- Please note that a file will contain different page breaks in TeX after conversion by the editor. The text should therefore not be optimised for specific page breaks.
- Formatting templates “Title 1” to “Title 6” in OpenOffice should be used for the formatting in order to retain the hierarchy of the chapters and sub-chapters.
- The names of any buttons etc. in the Zusi interface are to be placed in inverted commas, e.g.: Press “Next” to continue.
- Any menu functions that are being described should be placed in inverted commas and have → between the levels, e.g. “Navigation → Compass → Rotate compass by 90°”.

1.6.4 Images/graphics

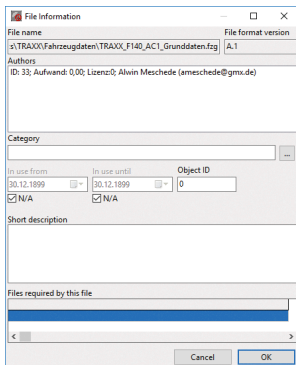
- Images and graphics are to be inserted with links. Select “Insert → Image from file” in OpenOffice and activate the “Link” checkbox at the bottom. Image files must, of course, be passed on with the odt file.
- Screenshots must be saved in png format. This is lossless, which makes certain post-processing tasks easier and leaves all the options for high-quality printing open. Digital photos may be left as jpgs.
- Screenshots should be saved with a resolution of 72 dpi.
- If possible, graphics should be created in a vector format (.eps is ideal). These can be created, for example, with OpenOffice Draw.
- Example photos should, if possible, be used in the standardised format of 400x400 pixels at 70 dpi, as they are then very easy to exchange.
- To get an idea of the approximate layout of the final documentation text in OpenOffice, any graphics that are to wrap around the text can be inserted with the anchor “To Para-



graph”, with the setting “Before” or “After” and with the “First Paragraph” checkbox activated. It may be necessary to end the last line of the surrounding text with a tabulator to achieve a clean finish. Graphics in continuous text can be anchored “As symbols”.

- For a more print-friendly design, the blue background of screenshots in the 3D editor should be replaced by a white one in an image editing program.
- Colours should only be used if greyscales do not transmit the necessary information (to save printing costs).
- Images with captions are difficult due to the characteristics of TeX global formatting, and should be avoided wherever possible. Instead, a description of what they show can be given in the text body.

1.7 File information



Every file type has file information with the name of the author and other details. In Zusi file formats, this information is saved as the first xml node in the file. For other file types, Zusi creates a file with the ending .author.xml (e.g. sifa.wav is given the file sifa.wav.author.xml in the same directory) containing these details. With regard to the author information, please also see Chapter 8.2.9.2. Every editor has an input form in the same design for entering this information, namely:

File name and version: The name of the open file is displayed relative to the Zusi working directory.

Authors: The list of authors of this file. In the case of further developments, additional authors may be entered on additional lines via the context menu.

Category: A text input that can be evaluated for the categorisation of the file.

Zusi does not evaluate the file, but third-party software may access it. To ensure the same terms are always used, the button can be used to call up and edit a structure with templates.

Use from/until: Zusi does not evaluate the file, but third-party software may access it, e.g. in order to select objects automatically for certain periods of time. These fields should not be used for rolling stock, as they have their own input fields in the variants.

Object ID: Zusi does not evaluate the file, but third-party software may access it.

Brief description: Any text that can be used, for example, to describe how to use the file.

Files required by this file: In certain cases, dependent files are not stored in the standard syntax of the Zusi xml file, and so are not included e.g. in the export and link auditing by management. These are commands that include a finished html file or sounds that are linked to an event. As it is easy to forget these files in an export, they can be entered in this list (context menu) so they are always automatically identified as dependent files in the future.



1.8 Formula symbols

F	Force
v	Speed Electricity
U	Voltage
ρ	Density
η	Efficiency
\ddot{u}	Translation
k	Evaluation function, constant
p	Print
m	Mass
g	Gravitational acceleration
s	Track width
R	Arc radius (track construction), or ohmic resistor
X	Reactance
P	Performance
f	Frequency

2 Driving simulator

This chapter deals with the specifics relating to the operation of the application, provides an introduction to the operation of typical cabs, outlines the integrated timetable editor and, in addition, explains the various aspects of railway technology and operation in order to provide the necessary background knowledge for the model.

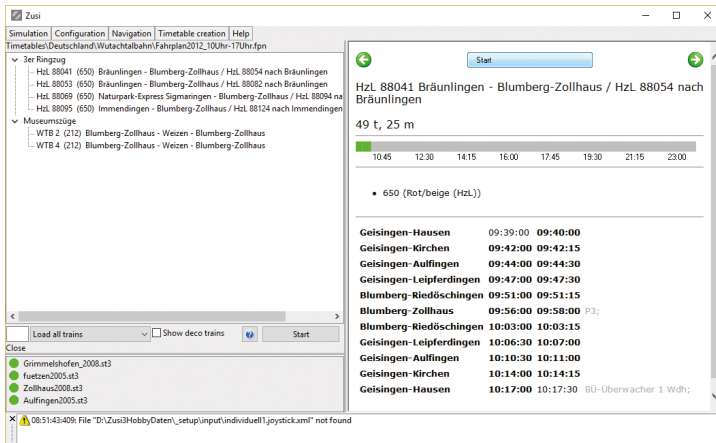
The next few chapters are designed for those wishing to drive according to existing timetables only, and cover the simulator functions relating to startup, as well as instructions on how to configure the simulator and operate the vehicles. Information on how to amend and create timetables, consists etc. is given in the later chapter entitled "Timetable Editor".

2.1 "Simulation" menu

2.1.1 Starting the Simulator

2.1.1.1 Starting via the Simulator

After starting the simulator, the timetable file must first be selected under "Simulation Open timetable". This contains information about the route modules to be loaded, and the train files they contain. The trains are listed on the left-hand side of the window, and the route module files are displayed bottom left. The trains can be divided into groups to make for easier viewing. The screenshot below shows four groups that have been created to distinguish between the four main routes. Clicking on a train reveals the train service data on the right-hand side, the status of the service within the timetable as a whole (run times — light green; dwell times — dark green), with the scheduled vehicle sequence and timetable underneath. When the timeline graphic is clicked on, the image jumps to the start of the timetable, which can initially be outside the image in the case of long trains.



Train search: The small input field between the list of available trains and the route module list is for initiating a search within the train list. The search can be made by entering a part of the train category, train number or class in this field. The search will then only bring up trains that contain the text that was entered. For example, if the digits "216" are entered, this will find all trains in class 216 or which contain the digits 216 in the train number, and if the letters "ICE" are entered, the results will show all ICE (intercity express) trains.

Train categories: This selection field will allow the scope of the timetable to be suited to the performance of the computer, if the creator of the timetable has grouped the trains into their relevant categories. Minor trains will not be loaded and will not run in the simulation if the selection is made accordingly. The list of trains displayed will immediately change according to what is selected, even at the preset stage.

Show deco trains These trains primarily have a decorative function. They only run very short distances, or do not run at all, or they are moved by a traction unit for which the cab or sound backdrop have not been comprehensively created and are therefore hidden in the standard train selection modes. When this checkbox is ticked, the deco trains will also be offered for driving.

The train to be driven by the user can be selected using the "Start" button on the timeline, the "Start" button in the bottom left of the window, or by double-clicking on the train. This will start the actual loading process.

The route modules are loaded first of all, the progress of which can be followed by switching the circular button to green on the bottom-left of the screen. In the second step, the scenery is loaded in the environment in which the simulation begins. Finally, you will find yourself in the cab of the vehicle, and the trip can start.

Since Zusi involves the progression of a complete timetable sequence, it may be that the user's own train is not running in the simulation right at the start of the simulation. If the train is not yet on the track, then the user will see the location where the train is due to come into play from a slightly elevated perspective.

2.1.1.2 Double-click to start

It is also possible to start a train file by double-clicking it in Explorer. The simulator will then be started immediately along with the corresponding timetable and the particular train in question. After double-clicking in Explorer, the simulation therefore loads completely without any further action on the part of the user, to the point where he/she is sitting in the cab.

It is also possible to start a timetable file by double-clicking it in Explorer. The file will be loaded as shown in the screenshot in the previous section. The train selection is then made as described above.

2.1.2 Fast forward

When the fast forward mode is activated (green fast forward symbol displayed in the 3D window), the simulation time runs ten times faster. The Sifa (DSD) is automatically deactivated in this mode. It should be noted that depending on the performance of the computer and the amount of scenery which needs to be loaded, lagging can occur due to the fact that the same amount of data has to load in one tenth of the time. This can be remedied by activating the pause and repeatedly allowing the simulation to run in short bursts, so that the simulator can initiate the queued loading tasks, which will not work when continuously paused.



2.1.3 Pause

The pause function temporarily stops the simulation as well as the simulation time. This is displayed as a blue pause symbol in the 3D window. Clicking on the symbol again will continue the simulation.

2.1.4 Autopilot

When the autopilot function is activated (displayed as a smiley face in the 3D window), the simulator takes over the train and drives it at the intended speeds around the route network. The driving behaviour of the train is then calculated in the same way as it is for all other automatically-driven trains. For autopiloted trains, simplified drive and braking calculations are used in order to make it possible to have minor differences in the driving dynamics between driver-operated and autopiloted trains. Because of the simplified calculation, not all physical quantities are determined, and so not all sound effects are functional in autopilot mode.

Autopilot does not operate the controls and devices in the cab. It is not designed to be an instructional aid, but instead has the function of moving the non-driver-operated trains in the network with as correct vehicle dynamics as possible. As a “by-product”, the user’s own train can be moved around, whether simply for recreational purposes and enjoying the scenery, or for testing it when creating routes and timetables.

The train protection systems are also active when in autopilot mode, meaning that braking curves etc. are also active in this mode.

When a train is switched from autopilot to manual operation, the train will revert to its default status. All brakes will then be released and all traction systems switched off, so the train will be rolling. If the train is approaching a stop signal at the time, the user should switch back to autopilot before coming to a standstill, as the autopilot does not have to reckon with long braking times thanks to its somewhat simplified calculation, and sometimes even brakes with unrealistically high deceleration in order to come to a halt before a stop signal. In this way, even a manually-driven train that has made an unsuccessful braking manoeuvre can still come to a standstill before a stop signal.

2.1.5 Time leap

The time leap only computes the simulation, without the graphics, and thus at the maximum possible computation rate. This function can be activated when the user’s train is not yet in the simulation, or when it is at a standstill at a stop signal. Time leap is ended manually by clicking it again. The simulator ends it automatically when the user’s own train is dispatched or when the stop signal changes to display a proceed aspect.

To retain some degree of graphic response during the time leap, the option exists in the settings to activate the graphics from time to time during the process.

2.1.5.1 Finish and interrupting

The simulation can be exited via the menu, under “Simulation Interrupt simulation...” or by pressing the “Esc” key. This interrupts the graphics only, whilst the actual simulation is still loaded. The simulation can be continued by selecting “Simulation Resume simulation”. Before resuming, the graphics settings etc. can be changed. For instance, to change the window to full-screen mode, the simulation does not need to be completely restarted; it can simply be interrupted, and the graphics output then resumed after changing the graphics parameters.

2.1.5.2 Restart timetable

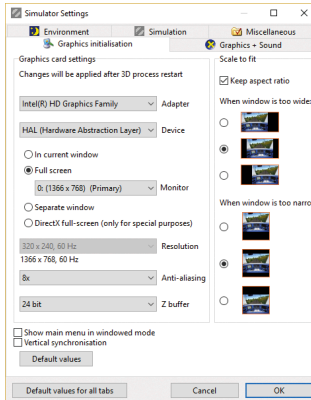
This function exits the simulation, but saves the route and timetable data in the memory. This means that the timetable can be restarted directly, without having to enter the entire route data once again.



2.2 "Configuration" menu

2.2.1 Settings

2.2.1.1 Graphics initialisation



Adapter: This contains the settings for the graphics adapter. For systems with more than one monitor, there is generally more than one adapter to choose from here. Depending on the system, it may be that full graphics performance is only available on the selected adapter. If the simulator is only running slowly on the selected monitor, this may be due to the adapter selection.

Device: HAL should always be selected here.

In current window: The graphics are displayed in the current simulator window. The dimensions of the window can be changed even while the simulation is running by clicking and dragging the window edges with the mouse.

Full screen: The image is displayed on the selected monitor at the currently selected screen resolution.

Separate window: The actual simulator window remains open, and an additional window is opened for the graphics output.

DirectX full-screen: This switches to special DirectX full-screen mode. Generally speaking, there is no reason to use this mode.

Anti-aliasing: Anti-aliasing (also abbreviated to AA) produces smoother edges. The higher the setting, the better the effect will be. However, this also places greater demands on computational power.

Z buffer: The higher the resolution of the Z buffer, the fewer graphic artifacts will appear when there are overlapping polygons that are

close together. A 24-bit setting would be typical here. Zusi does not use a stencil buffer. Combining with a stencil buffer therefore uses resources unnecessarily.

Keep aspect ratio: When this check box is ticked, the cab view is always displayed without distortion, even when the aspect ratio does not match that of the monitor or the Zusi window. When that is the case, the unused area is blacked out. The six options determine the position of the graphics and the black area. If the check box is not ticked then the cab view will be stretched to fit the size of the screen or window, and may therefore be displayed with distortion.

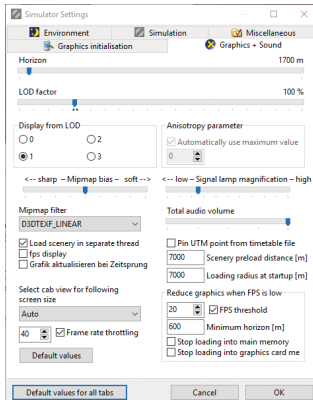
Show main menu in windowed mode: When this function is activated, the main menu remains visible even when 3D graphics are turned on. Since this takes up part of the window, this function should normally be deactivated. When deactivated, however, the menu can be still accessed via the context menu. Once the simulation has finished, the menu is automatically displayed again.

Vertical synchronisation When vertical synchronisation is activated, a new image is only loaded at the exact same time as the monitor starts on a new refresh cycle. This can result in a slightly lower frame rate due to the short delays that this function causes.

The frame rate can also never be any higher than the frequency of the monitor. If this option is not selected, however, slight horizontal distortions can appear in the image as the screen will be partly displaying the old image and partly the new one simultaneously.



2.2.1.2 Graphics + sound



Horizon: The scenery is displayed up to this distance.

LOD Factor: The further to the right the slider is, the later the switching between LODs. In the case of high screen resolutions (and sufficient computational power), this slider should be set more towards the right-hand side, otherwise the lower levels of detail in the 3D models will have a much less attractive appearance.

Display from LOD: This box is for selecting which LODs are displayed. LOD 1 is the recommended setting. At LOD 0, highly detailed models are also displayed (as far as they have been provided for the individual objects), which requires corresponding levels of processing power.

Anisotropy parameter: The higher the setting here, the sharper the textures will appear from a side-on perspective. The maximum value depends on the graphics card, which is why the “Automatically use maximum value” setting is recommended. It is only possible to set this value when the simulation graphics are running.

Mipmap bias: The default mipmap transition can be changed up or down using this slider. The “soft” direction tends towards mipmaps that are on the small side, which results in a smoothed or even blurry appearance. The “sharp” direction tends towards mipmaps that are on the large side, which appears sharper in static images, but results in flickering when images are moving.

Mipmap filter: The mipmap filter determines how the transitions between the mipmap levels of a texture are filtered.

Signal magnification: This slider is for setting the extent to which signal lights are magnified at greater distances in order to facilitate identification.

Total audio volume: This setting is for the 2D and 3D volume of the overall Zusi sound.

Pin UTM point from timetable file: When this checkbox is ticked, the UTM coordinate defined in the timetable file is used, which means that as distances increase, the scenery can start to vibrate as well as display fine cracks (noticeably at 50 or more km from the UTM coordinate). This function should be deactivated as standard, so that the UTM reference coordinate moves dynamically along with the viewer’s surroundings.

Load scenery in separate thread: This should always be selected, so that the scenery can load in the background with as little impact on the simulator as possible. In the case of multi-processor computers, when this checkbox is ticked the loading takes place on its own core.

FPS display: When this checkbox is ticked, the 3D window at the top left-hand side displays how many frames per second the simulator is working at. The time of day (hour) of the simulation may also sometimes be displayed here.

Refresh view during time leap: This option exists in order to create a response in the graphics while the time leap is running. When the checkbox is ticked, an image is displayed every few seconds, however, this increases the computation time.

Frame rate throttling: When this checkbox is ticked, the number of frames per second is capped at the limit that is set. It is recommended that this is left at the default value, so that the computing time saved is available for loading the scenery, and because even small variations in computing time lead to a noticeably uneven flow of images at very high frame rates.

Select cab view for following screen size: Several cab-view versions are available for different screen formats. The recommended setting is “Auto” (which selects the most appropriate format for the screen resolution currently in use). Otherwise, the preferred cab format can be selected here.

Scenery preload distance: The scenery surrounding the player’s current position is preloaded up to the selected distance. When a higher value is selected, preloading is started earlier, which means that the



computer has more time to load scenery objects in the background. This inevitably requires more memory. The value should therefore only be increased if gaps appear in the scenery when not in time-lapse mode.

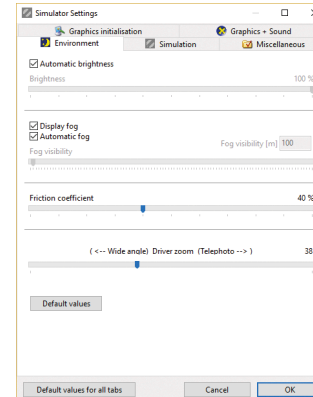
The landscape around the player's position is pre-loaded by the distance given here from the set horizon. Therefore if, for example, 1700 m is set for the horizon and 7000 m for the approach, then objects will be loaded as soon as they are within a radius of 8700 m around the player's eye. If the approach is greater, then loading processes will be initiated sooner so the computer has more time to load landscape objects in the background. However, more memory is then required. So, the value should only be increased if gaps appear in the landscape without time lapse runs.

Loading radius at startup: To shorten startup times, the scenery is only loaded up to the distance set here before the start of the simulation. The difference between this value and that of the "Scenery preload distance" setting must then subsequently be loaded once the simulation is running. Should scenery elements be missing after the simulation has started, a higher value can be set here, at the expense of longer startup times.

Reduce graphics when FPS is low: Graphics reduction helps to optimise the balance between visibility range being as extensive as possible on open stretches of track, and the refresh rate being sufficiently high even at detailed junction stations. If the FPS falls below the given threshold, then the measures defined here will kick in: The distance of the horizon is dynamically reduced so as to ensure that the image refresh rate is at least the same as the FPS threshold. However, the horizon distance will never be reduced below the value set in the "Minimum horizon" setting. To further increase performance, loading processes can be delayed until such time as the image refresh rate exceeds the FPS threshold once again. That said, such deferrals of the loading processes in the main memory only result in minimal performance improvement, as this process takes place to a large extent independently of the actual program in a parallel thread on a second CPU. If a computer does not achieve the minimum FPS threshold over a relatively long section (1 to 2 km, depending on the situation) and loading is also prevented, this will result in missing

graphic objects. In such cases, loading prevention should be disabled.

2.2.1.3 Environment



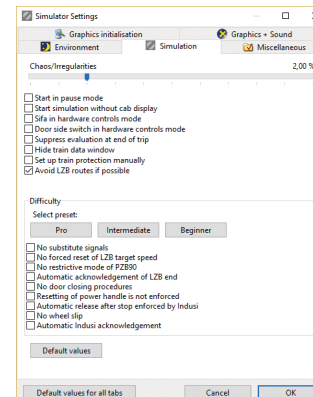
Brightness: When this checkbox is ticked, the brightness of the environment is determined by the time of day of the simulation, as well as the date and geographical location. When the checkbox is clear, the brightness can be adjusted using the slider.

Fog: Setting the visibility level in fog — this is normally selected at random by the simulator.

Friction coefficient: The friction between the wheels and rails can be set using this slider. A value of around 40% is realistic under good conditions.

Driver zoom: This value determines the level to which the image is zoomed in.

2.2.1.4 Simulation



Chaos/Irregularities: The higher the value of this setting, the greater the likelihood of there being signal delays and alternative possible routes.

Start in pause mode: The simulator switches automatically to pause mode after loading when this checkbox is ticked.

Start simulation without cab display:

The cab graphics are normally invisible, but can be displayed any time by pressing the F5 key.



Sifa in hardware controls mode: When this checkbox is ticked, the test run starts straight after the Sifa (DSD) switch is released, as is also the case in the ideal situation.

Door side switch in hardware controls mode: Special operation of the side selection switch would not be compatible with operation using external hardware controls. When this checkbox is ticked, the four switch positions can be controlled via two binary-coded closers.

Suppress evaluation at end of trip: At the end of the journey nothing further is displayed, and the simulation ends without commentary when this checkbox is ticked.

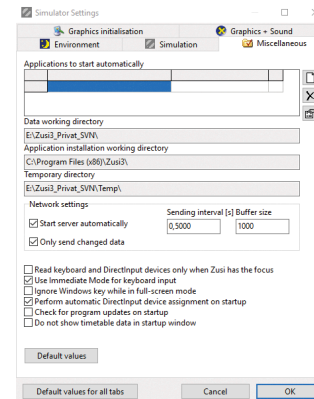
Hide train data window: The train data window with the working timetable is normally invisible, but can be displayed at any time by pressing the F7 key.

Set up train protection manually: Zusi normally sets the train protection automatically when the train starts, based on the train data and the timetable presets. When this checkbox is ticked, however, the systems revert to default and must be set using an external input facility such as ZusiDisplay. Zusi itself does not have a user interface for these settings.

Avoid LZB routes if possible: When this checkbox is ticked, Zusi automatically favours LZB Whole Block routes for trains operating with LZB. LZB Partial Block routes are only used in this case if the Whole Block is not free. This generally reflects the ideal real situation. When the checkbox is clear, LZB Partial Block routes are favoured.

Difficulty: The three buttons allow the user to select presets in order to set the simplifications listed.

2.2.1.5 Miscellaneous



Applications to start automatically: Additional programs can be entered here which Zusi will start automatically and close again at the end of the session. This includes, for instance, the automatic startup of a hardware controls environment. A settings dialogue box opens on double-click. The parameter is optional. Many programs can be controlled via this parameter; typically, the name of the file etc. to be opened is entered here. The “Inactive” checkbox allows an application to be temporarily disabled without having to delete the data from the table.

Data working directory: Display of the working directory for information/checking purposes.

Application installation working directory: Display of the installation directory for information/checking purposes.

Temporary directory: Display of the temporary directory for information/checking purposes.

Network settings: Zusi can operate as a TCP server, in order, for example, to supply clients with driving data. Detailed server data can be found under “Configuration Network”. When this checkbox is ticked, the server is automatically enabled at startup, which should only be activated if the user regularly needs to connect clients to Zusi. If a firewall is installed, this must be configured to allow Zusi, so that a network connection can be established. Zusi sends data packets at the sending interval that has been set. If the data cannot be sent immediately, Zusi initially fills a buffer and then tries again to send the data. If the buffer has exceeded a certain size, then Zusi treats that as an interruption of the data connection and aborts the TCP connection with the client concerned. The number of packets that are allowed to remain in the buffer before the connection is aborted is determined



by the “Buffer size” setting. Enabling “Only send changed data” has the effect that data packets are only sent over the network if the value in question has changed, which significantly reduces the volume of data being transmitted.

Read keyboard and DirectInput devices only when Zusi has the focus: When this function is activated, inputs from keyboard and DirectInput devices are only read if Zusi is the current active window. Otherwise, Zusi inputs are always read, even when it is running in the background.

Use immediate mode for keyboard input: In immediate mode, the keys in each computed frame are viewed and read once. If the user only presses very quickly between two frames, the operation is not recognised — and the lower the FPS rate, the more pronounced the effect. If this is not the case, an operations history is logged and then evaluated during the next computational step. This way, even very fast operations are fully registered.

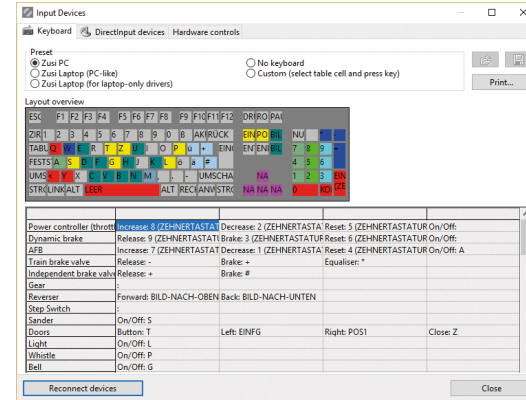
Ignore Windows key while in full-screen mode: The Windows key brings up the task bar in the foreground, which is intrusive in full-screen mode. The Windows key can therefore be deactivated using this setting to prevent this happening inadvertently.

Perform automatic DirectInput device assignment on startup: When this checkbox is ticked, every time the program is started, the function of the same name is activated from the configuration menu, where more detailed descriptions can also be found.

Check for program updates on startup: When this function is enabled, Zusi connects with the Zusi server (www.zusi.de) every time it starts up, and checks whether any new add-ons or main versions of the program are available. Only if that is the case, a message appears and, on clicking to confirm, the installation manager starts and the simulator is exited.

2.2.2 Input Devices

2.2.2.1 Keyboard



This tab is where the keyboard layout can be customised. At the top, a preset option can be selected, which can then be manually changed under “Custom”. In order to do so, the relevant field must be high-

lighted and then desired key pressed to which the user wishes to assign this particular function. If the key is free to be assigned, then the corresponding name will appear. The exact key is assigned, and not only the function of that key, so, for instance, there is a difference between the number 1 key in the main part of the keyboard and the number 1 key on the keypad, or the two shift keys on the right and left hand sides. If an assignment is deleted, a list of all keys can be seen by right-clicking the mouse. Here, the first entry in the menu deletes the function assignment.

The settings are saved in the file %Zusi-Daten%_Setup\input\individuell.keyboard.xml and automatically loaded from there the next time the application is started. Modified settings can be managed in other files using the “Load” and “Save” buttons. The key symbol displayed shows the current assignment, with a different colour being used for each function group. Clicking on the key displays the function group to the right of the keyboard.

The current keyboard assignments, including an image of the keyboard, can be printed out using the “Print” button.



2.2.2.2 DirectInput devices

This tab is where all devices which are read via the DirectInput standard interface can be managed, such as joysticks, gamepads and various other types of input devices and interface cards. These devices must also be available in the Windows Control Panel under “Game controllers”, which can be a useful tip for testing and debugging, if necessary. In normal operation, however, such devices are only configured via Zusi, and any calibration in the Control Panel is not relevant to Zusi.

2.2.2.2.1 Debugging

If certain buttons are no longer having any effect, it is possible that a particular device is no longer available in the simulator. A functionality test in the Windows Control Panel is a good place to start. If the device is not functioning there either, the USB cable should be removed and reinserted. The device must then be detected again in “Reconnect devices”.

If it is only in the simulator that the device is not found, then the aforementioned reconnection of the USB cable should not be necessary. Another possible source of error when several devices are being used is that devices could have been mixed up, in which case and the keys will have the wrong functions assigned to them. If the devices are always connected to the same USB ports, then this confusion should not occur. If the devices need to be reassigned in order for the predefined profile for each device to be read, please see also information on Automatic Device Assignment functions.

If the devices are functioning more or less correctly except for a displacement of the axis functions, then recalibration is needed.

2.2.2.2.2 Load/Save/Manage settings

The settings are saved in the file %Zusi-Daten%_Setup\input\individuell0.joystick.xml and automatically loaded from there the next time the program is started. The number (in this case 0) relates to the position of the device in the tab. If another device is then connected that appears first in the tab order, then this device will take on this configuration the next time the program is started, which is not usually desirable. For this reason, a separate joystick.xml file should be

saved for each configured device, which can then be used at any time to restore the device configuration. If the devices are always connected to the same USB ports, then the same configurations will be restored each time the program is started.

2.2.2.2.3 Reconnect devices

Zusi does not detect additional devices that are connected after the program has been started. In order to make new devices available without having to restart, the “Reconnect devices” button can be pressed, which results in all current devices being populated to the tabs and configured with their saved profiles according to the given sequence.

2.2.2.2.4 Calibration

The device axes need to be calibrated in Zusi, i.e. the relationship between the stick position and the measurement value needs to be established. The calibration dialogue box is opened with the Properties button at the top right, which displays a vertical bar for each axis. A distinction must now be made between linear and non-linear characteristic curves. In the former, the values are distributed linearly between the start and end values, as is the case with a joystick or an AFB (Automatic Driving and Braking Control) lever. Non-linear characteristic curves can define this relationship using an unfixed number of data points, which means that devices with an irregular notch arrangement, such as many original train brake valves, can also be compatible.

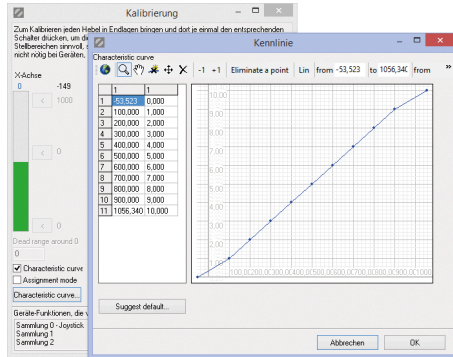
2.2.2.2.4.1 Linear characteristic curve

In this case, interpolation is linear, between the two end points. The checkbox “Characteristic curve mode” must be unticked for this setting. To calibrate the device, put the lever in the end positions and click the appropriate button to the right of the bar, which adopts the current value as the end point. Using the middle value and the dead area, a driver’s brake lever can also be installed that has a neutral position (with “dead area” for a degree of tolerance around the zero position) and a control area above and below neutral.

If there is only one control area, then the values for “middle” and “bottom” should be set with an identical value to one another.

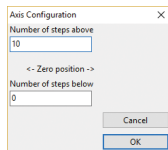


2.2.2.2.4.2 Non-linear characteristic curve



The non-linear characteristic curve can have an unlimited number of correlations between the lever position and the function. For this setting, the checkbox “Characteristic curve mode” must be ticked and the “Characteristic curve” button clicked.

The adjacent image shows the example of a train brake valve that has an irregular distribution of notch points, with a total of 11 notch positions. In order for all positions to be set correctly, the characteristic curve mode must be used. To create the table easily, the lever should first be calibrated linearly and also tested in the simulator, to ensure that the general relationship between control direction and function is correctly established.



After that, a table can be created as a basis using the “Suggest default...” button — shown here with values 10 and 0, which already contains the linear presets with the existing calibration values. The brake valve must now be moved to each notch and the actual current value entered in the table (shown

above, for example, in the window at the back, with a value of -152 at the top). Having established the rough settings in linear mode, it is also now easy to see in which axis direction the values are ascending, which means that the table fields can simply be assigned the actual values.

The ascending order in the left column of the table is very important. In other words, the raw data must always be sorted in such a way that the smallest value is at the top. The switching direction of the device is shown in the right-hand column — from 0 to 10 in the example shown here. If the 11 notches on the device lever are

arranged the opposite way around, then the sequence must be entered as 10 to 0.

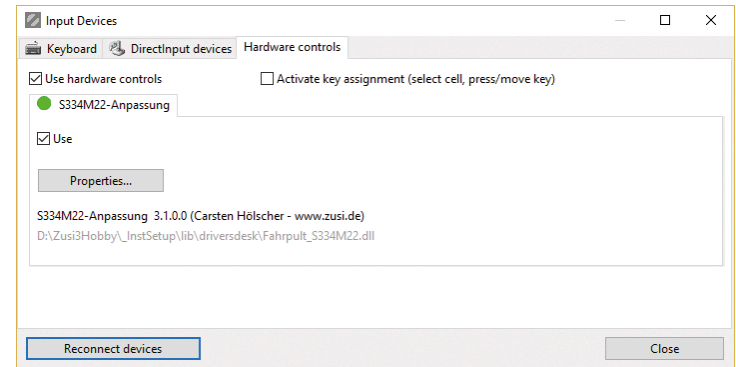
The blue value above the bar shows the notch identified by the simulator, and so it can be used as another way of directly checking that the assignment is correct.

2.2.2.2.5 Connection of more than one device

Any number of devices can be operated in parallel, and a new tab is opened for each device. Thus one joystick could be used as a brake and another as a power controller (throttle), for example. In order to avoid the configured devices being mixed up at the next startup, the user must make sure that the devices are managed in the system in the same order, which is ensured, for example, by their always being connected to the same USB ports.

2.2.2.2.6 Hardware controls

The “Hardware controls” tab is where hardware controls with particular interfaces and DLLs for data manipulation are managed.



2.2.2.2.6.1 DLL

Individual DLLs can be created that influence data flow within the simulator. In the above image, the control of an actual power controller (throttle) requires decoding of the switch positions in order to communicate the relevant positions for the purposes of Zusi. This



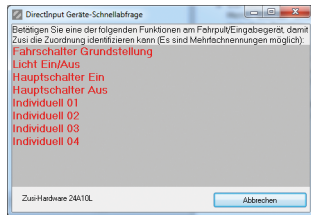
conversion and the generation of the corresponding operation commands is done with the help of a DLL. The DLL must be located in the %Zusi-Programm%_InstSetup\lib\driversdesk directory.

2.2.2.2.6.2 P.I. Raildriver

The Raildriver from P.I. Engineering is automatically recognised when it is connected to the PC, and it then appears in its own tab. Its operation within the Zusi device management is the same as the configuration of DirectInput devices. There is no need for additional software for Raildriver, as Zusi supports its functions directly.

2.2.3 Manual device assignment

If more than one DirectInput device is connected (and it is only then that this function is actually available), then the configuration files and, with them, the lever functions of the hardware controls are loaded in the same order in which the devices are found in the USB ports. If nothing is changed in the PC, this order will normally stay the same.



If the order happens not to be correct, which becomes apparent with incorrect function assignment of hardware controls, then this function can be used to correct it. This function facilitates the new assignment of DirectInput devices to the configuration files. Instead of manually

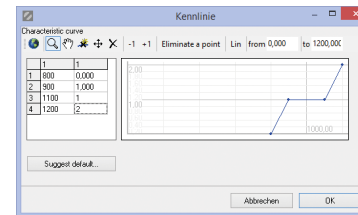
reassigning all layout files in the settings, only one of the keys shown needs to be activated for each device. All DirectInput devices are called up in order and displayed with their functionalities. For identification purposes, only one of the function keys on the hardware needs to be activated.

It can happen that one function group is called up more than once, and another not at all. The simulator is nevertheless able to bring up the devices in the correct order.

2.2.4 Automatic device assignment

This function allows several connected DirectInput devices to be fully automatically assigned to their corresponding functions, and is, in fact, only available if more than one device is connected.

A particularly convenient option is that each device can be fully automatically identified via an otherwise unused axis, irrespective of the USB connection sequence. For this option, the same axis must be identified as the assignment axis (for instance, always the first axis) for each of the devices, by ticking the "Assignment mode" checkbox.



A unique measurement value must be generated for the device. For instance, for each of three devices, a minimum value, maximum value and mid-value can be generated by connecting corresponding fixed resistors. The characteristic curve stored for

each axis must be structured in such a way that notch value 1 is always recognised. The adjacent image shows the characteristic curve for an example in which the measurement value on the assignment channel is around the 1000 mark.

When calling up the function for each device, the simulator looks for a configuration in which the identified axis gives a value of 1 with the help of the characteristic curve, and sorts the devices accordingly. In the first step, the current status is displayed: Red means incorrect assignment; green, correct assignment, and grey shows devices for which no assignment axis is defined.



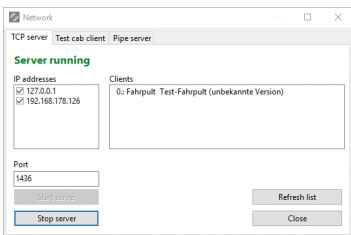
If everything is correct right away, the prioritisation is aborted; if not, then the two following windows will appear:



If there are no more axes free, then a defined initial position can of course be used for the lever in order to enable identification. Then all levers must be shifted into the first notch before calling up the function, and must also differ in their value ranges (measurement values/raw data) in order to make it possible for their assignment to be unambiguous.

2.2.5 Network

2.2.5.1 "Server" tab

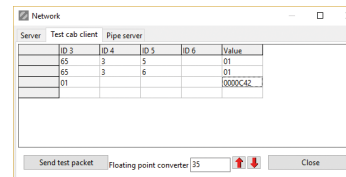


This tab displays whether the simulator's integrated TCP server is operational, and which applications have successfully connected to the simulator. "IP Addresses" lists the addresses of the simulator PC under which a client can log in.

Double-clicking on a logged-in client displays which values the client is requesting from the simulator.

If the message "Server stopped" should ever appear without this having been deliberately caused by clicking on the relevant button, then another application is blocking the designated TCP port (this could also be another driving simulator that is running in the background).

2.2.5.2 "Test cab client" tab



This tab assists in developing software that exchanges data with the simulator via the TCP interface. Specific data packages can be compiled here with the desired content in order to test the client application, without

having to create the conditions through an actual train journey. First of all, in the "Server" tab, click on the client to whom the test packet is to be sent. Each time the "Send test packet" button is clicked, a correspon-

ding packet is created and sent. No simulation needs to be started in order to do this. In order to generate the test packet, the required IDs must be entered in accordance with the protocol documentation. In the "Value" column, bytes must be entered in written hexadecimal form (always two digits per byte, with leading zeros where necessary).

To convert floating point values into bytes (or vice-versa), the two arrow buttons can be used to swap data between a highlighted cell in the value column and the floating point converter underneath the form. By right-clicking, more extensive conversations can be saved in the table in text format and reloaded.

In the image, train protection (x65) is addressed with IDs x03, x05 (Indicator 1000 Hz) and the value 01 (Indicator on) and corresponding IDs x03, x06 with value x01 (Indicator Train type U on). In the third line, ID x01 (speed in m/s) is set to the value x00000C42, which is 35 in the floating point converter.

2.2.5.3 Registerkarte „Pipe-Server“

This shows which applications have successfully connected to the simulator. For more information about the Pipe, refer to the ZusiDisplay integration. Double-clicking a registered client shows which values it requests from the simulator.



2.2.6 Show cab view

This function switches between displaying the cab view and just the scenery.

2.2.7 Show additional info in cab

This function displays additional information in some cabs, which can help in the operation of the traction unit. Not all cabs have to contain such textual information. The cab designer can incorporate it if, for example, some displays are not very easy to read.

2.2.8 Show train data window

This function switches the train data window with the working timetable and other train data on and off.

2.2.9 Show cheat sheet

This function displays additional information in the 3D window during the trip that the driver of the real locomotive would not have. This assists beginners who are not so familiar with the timetable and signals, so that they are always able to determine the permissible speeds, and it also helps route designers with debugging and quality control. From left to right:

- Current acceleration of the train in m/s² (negative values: train is braking)
- Current actual speed
- Current kilometre mileage
- Current permissible maximum speed
- Next scheduled stop including target route, as soon as the stop has been captured by the route analysis
- Next relevant braking point, with distance and permissible speed (most critical case from signal, route and train protection data)
- Simulation time of day

2.2.10 Hide menu

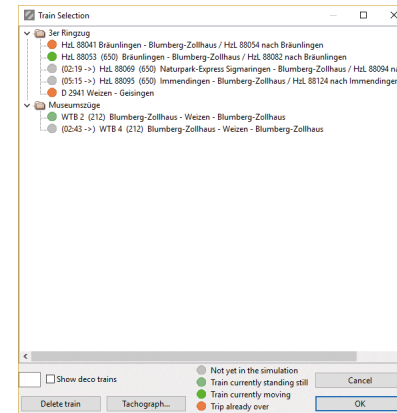
This function makes the main menu invisible. It can still be accessed at any time by right-clicking in the 3D window or in the basic simulator screen.

2.2.11 Set window size to cab view size

When this function is enabled, the window in which the graphics are displayed is set to exactly the same dimensions as the cab view, so that the cab view is displayed without scaling and therefore with optimal quality.

2.3 "Navigation" menu

2.3.1 Take over different train...



A different train can be taken over at any time and driven on from its current position manually. When the relevant menu function is selected, the window with the list of trains opens. Which trains are currently driving can be seen immediately from the colour coding (see legend). For trains which are still awaiting deployment, the length of time before it is due to become operational is shown in front of the train number (in hours and minutes).

Trains which have already exited the simulation are listed, although they cannot be selected.



Search: The field underneath the table enables the user to filter the listed trains by an element of the train description, e.g. by train number or category.

Show deco trains: Deco trains mostly travel only a very short distance, or do not have a traction unit. These trains are normally hidden in the train selection window, but can be unhidden by ticking the checkbox in the table, which will make them available to the player in the same way as other trains.

Delete train: The highlighted train will be removed from the simulation, and all of the routes travelled by it will be deleted.

Tachograph: The tachograph of the highlighted train is called up, and contains the entire route travelled from the start to the current point in time.

2.3.2 Train locations

This relates to the viewpoints around the train being driven by the user. In addition to the usual cab view, views from the outside are also possible.

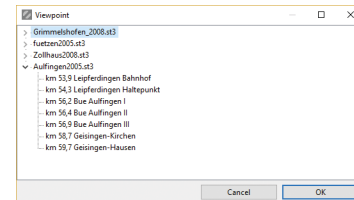
2.3.2.1 Viewpoint in driver's cab

The cab view is the standard one. In addition to the normal view, any number of additional perspectives in the cab can be defined. These are all of equal value in terms of function, and can also display the visible operational elements as animated objects. The other views are normally controlled using the four arrows separate from the numeric keypad, with which the user can toggle from one view to the next within a cross shape on two axes. In the example on the right, starting from the standard view 0.0, there are two additional views (1.1 and 1.2) in front, which can be accessed by pressing the top arrow key once or twice, respectively. The down arrow switches back again to the previous view. On the left and the right in this example, are the views 2.1 and 3.1, which are accessed via the left → and right ← keys.

2.3.2.2 Viewpoint external view of train (front/rear)

For this view, the camera is positioned outwards from the front or the rear of the train. Moving the mouse while holding down the left mouse button allows the user to pan on the vertical axis. While doing so, the train remains in manual operation.

2.3.3 Viewpoint trackside location



Any number of fixed viewpoints can be defined in the route, from which the proceedings can be observed. All trains will then drive in autopilot mode. Returning to the train which was last being driven by the user will then only

be possible using the “Take over different train” function.

The list of trains will be grouped by route modules.

2.4 “Timetable creation” menu

This menu is used to create the timetables, i.e. when which trains are travelling on which rail network and how. The timetable consists of a basic file (file extension fpn) and any number of train files (trn). The menu item “Create new timetable” is used to create a new timetable with the aid of a wizard. If an existing timetable is to be edited, the menu item “Edit current timetable” is selected after loading the timetable instead of starting the simulation.

2.4.1 Timetable file

The timetable file contains the list of trains and route modules which can be edited in the tabs outlined below. When “Save timetable” is clicked, the selected timetable file is filed, and a trn-file for each train is also saved in the subdirectory %Dateistamm%.

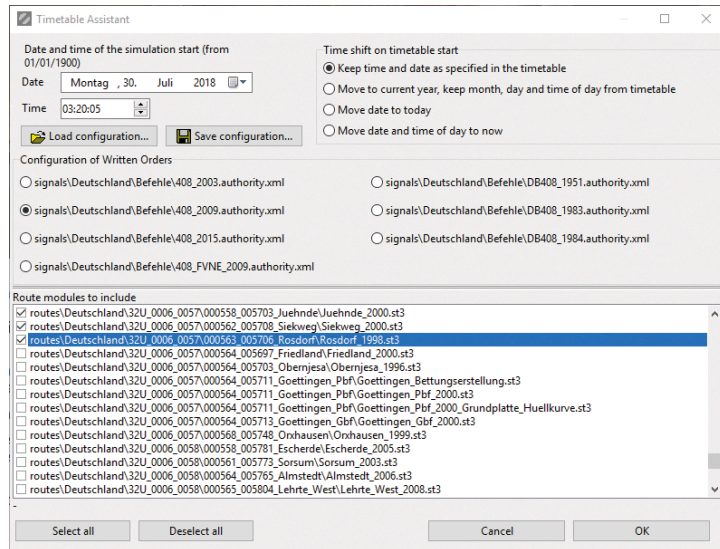
%Dateistamm% stands for the file name of the timetable file, without



the filename extension. If a timetable is saved under a new name, a full copy of all timetable and train data will be created.

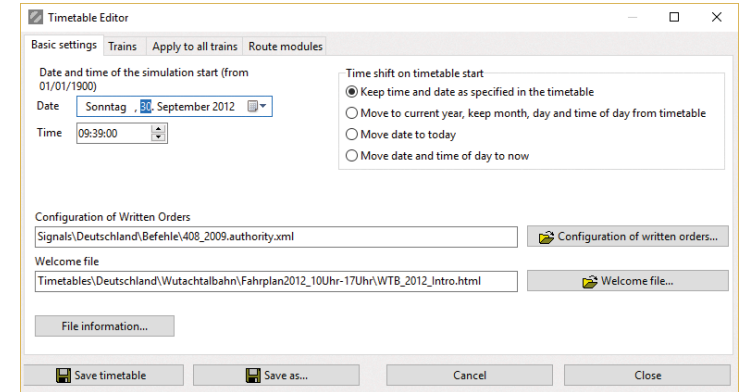
Also, all timetable files that belong to the trains will be copied into the new directory and the paths will be adapted.

2.4.1.1 Timetable assistant



The menu item “Create new timetable” queries the basic settings for the timetable. These are the start time and mode, the command configuration to be used and the modules to be driven. The current choice of route modules can be saved under Load/Save configuration, or reloaded again later. For the list of command configurations and modules, the files in the sub-directories Signals and Routes on the hard drive are searched and displayed for selection. After selection, the optimum UTM point is calculated, which may take a little time, and the timetable editor opened where the trains can be created.

2.4.1.2 “Basic settings” tab



Date/time: Start of the simulation

Time shift on timetable start: The start time of the simulation — i.e. the date and time contained in the simulation data, which affects time display, and weather and timetable data — can be set in four ways. The standard setting is for the simulation to start running as per the date defined in the timetable. Using one of the three other options, the start of the simulation is moved to the current year, date or real time before the trains are brought into the simulation.

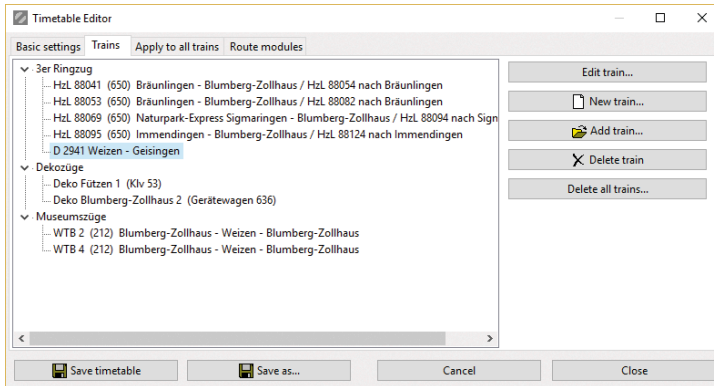
Configuration of Written Orders: This file contains the settings relating to the order forms and rear signals to be used in this timetable. Further information on this can be found in the sections on signals in the chapter that concerns the 3D Editor.

Welcome file: An optional html file which is displayed on the right-hand side of the simulator window when the timetable is selected, and provides brief information on the timetable and the route.

File Information: see section ??



2.4.1.3 “Trains” tab



The “Trains” tab lists all the trains in the timetable. Using the buttons on the right, trains can be added, deleted and edited, as explained in the “Train Editor” chapter later on. (The Train Editor can also be opened by double-clicking on a train.) When a train is deleted, it is removed from the timetable. The train file remains on the hard drive and can be restored to the timetable by clicking “Add train”.

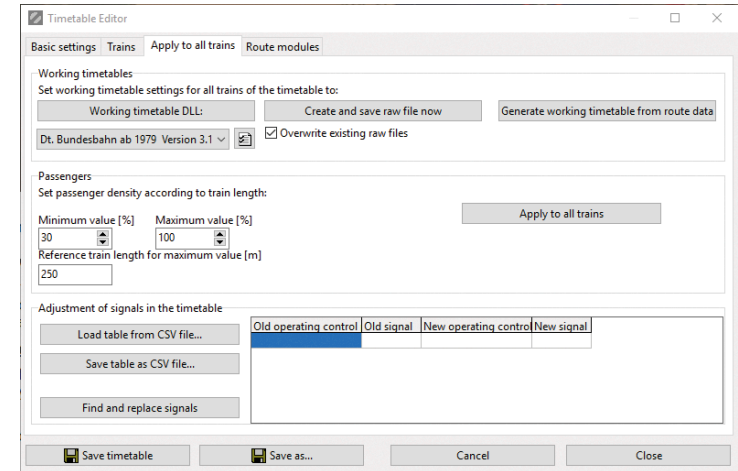
2.4.1.3.1 New train

This function starts up the Train Assistant, which requests the key data, transfers these to the detailed form and generates a raw timetable. This will be explained in detail later.

2.4.1.3.2 Add train

With this function, a train file that is already saved on the hard drive can be imported into the timetable.

2.4.1.4 “Apply to all trains” tab



2.4.1.4.1 Working timetables

The working timetable is adjusted individually for each train, and this process is explained in full later on, in the chapter on train settings. In order to understand the explanations below, the relevant chapter should be read first.

Working Timetable DLL: If a complete timetable is to be converted to another working timetable DLL or generated from scratch, this can involve a tremendous amount of work if it is a big timetable. The workload can be reduced in one click of the mouse, using the “Working Timetable DLL” button: The selected DLL will then be assigned to all trains.

Create and save raw file now: In order to avoid having to generate working timetables from scratch for this timetable each time the simulator is started, the timetable.xml file for each train needs to be moved from the temp folder to the timetable folder, and assigned to the train. This would be extremely time-consuming for large timetables if carried out manually, but this button cuts down the work. Every train is changed to “Supply raw file” mode, and a timetable.xml



file is created and saved in the train directory, and assigned to this train. The advantage of this process is that the simulator takes less time to start up for large projects, as it does not have the laborious task of computing the route analyses each time for the timetable.xml files. It should be noted, however, that if changes are made to routes or train data, then a new set of timetable.xml files will need to be created. It is therefore only worth doing once the simulation is fairly well established, e.g. ready for publication.

Generate working timetable from route data: This button switches all trains in the timetable to the “Generate working timetable from route data” process, thereby effectively undoing the step described above.

2.4.1.4.2 Passengers

This function allows the passenger density on the platforms to be set to the appropriate value for the timetable.

Minimum value and maximum value: The result will always be somewhere between these two settings.

Reference train length for maximum value [m]: The train length is considered in relation to this reference value when calculating the passenger density. The formula is as follows:

$$\text{Density} = \frac{\text{Train length}}{\text{Reference length}} \times 100$$

If the result of the formula lies outside the boundaries of the minimum and maximum values, it will be capped at the relevant threshold.

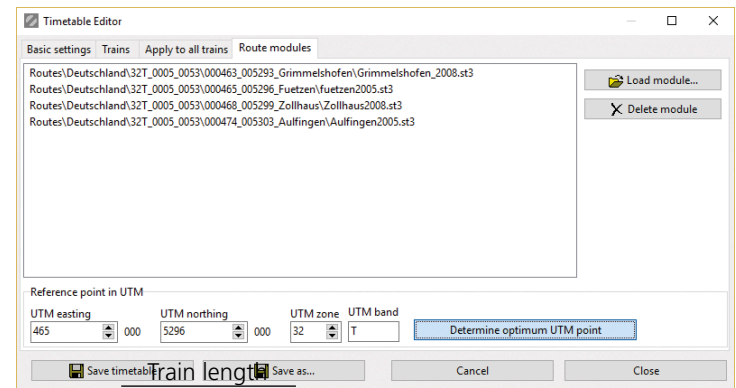
2.4.1.4.3 Timetable signal adjustment

This function is used if any signal names have been changed on a route and there are already timetables that need to be adjusted. Revising all the trains manually would be a tremendous amount of work. The item “Search and replace signals” can be used to change all the timetable entries, rerailing lines and route specifications in the timetable. A line is entered in the table for every signal change that needs to be made. The table can be saved/loaded to a csv file for external editing using the two buttons. The function searches the timetables for old signal names (the first two entries for operating

unit and signal) and replaces them with the new signal name (third and fourth entries for operating unit and signal).

If, for instance, the signal “Uelzen A” is changed to “Uelzen A432”, one line is to be used for this in the table with the 4 entries “Uelzen”, “A”, “Uelzen” and “A432”. Note that the lines are processed from top and bottom to keep them in the current versions. So, a crossover of signals will only work if the first edited signal is temporarily given a different name.

2.4.1.5 “Route modules” tab



This tab is for compiling the route modules on which the trains will be running. The order of the modules has no bearing on this function. A UTM point must be defined to sit as centrally as possible within the whole route, so that the route can be loaded with as small coordinates as possible. The individual modules will then be loaded in relation this central point. The “Determine optimum UTM point” button temporarily loads all the modules listed above and determines this point automatically. This can be a somewhat lengthy process owing to the time it takes to load the whole route.

After the module has been assembled, the timetable has to be saved, the timetable editor closed, and the timetable loaded once again. Only once this has been done are all the files correctly loaded, after which the trains can be created.



2.4.2 Train Editor

2.4.2.1 "Basic train data" tab

The basic train data settings are established in this tab.

2.4.2.1.1 Basic train data

Train category: Free text field for defining the train category, e.g. ICE, E, Dg

Train number: Free text field for entering the train number. Each number may only be entered once in a timetable. The file name for the train file is generated from the train category and train number, which means that if there are duplicate entries, data will be lost.

Train run: Free text field for entering the train run, which can be longer than the section that is reproduced in the simulation.

Train priority: The train priority is the distance at which the train is announced in advance at operating control points — in this case

2500 metres before the first main signal. This setting allows trains to be prioritised to a degree, as a train with a higher value in this field will be processed earlier by the signal box routines and will therefore be given its route before trains with a lower priority setting.

Custom vehicle designation for working timetable: A traction unit class can be entered here for the header of the working timetable. If this field is left empty, the contents of the "Class" field from the vehicle file of the train being driven is used instead for this setting.

Timetable group: Free text field that sorts trains into groups in the selection dialogue boxes to enable easier viewing. One node is created in the selection tree for all trains in the same timetable group. The trains can be subdivided into routes, deco trains, etc. if desired.

2.4.2.1.2 Definition of train entry point

These settings specify the point at which a train enters the simulation, for which one of the two possible methods must be selected:

- Under normal circumstances, the train will enter the simulation by means of specifying the route. This is selected in the box to the right, and transferred to the field by clicking the red arrow. During the simulation, this route will be set with all the dependencies and conditions that are normal for the dispatch process, and the train will then enter the simulation. It is important that the registers for the route are free — in other words, the route is free of other vehicles.
- The alternative to this is to bring the train into the simulation directly at the train entry point defined in the route. This will then take place outside the route logic at the precise time that is specified in the timetable. The train will only be included in the signal box routine after the next signal, and could therefore be brought into the simulation on a block section that is already occupied. This option is therefore not suitable for normal timetable operations with several trains running.

Train position after entering the simulation: There are four options for determining how precisely the train will be placed on the route. If "Start of route" is selected, the rear end of the train will be at the starting signal of the route; with "Advance to signal", the front end



of the train will be at the end of the route just before the final signal, and positions between these two boundary conditions can be set by entering a value in the “Specify value” field. Generally speaking, however, “Automatic” should be selected, in which case a passenger train is put into the simulation at the relevant platform or, where there is no platform or the train is a freight train, it will be put in front of the signal if the route is somewhat short, and at the beginning if the route is long, in order to ensure that a distant signal is passed and the driver does not encounter a main signal unexpectedly.

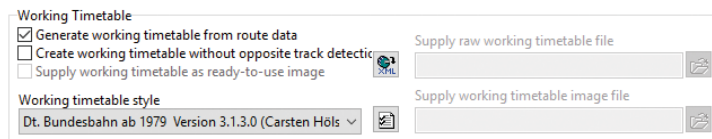
2.4.2.1.3 Train type

Freight trains do not take the platform status into account when stopping, but are only concerned with the signals; nor do they carry out door-closing procedures.

2.4.2.1.4 Working Timetable

The following three options are available for preparing a working timetable. It should be noted that the possibility exists to assign these settings to all trains with one click of the mouse. For more information see the 2.4.1.4 chapter on the Timetable Editor, on page 25.

2.4.2.1.4.1 Generate working timetable from route data



With this setting, the working timetable is generated from the train and route data every time the simulation is started. A timetable.xml file is first created and saved in the temp directory. This file contains all the data which may be useful for working timetables, in a universal format. Graphics are created from these data in a subsequent step. This can be done using external software such as Zusi-Display that is supplied with the timetable.xml file, or using Zusi’s own working timetable display. A DLL is used to convert the timetable.xml file to a bitmap graphic for the purposes of Zusi, and this must be selected under “Working timetable style”. This DLL reads the timetable.xml file and stores a bmp or tiff file in the temp directory, which the simulator displays when a train is taken over.

Create working timetable without opposite track detection: Under normal circumstances, information on regular and opposite tracks is gathered for tracks on open sections irrespective of the timetabled itinerary, and is stored in the timetable.xml file so that the timetable display can show opposite tracks if necessary. When this checkbox is ticked, only the train’s standard itinerary is looked up and stored in the timetable.xml file. This checkbox should normally be left unticked.

Sequence in Zusi using the example of a simulation start-up with the D 841:

Creation of the file%Zusi-Daten%\temp\D841.timetable.xml from route and train data

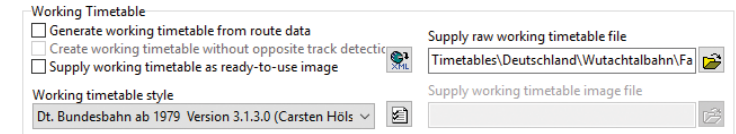
↓

Creation of the file%Zusi-Daten%\temp\D841.bmp by DLL

↓

Display of the file%Zusi-Daten%\temp\D841.bmp in the working timetable window

2.4.2.1.4.2 Supply raw working timetable file



If the automatically-generated timetable.xml file does not reflect the desired result, an individual, manually-generated timetable.xml file can be supplied.

The first step in the simulator start-up will thus be skipped, and the timetable graphics will have to be generated using DLL. The individual timetable.xml file should be saved in the timetable directory.

Sequence in Zusi using the example of a simulation start-up with the D 841:



Specify the saved file %Zusi-Daten%\Timetables\Deutschl...\D841.timetable.xml



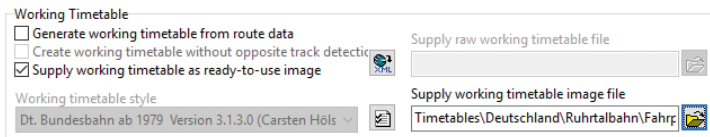
Creation of the file %Zusi-Daten%\temp\D841.bmp by DLL



Display of the file %Zusi-Daten%\temp\D841.bmp in the working timetable window

The “Create raw file now” button creates the xml file from the current train and route data and saves it in the timetable directory.

2.4.2.1.4.3 Supply working timetable as ready-to-use image



If the desired result cannot be achieved using a manually-specified timetable.xml file either, then a third option is to manually create a bitmap file and use this directly. This has the distinct disadvantage, however, that an external program such as Zusi-Display will not be able to display the timetable, as the required universal timetable.xml file will not be available. This option should therefore only be used as an exception. The individual bmp file should be saved in the timetable directory.

Sequence in Zusi using the example of a simulation start-up with the D 841:

The first step is skipped.

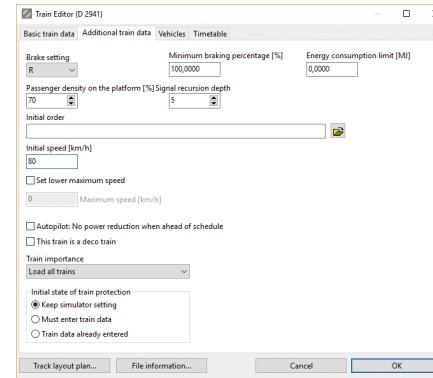


Specify the saved file %Zusi-Daten%\Timetables\Deutschl...\D841.bmp



Display of the file %Zusi-Daten%\Timetables\Deuts...\D841.bmp in the working timetable window

2.4.2.2 “Additional train data” tab



Brake setting: Brake setting for the whole train. If individual vehicles are to run with deviating brake settings, the stored preset can be overridden via the vehicle settings tab.

Minimum braking percentage: This gives the option to enter the minimum braking percentage, which will then appear in the

working timetable header. There is currently no effect on train operation if the train falls below this braking percentage.

Energy consumption limit: If this value is greater than zero, the energy consumption is included in the evaluation at the end of the trip. If the value set here is exceeded, points will be deducted in the evaluation.

Passenger density on the platform: This is a number between 0 and 100%, which determines what proportion of the passengers created in the system for a station platform will be activated when the passenger train stops at that platform. The longer or busier the train is, the higher this percentage should be.

Signal recursion depth: The meaning of signal recursion depth is explained under “Timetable basics”. The value should not be set very high, as the resulting high number of route variants that would be investigated can lead to significant computation times, thus compromising performance.

Initial order: A train-specific order form (HTML format) can be defined here, that will be displayed on startup.

Initial speed: The train is brought into the simulation at this speed. If the value is not set at 0, then it must be ensured that the train does not come into the simulation shortly before a main signal, otherwise this would be overruled and the train would fall out of the simulation logic.



Set lower maximum speed: This gives the option to limit the maximum speed of the train to a lower value than the speed that would actually be allowed for the route and vehicles.

Autopilot: No power reduction when ahead of schedule: The standard behaviour of the autopilot is to stick to the timings in the timetable as far as possible. If a train is running before its scheduled time, the autopilot will seek to address this by driving more slowly along a section. If the “No power reduction...” checkbox is ticked, then the autopilot will always drive at the highest possible speed. With complex timetables, this setting can lead to complications: in the case of a train that is running considerably ahead of schedule, it is possible, for example, that the tracks it is supposed to run on are not yet clear and the train will thus block the route for other trains.

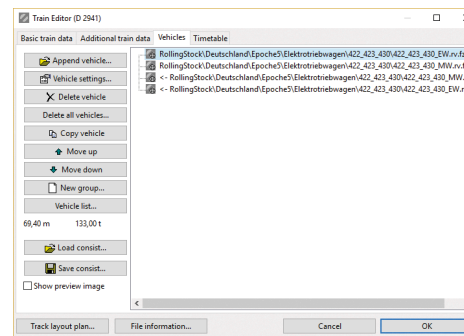
This train is a deco train: These trains are not shown by default in the train selection list. This setting should be selected for trains that consist only of stabled wagons and can therefore not be driven by the player, or can only run for very short distances and therefore do not offer the user much of a driving experience. Even if this checkbox is not selected, a train can automatically be deemed a deco train by the simulator. This is the case if the leading vehicle in the train has been marked as a deco vehicle in the vehicle editor (see section ??).

Train importance: For less powerful computers, the amount of railway traffic can be reduced by the end user in the main simulator window before the start of the simulation. This setting determines at which importance level the train being edited will be included in the simulation. Those creating larger timetables should prioritise their trains accordingly in order for this option to actually be available to the user. The option to “Load all trains” is the lowest priority setting available. This is designed for deco trains. Trains that are particularly significant to the timetable should be marked with the priority level “Load only the most important trains”.

Initial state of train protection: A train-specific setting can be selected here that may possibly override the basic setting of the simulator to “Set up train protection manually” (see section 2.2.1.4). For timetables that are designed for the general public, the option to “Keep simulator setting” should be selected here, as not all users will have

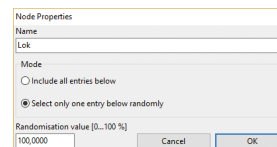
the necessary peripherals to set the train data manually. For one’s own timetables, however, train-specific behaviour can be set if desired, without having to always change the simulator settings first.

2.4.2.3 “Vehicles” tab

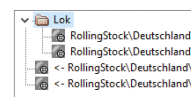


This tab contains the list of vehicles of which the train will consist. The order and selection of vehicles can be managed using the buttons on the left-hand side. The individual entries in the list can also be moved around by dragging and dropping with the mouse.

2.4.2.3.1 Vehicle groups and random selection



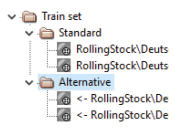
In the screenshot above, the train has a fixed consist of four vehicles. To build in more variety with the trains, the vehicle list can be organised in a hierarchical structure that can be managed on the basis of random settings. To build the hierarchy, a tree must be created using the “New group” button. The window shown here on the right is opened by double-clicking, or by single-clicking on the “Properties” button. The group can then be given a name, and it can be determined how the subordinate objects are treated. This behaviour can be explained using two simple examples, although very complex structures can, of course, also be created.



Example: The locomotive of a train is to be swapped at random with another one, while the coaches are to always remain the same: A group named “Lok” (any name can be given) is created and the setting “Select only one entry below randomly” applied, and



the two locomotives in question are added as a subgroup. The three coaches are added at the parent level. For the purposes of timetable creation etc., the first entry under the “Lok” group (i.e. E40.rv.fzg) is used without randomisation. However, when the simulation is started, one of the two locomotives is selected at random. The likelihood of the first locomotive being exchanged is determined by the “Randomisation value” setting. At a setting of 100% as shown in the screenshot above, both locomotives are equally likely to be selected. If the value is lowered to, say, 20% then the first locomotive has an 80% chance of being selected, while the second one has a 20% chance of being selected (in other words, one or other of the two vehicle files).



Example: A multiple unit is to be replaced by another one at random: Since all entries in the lowest level always have to be taken into account, a node with influence on randomness must first be created (the name allocated in this case is “Train set”). Below this, a node with no influence on randomness is created for each of the two multiple units in question, each of which contains the vehicles in the multiple unit. The simulator now does the following: At the “Train set” node, one of the two subordinate objects is selected at random (i.e. either “Standard” or “Alternative”). The selected node in both cases belongs to the “Include all entries below” type, so the two — or three — vehicles listed underneath will be taken as a whole into the consist.

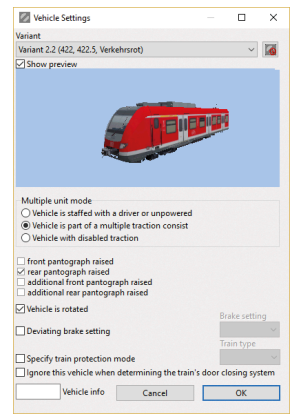
2.4.2.3.2 Vehicle list

When the “Vehicle list” button is clicked, a list appears that resembles an operational vehicle list, providing a quick overview of maximum speeds, weights and braked weights in the various brake settings for the individual vehicles as well as for the entire train. After adding or deleting vehicles, the vehicle list is only updated once the train editor has been closed by clicking OK, and the train has been called up again.

2.4.2.3.3 Vehicle Settings

The data for the highlighted vehicle are displayed for editing by double-clicking on a vehicle or clicking the “Vehicle Settings” button. The window described below will then open.

2.4.2.3.3.1 Vehicle variants



Variant: The vehicle variant is chosen from the selection list (e.g. by colour scheme, depending on the vehicle file). The sequential number variant is displayed in square brackets in the vehicle overview.

Show preview: Ticking this checkbox creates a preview of the selected vehicle variant. This image is created directly from the 3D file for the vehicle, which requires a certain amount of computing time. This option is therefore deactivated by default.

2.4.2.3.3.2 Multiple unit mode

When several powered vehicles are running in a consist, their behaviour can be configured here. Depending on the setting, another symbol is displayed in the overview to make the consist status visible at a glance.

Vehicle is staffed with a driver or unpowered:

When locomotives that are not the lead vehicle are running with this option, they will reflect the driving behaviour (power/braking) of the lead vehicle. No numeric data are transmitted from these vehicles to the lead vehicle, however. From a visual perspective, an individual (virtual) driver will be seen to be operating the vehicle. Examples of use: Wagons, trains with only one powered vehicle at the front of the train, a second locomotive in double heading or where there is a helper locomotive in trains with excessive weight.

Vehicle is part of a multiple traction consist: The vehicle mirrors all the operations of the lead vehicle, including main-switch and pantograph operations. The lead vehicle and the vehicle being pulled must be technically compatible for such an arrangement, as otherwise not all of the operations may be able to be carried out on the pulled vehicle. Vehicles that are capable of being used in multiple unit mode in



reality should also be set up as such in the simulator.

In this mode, if the lead vehicle is a cab car, then the measurement values of the first powered vehicle with this setting in the consist will be reported to the lead vehicle and can be displayed there in the driver's cab.

Examples of use: Double heading, push-pull trains, tractive units and other cases where powered vehicles are not staffed by a driver. Note: With trains that are scheduled to switch to the cab at the other end of the train, the lead vehicle should also run in multiple unit mode, as the vehicle previously driven by the player will have to continue without a driver after the manoeuvre.

Vehicle with disabled traction: The traction system of the vehicle is switched off and cannot be activated retrospectively during the current simulation. This option is designed for locomotives that are running cold in the consist.

2.4.2.3.3 Pantograph

This section is for selecting which pantograph is addressed when pressing the Pantograph button in the cab. This configuration is raised after the train is brought into the simulation. The pantograph is not only visibly raised, but also from a functional point of view, there will only be a power supply to an electric vehicle if a pantograph is raised. When none of the checkboxes is ticked, electric drive units on the vehicle in question will be permanently deactivated and cannot be made operational retrospectively.

Extra care must be taken here with certain tractive units. The vehicle component that carries a 3D pantograph is not necessarily identical to the vehicle component that contains an electric drive unit. It is therefore recommended that with these kinds of electric traction units that at least one of the checkboxes is ticked on all of the vehicle components.

Pantographs 1 + 2 and 3 + 4 are swapped over when trains are reversed. A vehicle with a raised rear pantograph lowers this during the reversing manoeuvre and raises the front pantograph. The same applies if one of the additional pantographs was raised. This is then lowered and the other additional pantograph is raised.

2.4.2.3.4 Deviating settings

Vehicle is rotated: When this checkbox is ticked, the vehicle is rotated 180° in the consist, as would be the case, for example, with a cab car running at the back. The rotation is also displayed in the vehicle overview by a left arrow.

Deviating brake setting: Here, a brake setting that deviates from the global train setting can be selected for the vehicle. This is also displayed in brackets in the vehicle overview.

Specify train protection mode: A train-type custom setting that deviates from the default value for this vehicle. This is also displayed in brackets in the vehicle overview. Otherwise, the train type is generally determined by the braking percentage.

Ignore this vehicle when determining the train's door closing system: When this checkbox is ticked, the vehicle is not included in the calculation of the lowest common denominator for the door closing system in the train. This means, for example, that a freight wagon can run in a passenger train consist without this giving rise to the designation of "No door closing system" for the whole train. This setting is indicated in the vehicle overview by a "T".

2.4.2.4 "Timetable" tab

2.4.2.4.1 How it works

The timetable for the train specifies its routes and running times. It works on the basis of a long list of signal entries, each with its own arrival and departure time, which the train is set to pass consecutively. When the simulation is running, the signal-box functions search all the train routes connected with the relevant presets and set the appropriate routes, provided they are not being used by other trains. There can be a certain degree of leeway with the process, so that, arbitrarily, not always the same train routes will be set each time the timetable is run.

The timetable entries can be defined as a stop (specified arrival and departure times) or as a pass (arrival time is 0, displayed as 30.12.1899, 00:00:00). Pass times are useful if the train is not stopping for a longer period of time, so that the driver has a reference



point from which he/she can tell whether the train is on time and also whether the defined route is the desired one where there is more than one option. Furthermore, there should not be any large gaps in between timetable entries. How large these gaps are allowed to be is determined by the signal recursion depth that is set individually for each train. This specifies over how many main signals the route will be found without any other details being specified. For instance, if the value is set to 3, the route will still be found if every 3rd signal in the journey is given as a timetable entry.

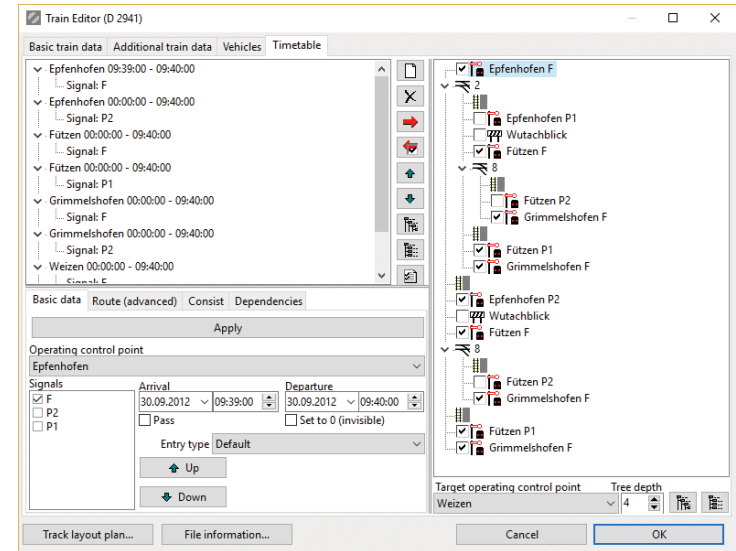
The next upcoming signals are set when the train approaches at a distance that is less than the “Train priority” status that can be set for each train. In the case of scheduled stops, the signal that follows the stop is set no earlier than 1 minute before the scheduled departure time. In the case of passes, the signals are also set if the train is running ahead of schedule. In LZB operation, the train priority is increased to the maximum LZB target distance.

The train is thus brought into the simulation at a specified start time (i.e. the arrival time of the first timetable entry); it runs along the routes until the last signal and is then taken out of the simulation (i.e. at the departure time of the last timetable entry).

If a timetable is created that is not technically operable from the point of view of the track, then the train will only run until the next signal that it is technically able to reach and will stay there permanently. Such errors should, however, be identified when the working timetables are generated, as a corresponding error message will appear.

2.4.2.4.2 User interface

Below is an overview of the control elements:



The timetable for the train is displayed in table form in the top left-hand corner (here shown with stations Bad Driburg, Langeland and Altenbeken). This table always shows the current, definitive timetable for the train. The other input options simply assist with creating this list.

The timetable entry selected here is made available in the tabs below to enable editing of the departure and arrival time along with other settings. Changes must be saved using the “Apply” button.

On the right is the route structure tree. This helps with orientation along the route, as it lists the main signals and platforms in the correct order.

On the bottom right, the destination station for the trip is selected. This is not actually stored in the train file, but simply ensures that the structure tree is built in the direction of the desired trip destination.



2.4.2.4.3 "Basic data" tab

2.4.2.4.3.1 Operating control point

The name of the operating control point is typically a station or part of a station, a flagging stop etc. The name may only occur once in the loaded route network.

2.4.2.4.3.2 Signals

This is for the selection of signals that the train may encounter with this timetable entry. For flagging stops, there are no signals to be selected. In all other cases, at least one signal must be defined. This will then be encountered with 100

When adding signals, care must be taken to ensure that the timetable is ultimately still operable. For example, although the final destination of the timetable may be reachable via a second, alternative signal entry, it could be that the next signal given in the timetable cannot be reached via that alternative signal. In such cases, a train that has been driven to this second signal would not be allocated any further route, and would stay in that spot permanently.

2.4.2.4.3.3 Arrival, Departure

Arrival and departure times at this operating control point, as explained in the introductory paragraph for this section. A pass-through is defined by a zero (0) arrival time, displayed as 30.12.1899, 00:00:00. If the departure time is also set to 0, then the train is controlled by this timetable entry, although this will not appear in the timetable.

There are two other special functions: The arrival time of the first timetable entry defines the time at which the train will be brought into the simulation. The departure time of the last timetable entry defines the time at which the train will be taken out of the simulation.

2.4.2.4.3.4 Entry type

The entry type specifies the desired behaviour for scheduled stops:

Default: The "Default" type stipulates normal stopping. Typical uses of this setting are passenger trains with scheduled stops, and all types of trains that are due to stop somewhere, e.g. to allow another train to overtake.

Auxiliary entry, no significance for operation: This type is intended for cases for which the Zusi timetable process requires an arrival and departure time, but where no scheduled stop is stipulated. An example of this is a train entering the simulation at a train entry point on an open stretch after which the next main signal is an automatic block signal or an entrance signal. The setting for the train entry point requires an arrival and a departure time, even though a passenger train stop is not possible in this case. Another instance of where this setting would be selected is when the target signal at end of the route module cannot be reached owing to a "Remove train" event that is in front of it. A failure to stop in this case would not lead to points being deducted at the end-of-trip evaluation due to a scheduled stop that was not achieved.

Intermediate stop: In the case of an "Intermediate stop" the train does not have to stop if this is not necessary. The simulation runs according to the "Default" type, however, it is possible with this specification to show a "+" in timetable displays.

Stop on request: A "Stop on request" currently behaves in the simulation in the same way as a "Default"-type stop, but can be denoted in timetables with an "x".

2.4.2.4.4 "Route (advanced)" tab

This tab allows further customisation of the route to be selected.

Enforce routes: With this setting, a route can be specified that is to be set for this train at the selected timetable entry.

Generally speaking, this is not necessary and should therefore not be selected, as the route is explicitly defined through the designation of

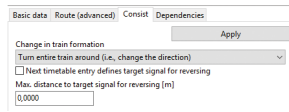


the start and target signals. There can also be situations, however, in which routes run in parallel, e.g. for short and long entrances in connection with marker light switches, i.a. In such cases the start signal and target signal are not always clear, so the desired route can be explicitly defined using this route specification option.

Trigger additional events: Here, additional events can be triggered that are not contained in the route itself (not all the available events would be appropriate, however). The events are triggered as soon as the train has passed the signal defined in the timetable entry under the “Basic data” tab.

Trigger substitute signal: A substitute signal can be specified here that is showing a different signal aspect to the regular one. When several signals are selected for this timetable entry, then it must be manually ensured that they can all show this substitute signal. This selection only relates to the first signal in the selected list.

2.4.2.4.5 “Consist” tab



Change in train formation: This function enables scheduled turning of the train. Turning manoeuvres are possible anywhere where there are main signals

in front of the train in both the old and the new driving direction. There are two possible kinds of turn:

“Turn entire train around” rerails the train in the opposite direction. The old lead vehicle also becomes the new lead vehicle. Application: Freight trains and other trains that do not have a cab at the rear end.

“Switch to cab at other end of train” requires there to be a cab in the last vehicle of the train. Application: Tractive units, push-pull trains, and trains with tractive units at both ends.

“Next timetable entry defines target signal for reversing”: This checkbox must be activated when (and only if) there is a set of facing points in between the new front of the train and the next main signal after the train has been turned around and so the intended main signal for the next part of the route needs to be defined more precisely. If the checkbox is left unticked, then the direction in which the train will continue depends on the direction in which the points

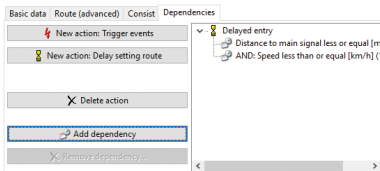
are facing when they are reached. In some circumstances this could result in the train not being able to reach its intended destination.

Max. distance to target signal for reversing: This field must be set to a sensible distance. Generally speaking, the simulator carries out a prescribed reversing manoeuvre as soon as the train stops when a reversal is planned at the next main signal. In view of emergency braking events etc., it is possible that this stop might not take place at the intended stopping place. This would result in an untimely reversing manoeuvre, with the possibility of the train being turned in a place that is not before the intended signal in the opposite direction. This maximum distance setting therefore suppresses the reversing manoeuvre for as long as the train is not close enough to the reversal target signal. Based on the length of the train, this setting should be low to ensure that the whole of the train will fit on the intended reversing track. On the other hand, the maximum distance should not be unnecessarily small, so that the intended reversing manoeuvre can still be carried out in the event of an emergency braking incident that takes place very close to the target signal.

Timetable structure after the reverse: The Train Assistant is not able to deal with reversing manoeuvres, but can only find routes that are continuous from start to finish. There are two options for creating a route after a reversal: A second train can be created for the train run after the reversal, and the file for this merged with the first train file using Text Editor. Alternatively, the entries have to be created manually after the reversal. The process is explained later on under “Structure tree”. In order to be able to use the structure tree, a starting route and target operating control point must be selected temporarily that are suited to the run after the reversal manoeuvre, so that the structure tree is built with the appropriate signals. The longer the train is after the reverse, the more practical it is to create a 2nd train and add it via a text editor.



2.4.2.4.6 “Dependencies” tab



Dependencies enable certain functions to be triggered that are dependent on the timetable. For example, it can be specified that the next route will not be set until the train is within 200

m of the signal and is driving at a speed of less than 10 km/h.

The desired process to be added to the highlighted timetable entry is first selected. The process is activated in the simulation when a train passes the timetable entry, and applies in the section between this timetable entry and the next. As many dependencies can be added to the process as desired. The process is only triggered when the conditions of these dependencies are met. If no dependencies are set, then the process will be triggered as soon as the train passes the timetable entry.

A description can be entered as free text for each process, which simply serves the purpose of making the timetable easier to read.

2.4.2.4.6.1 New action: Trigger events

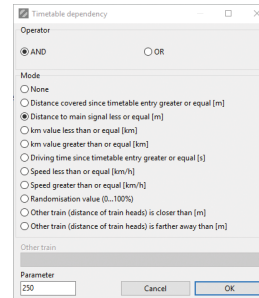
As many events as desired can be defined under “Trigger additional events”. Not all events that are available are necessarily appropriate for every situation. The events that are typically used can be set directly under “Add standard event”.

2.4.2.4.6.2 New action: Delay setting route

This function does not have any further settings. It prevents the next route being set until the assigned dependencies have been met.

Note on LZB 80 train control systems: On trains with LZB 80 [continuous automatic train running control], the train priority value set in the timetable editor is ignored during the LZB run. The route reservation is instead orientated to the maximum preview range of the LZB (10 km without CIR-ELKE, 13 km with CIR-ELKE). However, the simulator is unable to establish whether a route reservation of this range is of benefit to the remainder of the timetable. It might be sensible to delay the setting of routes using “Delay route”.

2.4.2.4.6.3 Add dependency



A dependency is added to the process. More than one dependency can be linked together using the AND and OR operators. The list is considered in order from first to last without parenthesis. The process is only triggered if “True” is returned at the end of the evaluation. Example: Dependency A AND Dependency B OR Dependency C: The first step checks whether A and B are met. This result is then reconciled with C using logical OR. If the result of A

AND B is True, then the overall result is also True. If A+B does not return a True, but C is True, then the overall result is also True. A False is only returned if A+B as well as C are not True. A tree structure can also be created to nest the dependencies.

The dependency settings are set using the options at the side of the dialog box, whereby one parameter can be specified for each, the function and unit for which is specified with the option in question.

None: The result is immediately True.

Weg gefahren seit Fahrplaneintrag größer oder gleich [m]: As soon as the front of the train has covered the distance from the timetable entry that was specified as the parameter, a True is returned for the condition.

Weg bis Hauptsignal kleiner oder gleich [m]: This condition returns True as soon as the train has arrived at the specified distance away from the next signal.

km-Wert kleiner/größer oder gleich [km]: This condition returns True as soon as the current route mileage (km) at the front of the train is smaller/greater than the specified threshold.

Gefahrene Zeit seit Fahrplaneintrag größer oder gleich [s]: This condition returns True as soon as the specified amount of time of the timetable entry taking place has passed. It is the simulation time that is used, and not the real time that is passing (which is relevant if the simulation is paused or fast-forwarded).



Geschwindigkeit kleiner/größer oder gleich [km/h]: This condition returns True as soon as the train goes below or above the specified speed. A 0 value returns true when the train is at a standstill.

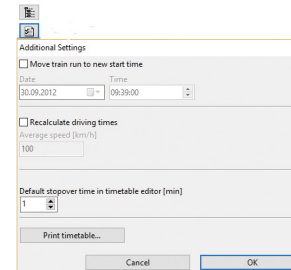
Random value [0...100%]: The condition is true if a random value calculated at the time of the simulation is less than the parameter stated here. If, for example, 25 is given as the parameter, then the result "true" will occur on average every fourth time. Note that when used with the procedure "Delay route", the random event must be designed so that the result "true" occurs at some point, otherwise the route will never be set.

Another train (distance between ends of trains) is nearer/further away than [m]: The condition is true if another train falls below or exceeds the distance given as a parameter and measured as a direct line from the end of one train to the other. Once the other train has fulfilled the condition after activation of the procedure, it will remain true regardless of how much the distance then changes by. The activation of the measurement occurs on passing the timetable entry where the procedure is entered.

This function may be used, for example, to ensure an overtaking process even if the train being overtaken is not running on time. However, the overtaking process can also be omitted if a maximum distance is entered while the train being overtaken is still a long way away by linking one dependence with a minimum distance and one with a maximum distance using OR.

If the other train is deleted, has already been removed from the simulation or has not yet been rerailed, then this condition will instantly become true.

2.4.2.4.7 "Additional Settings" button



This dialog box is accessed by clicking on a button in the centre of the window. It offers the following functions:

Move train run to new start time: The entire inputted timetable is moved to a new start time. All arrival and departure times are updated accordingly.

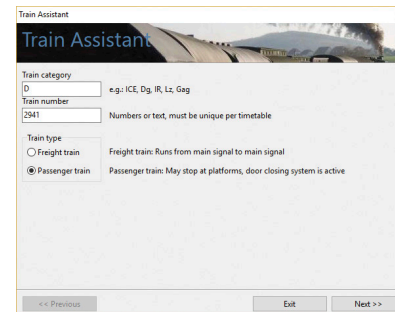
Recalculate arrival and departure times: The arrival and departure times are recalculated from the first operating control point in the timetable with the specified average speed. The duration of stopover times does not change. The program depends here on distance data stored in the routes when the routes were created using the 3D Editor. The actual permissible speeds are not taken into consideration.

Default stopover time in timetable editor: The default stopover time for newly-added stops is set here. If the value is changed here, this does not affect any entries that have already been made.

Print timetable: The train timetable is sent to a printer in plain text format.

2.4.2.5 Create timetable

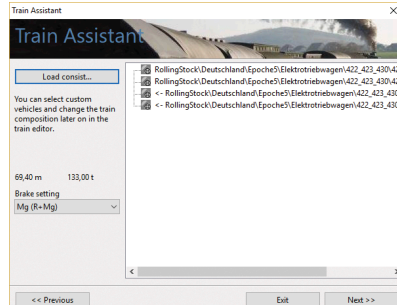
A timetable can be created completely manually using the methods outlined below, by manually selecting each signal entry in the structure tree and moving this over to the timetable.



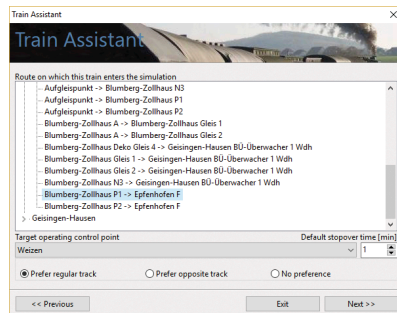
There are Train Assistants, however, that simplify this laborious task by requesting all the essential train data and then generating a train from these that is immediately usable. Generally speaking however, the user will want to make subsequent adjustments to the Train Assistant's result.



The Assistant is called up in the timetable editor under “Trains New train...”, and it then asks for a few basic details in the first input mask.

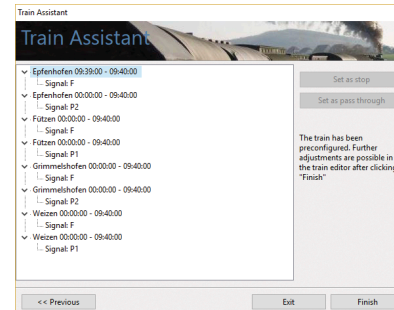


In the second mask, a predefined consist can be loaded. If there is no appropriate template for the train, this step can be skipped. The vehicles must then be manually assembled together from the vehicle selection list after closing the Assistant.



will end is selected.

The Default stopover time determines the length of time between arrivals and departures, and this entry impacts on the next mask. At the very bottom of the mask, the user selects whether the Assistant should choose the regular track or the opposite track where there are double-track routes. If “No preference” is selected, the route that is found will be based on the reset position of the points. The route that is found will be the one that most enables driving as far as possible on reset points.

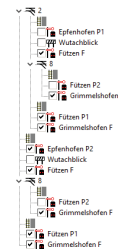


The route found by the Assistant is shown in the last mask. If a destination was selected that is impossible to reach from the starting route, the list will be empty. An arrival time can now be entered by selecting an operating control point and pressing the “Set as stop” button. “Set as pass through”

sets the arrival time as 0 accordingly.

Finally, the Assistant is closed and everything is then populated into the corresponding input fields in the Train Editor, where the details can be manually adjusted as required.

2.4.2.5.1 The structure tree



In the structure tree, the order of the main signals, platforms etc. is shown in the correct, logical structure. Diverging tracks are contained in a lower level of the tree, whereas plain line track is contained in the root level. The tree starts after the timetable entry that has just been selected (in this case, Bad Driburg F is selected). If there is no timetable entry yet, then the tree starts at the entry point element. Only those sections of track will be listed that offer a route to the target operating control


point that is selected at the very bottom of the window. There will always be a limit on the tree depth (i.e. the number of nested levels of the subsequent signals). This tree depth is normally the size specified under “Signal recursion depth” in the Train Data, but can be further reduced here via the “Tree depth” setting to make viewing easier. To help in the case of passenger trains, the position of the platform is also given in the tree.



2.4.2.5.2 Interaction of the structure tree and timetable

The manual adjustment of the timetable is essentially a process involving alternating use of the structure tree and the timetable list. Data exchange between the two does not take place automatically, but has to be effected using the two red arrows. The left arrow populates the timetable list all of the ticked stations/stops in the structure tree. This function adds the ticked entries, but does not delete any existing entries even if they are no longer ticked in the structure tree. The right arrow recreates the structure tree. The start of the tree is set as the timetable entry that is currently selected (Bad Driburg in the above image), and all the entries that are available in the timetable are given a checkbox in the structure tree (e.g. Bad Driburg B in the above image).

In order to carry on building the timetable in the direction of Altenbeken, the next stops/pass-throughs must be ticked in the structure tree, e.g. Bad Driburg platform B and Langeland F, and then activated using the left arrow. Bad Driburg and Langeland will now appear in the timetable list. When the route continues further, the user must select the last entry in the timetable list and click the right arrow. The new tree is generated, and the user then ticks the new entries, clicks the left arrow, etc.

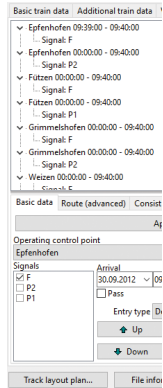
 A new timetable entry can be created using the button at the top of the column of buttons in the centre. This will be completely empty to begin with, and must first be given an operating control point, signals and arrival and departure times manually. An entry is deleted using the button below the “New” button.

2.4.2.5.3 Stations and stops

In Zusi, there are two different types of timetable entry. The normal type is a station. (The timetable entry is defined via the designation of the operating control point and the main signal). For passenger trains, there is also the option of including a halt (platform only, without main signal) in the timetable. In terms of the way Zusi operates, a platform is deemed to be a halt if it has been given a name that is different from the name of the operating control point of the subsequent main signal. The trip route is not defined in terms of halts, as that is done purely using signal names — neither does a

halt have any influence on the route being found within the signal recursion depth. An entry for a halt is completely ignored when routes are being searched or created. A halt therefore only serves to flesh out a timetable (“stop here if you happen to be passing”) between two full timetable entries. The structure tree identifies a halt with the halt board symbol (e.g. as for Reelsen, above), and in the timetable list it can be recognised as such from the fact that it is not associated with any signal entries.

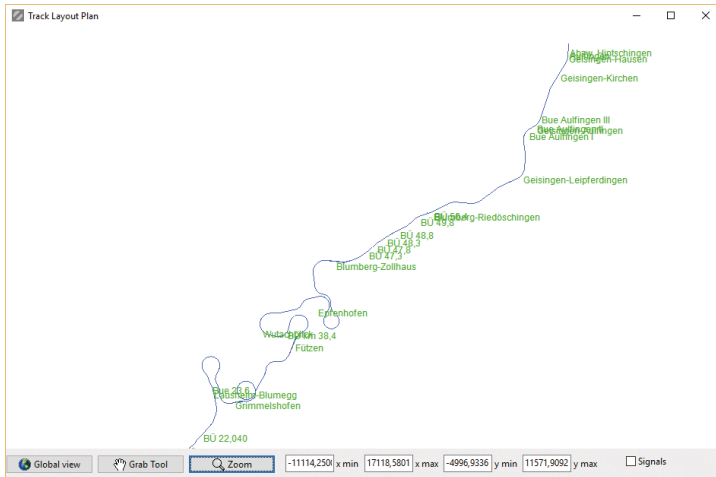
2.4.2.5.4 Adding/deleting signals

 If there are several signals available for selection for a train in a station, it is easiest to add the best track found into the timetable list, and then to click on all of the desired signals in the signal selection for the timetable entry. The image on the right shows that Altenbeken station has been brought into the list via signal P2. Signal P1 can then be clicked subsequently in the bottom left-hand corner. This process requires existing local knowledge with regard to the particular platform situation. If the user does not have this knowledge, then the structure tree must be brought into play. (Here, only those signals which actually lead to the chosen destination station will be available for selection.) Signals can be deleted by unticking the checkbox. After this, the tree should be updated using the red right arrow button, as a checkbox could still be hidden somewhere, which would otherwise be moved across into the timetable the next time the left arrow button is clicked.

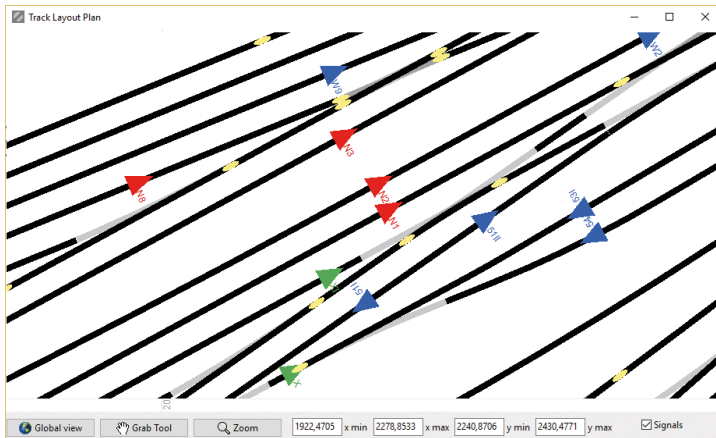
The order in which the signals appear can be changed using the up/down arrows. The signal box will always attempt to use the first signal, and only if this is already being used, or if the randomness settings decide to do so, will the subsequent signal entries be brought into play.

2.4.2.6 Track Layout Plan

When the “Track Layout Plan” button is clicked, a window opens in the bottom left corner which displays the exact track layout of the route in a 2D map. The window can stay open in the foreground and thus always be in view to assist with the creation of the timetable.



Sections can be magnified using the mouse scroll wheel or the zoom tool. When the “Signals” checkbox is ticked, signals will also be displayed, with main signals in red and shunt signals in blue, as shown in the image below.



The location of the UTM coordinate can also be checked on this plan. This is located at the intersection point of the two 0-coordinates, which are displayed with the signals and ought to be around the middle of the track layout plan.

2.4.3 Test working timetable

This menu item is mainly for the purpose of checking that manually adjusted timetable.xml files are displayed correctly without having to first start a simulation. A bitmap file is created from the contents of the selected timetable.xml file and the working timetable DLL that is selected in the menu. The bitmap file is saved in the temp directory of the database, where it can be viewed.

2.5 “Help” menu

2.5.1 Debugging

This menu provides developers and add-on authors with more detailed insight into the status of the simulation.

Some of the tabs require longer loading times before the data can be displayed.

Save report: This function writes the content of most of the tabs to a file on the hard drive. Alternatively, the data can normally be saved in each tab via the relevant button, or copied to the clipboard via the context menu.

2.5.1.1 “Train status” tab

This tab lists all the train systems hierarchically and highlights all systems in red that are currently preventing the train from proceeding, and thus assists the user in ascertaining the reason for a train not being able to proceed. The tree is expanded in a way that provides an immediate overview of the systems highlighted in red.



2.5.1.2 “Vehicle files” tab

This list displays the actual consist of the player’s train that is currently in the simulation. Next to the file names, the variant numbers are also displayed, in square brackets, along with any other special settings for the trains. Double-clicking on the file opens it in the standard application (normally the Vehicle Editor).

2.5.1.3 “Train Data” tab

This tab provides information about the autopilot initial data for the train which the player is using. If the autopilot displays unexpected driving behaviour, the cause of this can be diagnosed with the help of the data in this tab. These data are also available even when autopilot is not enabled. The table in the lower half of the tab shows which of the data derived from the route are directly relevant to the driving behaviour of the autopilot. Entries with negative distance lie behind where the front of the train is currently, but should still be taken into consideration (e.g. the speed information from the last signal that was passed). The projection data (entries with positive distance) finishes at the next signal showing a stop aspect or at the train priority distance.

2.5.1.4 “Driving data” tab

This list displays the physical quantities for the train which is currently occupied by the player, which is of particular interest to developers of vehicle models. The top section contains data on the leading vehicle, which is typically the first locomotive (if the first vehicle is a driving trailer, then it will be the data for the driving trailer that are displayed here). The middle section contains the total values for the whole train. The bottom section shows constants which do not change during the trip.

2.5.1.5 “Safety systems” tab

This tab displays information on the internal status of the train protection systems of the player’s train, for instance what mode the LZB is in, and which system is installed.

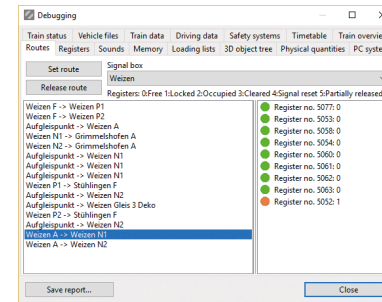
2.5.1.6 “Timetable” tab

This is where Zusi’s internal timetable for the player’s train is displayed in text format.

2.5.1.7 “Train overview” tab

This list provides information on the speed and position of the trains. Trains shown in brackets are not yet in service, while trains that have already finished running are not listed.

2.5.1.8 “Routes” tab



This function gives information on the status of the route register and enables experimental activating and deactivating of routes. After bringing this tab up from the currently running simulation, the signal box is selected that is responsible for the train being driven by the player, as well as the first route of the next signal to come.

Signal box: This provides a list of all signal boxes in the simulation which is currently loaded. After selecting a signal box, the available routes are listed on the left-hand side. A route can only be set if the status of all registers is shown as green.

Registers: After clicking on a route, all the registers for that route are listed with their status on the right-hand side.

Note: A train for which a route has been activated or deactivated manually on this tab normally drops out of the timetable logic of the simulator, and will not be automatically allocated routes in subsequent simulation runs.



2.5.1.9 “Registers” tab

This is where all route registers and their statuses are listed by route. The status given after the register number is the same as the legend in the “Routes” register. When comparing the registers with the st3 file in the 3D editor, care should be taken to ensure that the numbers of the registers in the simulator are re-numbered when loading several route modules, as each register number must only be assigned once along a route.

2.5.1.10 “Sounds” tab

This list provides information on the current volume and playing speed of the sounds that are loaded (including 3D sounds from the 3D world), in order to assist vehicle designers with debugging.

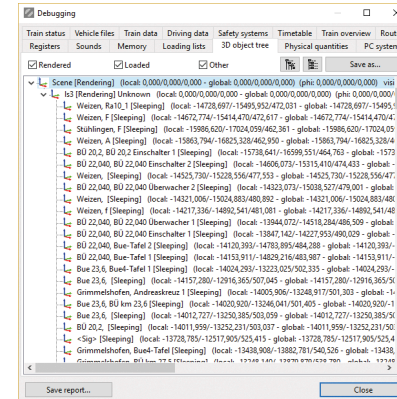
2.5.1.11 “Memory” tab

This tab lists the memory requirements of the timetable data (without vehicles, sounds etc.), route data and 3D raw data (raw geometry data and texture dimensions). The 3D data are listed individually with their memory requirements and the number in current use. An object that is used more than once still only uses the same amount of memory.

2.5.1.12 “Loading lists” tab

When file names are displayed on this tab, then these objects are in a loading backlog in the simulator. They will not appear in the simulation until they have loaded. The loading of the backlog will take place while the simulation is running as well as in pause mode. “HD” means that the data have not yet loaded at all, while files marked “DX” are already in the main memory but still have to be transferred to the graphics card.

2.5.1.13 “3D object tree” tab



The Object Tree displays 3D objects in the simulation as a tree. This allows the user to identify which 3D objects have just loaded and to see their status. The entries are explained in detail in subsequent chapters. The list of objects which are displayed can be filtered using the three checkboxes at the top.

2.5.1.13.1 Name

For reasons of clarity, the full path of an LS3 file is not shown here. In the case of signals, the name of the signal is given.

2.5.1.13.2 Status (in square brackets)

Sleeping: Only object data known, object is not loaded.

Load deferred: Object needs to be loaded, but is still waiting in the queue.

Load immediately: Object must be loaded immediately and not in the background.

Loading Win: Object is now being loaded from the hard drive. Ready

Win: Object has finished being loaded from the hard drive. Loading

DX: Object is now being loaded to the graphics card.

Ready: Has finished loading, but is not drawn (e.g. outside the field of vision).

Rendering: Is currently being drawn.

Delete: The object is to be deleted.

Loading error: An error has occurred, e.g. the file was not found or was corrupt.



2.5.1.13.3 Position

“Local” indicates the position (x/y/z) in relation to the higher-level file. “Global” shows the absolute position (here under “phi” along with the angles) in the global coordinates system.

2.5.1.13.4 Visibility

“visible x to y” shows what distance away the object should be drawn, in other words if the distance from the observer lies between x and y.

2.5.1.13.5 Distances

The bounding radius is displayed under “R”, “distance” is the distance to the coordinate origin of the file, and “net” is the difference, so, the distance that ultimately determines whether or not the object is to be drawn.

2.5.1.14 “Physical quantities” tab

All the physical quantities supported by the current version of Zusi are listed here. This list can also be found in the data format documentation. Thus, if there is uncertainty over what the simulator actually supports following version updates, for example, then this can be checked here.

2.5.1.15 “PC system” tab

This list provides information on the computer on which the simulation is running, as well as the versions of the Zusi program components installed. In the case of questions about hardware or software problems, this entire list should be sent by the inquirer together with the question.

2.5.2 Show message window

Right-clicking in the message window allows the user to select the messages which Zusi shows in this window.

Red messages (Fatal errors) are serious errors that generally prevent the simulation from continuing to run.

In the case of yellow messages (Warnings), these denote serious errors with an effect on the running of the simulation, but which do not necessarily have to lead to the simulation being aborted. They often occur due to errors in the database (e.g. missing files) that need to be resolved. For these reasons, red and yellow messages should always be switched on. In the case of yellow messages for an add-on, either the add-on author should be informed, or, if the author is not known, then the issue should be flagged up in the Zusi Forum (<http://forum.zusi.de>).

Dark red messages (Help messages) provide assistance for beginners in certain situations.

Blue information messages and green debugging messages are normally only useful for developers and add-on authors for debugging purposes, and not be activated in normal operation. The issuing of messages does, itself, have an impact on the system performance. For this reason, therefore, only the red and yellow messages should normally be activated.

2.5.3 Show last order

The last order form produced is displayed again. When orders are created, they are filed as html files in the temp directory and read from there.

2.5.4 Updates, add-ons...

The manager is started up and a window opens from which new versions can be installed from the Zusi server.

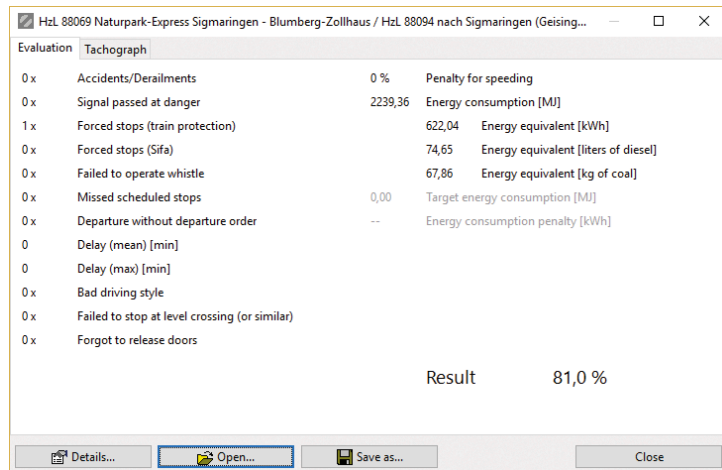


2.6 Evaluation at end of trip

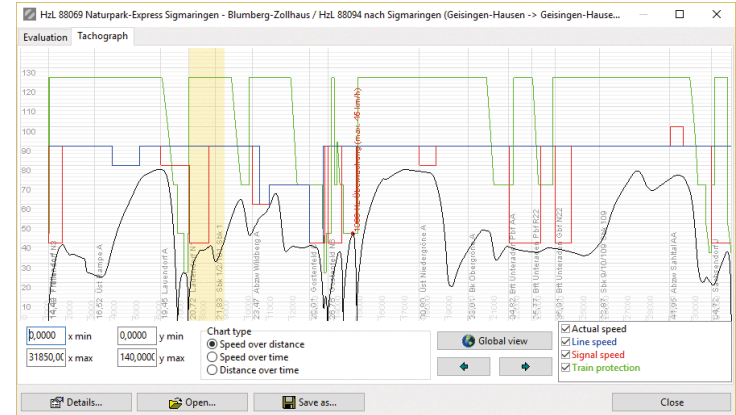
The evaluation window appears at the end of the trip, and also in the following circumstances:

- At the point at which the player's train is taken out of simulation.
- When Zusi is completely exited.
- If the player's train is deleted from the train list while it is being driven.

The "success" of the virtual locomotive driver in terms of safety, punctuality and efficiency is expressed as a percentage. It is possible to attain a mark of 100% if no points have been deducted during the trip in the evaluation categories listed, and the end operating control point of the train has been reached. In addition, the use of the following simulator functions leads to fixed amounts being deducted from the percentage mark: Display of additional trip information using the F8 key, use of autopilot (F3 key), reduction of the difficulty level in the menu under "Settings Simulation" or calling the menu function "Debugging". A derailment or overrunning a stop signal will always result in 0%. The energy footprint is only included in the evaluation if reference values are set in the timetable.

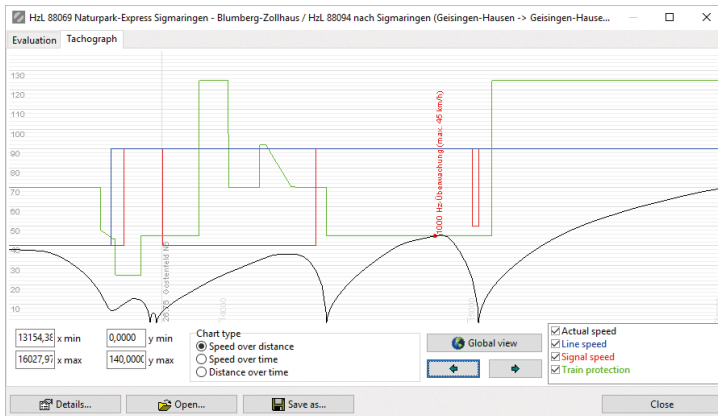


On the "Tachograph" tab, trip data are displayed in graph form. Three chart types are shown: Speed over time, speed over distance, and distance over time. In the first two cases, the curves seen in the image below are displayed:

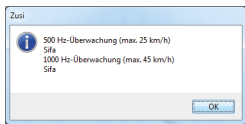


In the third graph, the timetable route is also displayed in magenta. "Line speed" is the speed recorded in the Track Element Properties. If the line speed is reduced because of signals, the red line will appear as shown. The train protection monitoring curve is displayed in green.

The fields in the bottom-left corner enable scaling of the chart. Dragging the mouse over a section of the graph with the left mouse button depressed will zoom in to enlarge the corresponding section of the graph.



The two arrows underneath “Global view”, allow the user to scroll through the trip step by step. Clicking on “Global view” displays the whole trip again.



Operating and driving errors are displayed on the curve, along with corresponding explanatory text. If the points are so close together that they are difficult to read, clicking on the individual points. will open a small window in which all events that occurred in the area are listed.

For archiving purposes, driver ID and comments can be entered by clicking on the “Details” button. The tachograph results can be saved as a file using the “Save” button.

Note: In the case of old PZB systems without braking curves, no green PZB curve is displayed, as such systems do not have one (e.g. Indusi I54, I60).

Note on evaluation category “Whistle board disregarded”: The system checks whether the whistle was operated in the area before and after the whistle event in the route travelled. Here, a certain degree of spatial and temporal tolerance is allowed, to take account of high and low trip speeds. Please note: With route modules dating back to the 1980s or earlier, whistling on entering a tunnel may also be required.

At that time, it was customary to whistle when entering a tunnel in order to warn people (crew) walking along the tracks inside the tunnel.

2.7 Operation during the trip

It is recommended that beginners use the demo version with the driving school assistant, as all operations are explained during the trip in this mode. Otherwise, in an “emergency”, help is available in the form of the autopilot, which will always know what action needs to be taken, even if the train is refusing to cooperate, and will return all systems to their default status. The next few pages provide a brief overview of all operational processes during a trip.

2.7.1 Braking

Depending on the vehicle construction type, several different train braking systems are available.

The most important one is the indirect air brake, which is activated using the train brake valve, and which brakes the whole train. This is installed in every train as standard.

A later chapter contains more detailed information on braking technology and historic development.

2.7.1.1 Skidding

When braking too heavily, the wheels can lock and skid on the rails (wear and tear, reduced braking effectiveness). If the locomotive has anti-skid protection (similar to ABS in a car), the corresponding indicator will light up, and the tachometer will display 0 km/h. In the event of this happening, the brake should be released and sand deposited on the rail.

2.7.1.2 Indirect air brake

The main brake pipe runs the length of the train (referred to as “MBP”), through which braking takes place centrally for all wagons in the consist. The brake is released at a pressure of 5 bar in the MBP,



and at 3.5 bar full braking power is exerted. It should be noted that the longer the train is, the more sluggish the system. The actual pressure exerted on the brake takes effect only gradually after activation via the MBP. The user can monitor this process for the locomotive with the help of the brake cylinder pressure indicator (0 bar = no brake force). Braking is increasingly delayed for a vehicle, the further back it is located in the train.

With the help of the train brake valve (TBV), the desired pressure in the main brake pipe is set in the locomotive, so, 5 bar during normal driving, and down to 3.5 bar during full braking.

The operation of the train brake valve can vary widely depending on the construction type. It is helpful to describe two standard designs here in greater detail — the conventional Knorr standard brake valve and the more modern D2-/D5 construction (“+” and “-” keys in the numeric keypad):

2.7.1.2.1 Position-dependent train brake valve

Firstly, the simpler, more modern position-dependent train brake valve, typical examples of which are the D2/D5 and its modern successors: The “Running” position maintains a constant pressure of 5 bar. For braking, there are several fixed pressure levels, e.g. 4.6 bar, 4.45 bar, 4.3 bar etc., down to 3.5 bar. The TBV is thus moved a few notches down in order to brake, and the further down it is switched, the lower the controlled pressure will be, and the greater the brake force. The final position is for application in an emergency, when all of the air is quickly vented from the MBP. To avoid accidentally putting the handle into the emergency position, the TBV in Zusi should be fitted with a locking facility. The key has to be pressed and held for approximately 0.5 seconds before it switches further. Above the “Running” position is the Fill position, in which the MBP is replenished quickly. Excessive use of this leads to an overload on the brakes. Since the effectiveness of the brakes is directly dependent on the position of the control handle, this type of construction is known as a “position-dependent train brake valve”.

2.7.1.2.2 Time-dependent train brake valve

The time-dependent train brake valve (a particularly common example of which is the Knorr 8) does not have fixed pressure levels but simply a “Brake” position and a “Neutral position”. For as long as the valve is in “Brake” position, the MBP is vented, and the pressure in the MBP sinks while the brake force increases accordingly. By shifting back to the neutral position, the pressure level reached is kept constant, thus ensuring braking at a constant level of force. To release the brake, it must be returning to the “Running” position. Shifting back again to neutral halts the releasing process. For example, if the driver wants to slow down from normal running speed to a pressure of 4 bar in the MBP, he will switch the TBV from “Running” to “Brake”, monitor the decreasing MBP pressure in the manometer, and when 4 bar MBP pressure is reached, switch back to neutral. The 4-bar pressure is then kept constant.

2.7.1.3 Independent brake

This brake acts directly on the locomotive's brake cylinder, and therefore reacts very quickly. It can be used, for example, when stopping a train on a slope. There are three positions: Brake, Middle, Release. When switched to the Brake position, the cylinder pressure increases, along with the brake force. The Middle position keeps the current brake force constant, while the Release position allows the pressure to sink, thus fully releasing the brake (keys “#” and “+” by default).

2.7.1.4 Dynamic brake

The dynamic brake is very resistant to wear and should therefore be used before the air brake. If there is insufficient brake force, the air brake must be used in addition.

The dynamic brake only works in locomotives where there are various different types of brake (in particular, hydrodynamic and electric for regenerative brake and dynamic brake).

The dynamic brake is generally operated using a separate handle on the train brake valve, which is coupled with the normal train brake valve but can also be released.



If the handle for the dynamic brake is operated directly, the dynamic brake can operate independently of the indirect air brake (keys 3, 6 and 9 on the numeric key pad as default, whereby 6 switches the brake off immediately).

2.7.1.5 Magnetic brake

The magnetic brake, which consists of sliders being let down onto the rail head through magnetic force, is not used for normal braking, but is only intended for emergencies. For this reason, it is connected with the pressure in the main brake pipe, and is activated automatically when the pressure is very low. In some vehicles, however, it can also be activated manually using a separate switch ("M" key by default).

2.7.2 Driving

This section is concerned with generating tractive power in order to set the train in motion. Most vehicles have a fixed number of speed levels/notches at which the drive system can operate. The higher the notch, the more power, or tractive power, is generated. As a rule, the locomotive driver only specifies the speed level via the power controller (throttle), and the drive control then produces that status, which can easily take several seconds.

When the train is to be set in motion, then the throttle is moved a couple of notches up (the "/" key on the numeric keypad by default). Initially, not so much power is needed to start moving. A helpful reference point can be found in the cheat display — an acceleration rate of more than 0.5 m/s² should be avoided. In notch 0, the train rolls without drive power.

2.7.2.1 Wheel slip

When the drive power is too high, the wheels spin on the rails. This is evidenced by the tachometer needle vibrating relatively strongly. This then quickly leads to wear on the rail heads as well as placing heavy demands on the locomotive's drive system. Besides, only a small amount of motive power is transferred at this stage, as the sliding friction coefficient between wheel and rail is in play, which is significantly lower than the static friction coefficient that is in play when the wheels are rolling. Locomotive wheels have a tendency to slip

particularly when just setting off and when the rails are slippery. When this is the case, the drive power must be throttled down straight away until the wheels start to roll again. Sand can be deposited on the rails as an auxiliary measure ("S" key by default), which improves the friction between wheel and rail.

2.7.2.2 Power controller (throttle)

The desired speed level is selected using the power controller (throttle). With diesel hydraulic locomotives, the power controller must remain in the first notch until the converter has filled up (if there is a "Transmission" indicator light, this must first go out).

There are two basic types of power controller:

2.7.2.2.1 Step switch

On the classic power controller there is a separate notch for each speed level of the drive system. If, for example, speed level step no. 8 is required, the power controller is switched up from 0 to eight notches higher.

2.7.2.2.2 Increase/decrease control

In the case of Increase/Decrease control, the only positions are Decrease/Drive/Increase, or sometimes Off/Decrease/Drive/Increase. In this case, if the driver wants to switch to speed level 8, then he has to set the switch to Up and then wait until the speed levels have climbed to 8 (there is normally a speed level display on such vehicles). When 8 is reached, the switch is moved to "Drive". The level is then kept constant. With "Decrease" the speed levels are switched down in the same way.

"Off" switches the drive off straight away.

2.7.2.3 Forced reset of power handle

After forced braking or intervention using the train brake valve, the power can no longer be switched on until the power controller is returned to the zero position once again. This safety precaution is designed to prevent the train being set in motion again accidentally. This status is not indicated specifically, but only becomes apparent in the fact that no tractive power is generated when the power controller is operated.



2.7.2.4 AFB



With a conventional power controller, the power has to be adjusted frequently in order to maintain a constant speed, e.g. when the elevation is changing. The AFB in modern locomotives is therefore a significant improvement in terms of convenience, working in a similar way to cruise control in a car to maintain a constant pre-set speed.

In order to make use of AFB, this must first be switched on (“A” key by default), with the power controller/tractive power controller in position 0. Next, the desired speed is set using the AFB speed regulator, with the target speed displayed in the tachometer by the small red or yellow indicator, as seen in the image opposite, where it is set at 50 km/h (keys 1, 4 and 7 on the numeric keypad by default; “4” switches immediately to 0 km/h).

After the brakes are released and maximum tractive power has been achieved, the train moves off and constantly maintains the set speed. If the train needs to coast before a station, then the power controller must be set to zero, leaving the AFB target speed unchanged. If the target speed is in fact slower than the current driving speed, the AFB initiates heavy braking.

The AFB may have an automatic holding brake. This is active as long as the train is at a standstill and Speed level/Tractive power 0 is selected. As soon as the power is activated, this brake is automatically released and the train moves off. The train brake valve remains all the while in the running position.

2.7.3 Doors

Depending on the vehicle specification, the driver may also have to take care of opening and closing the doors. The operative system depends on the systems in all the vehicles in the consist. The lowest common denominator is generated and displayed in the train data window. The following systems are available in Zusi:

2.7.3.1 No door closing system

This is the conventional set-up, in which the conductor takes care of the doors and gives the locomotive driver the all clear to depart once the doors are secured and the train is permitted to move off. The green departure indicator (Zp 9 in Germany) is displayed at departure time in the bottom left of the 3D window. The driver can then move off straight away. The doors can be secured using the TB5 system, which prevents doors from being opened at speeds of over 5 km/h. This does not have any effect on the door-closing procedure. When coming to a halt, there is nothing further that driver needs to take account of.

2.7.3.2 SAT

SAT (driver-operated door-closing procedure) was introduced by the Federal Railway in the 1980s, when services without separate conductors were being introduced on less-frequented lines in order to cut staff costs. The first of these vehicles to be introduced were the 796 and 628-class railcars.

The driver assumes the conductor’s tasks and is therefore also responsible for the doors. Before halting at the platform, the driver must select the appropriate side to be opened, using the side selection switch (in Zusi controlled with the “Insert” and “Home” keys by default) and lock the corresponding doors at the scheduled departure time by switching the side selection switch to “Close”. In doing so, he must also have a look to make sure that no-one is at risk from the doors. In the absence of a conductor, there is no all-clear order, and the locomotive driver proceeds autonomously at the scheduled departure time.

Typical application: 628, 614/624/634 (after modernisation), S-Bahn trainsets, 420, back-up measure for TAV.

2.7.3.3 TB0

TB0 (door-locking over 0 km/h) was introduced in 2001 and keeps the doors locked until the locomotive driver releases them with the TB0 button. It is not possible with this system to select a particular side.



The driver must give clearance for the doors before stopping at the platform by pressing the door button (“T” key by default). When the train slows to below 20 km/h, a bleep is sounded which reminds the driver to give clearance for the doors. Thanks to the systems installed in the railcars, the doors are prevented from opening before the train has come to a standstill, even when the driver has already pressed the door button. It is the conductor who takes care of closing the doors. The all clear to depart is given using the green Zp 9 indicator at the bottom of the 3D window.

Typical application: IC trains, regional trains of older makes and single storey construction.

2.7.3.4 SST

Side-selective door operation works in the same way as TBO, but the exit side of the train can be selected using the side selection switch. The train crew are responsible for the door-closing procedure. The doors must then be locked by resetting the door switch.

From the driver’s point of view, the door control system on ICEs functions in a very similar way to SST, and so can be represented by the SST system on Zusi. The ICE system was introduced in 1991 with class 401 trains. With this system also, the driver has to release the appropriate door side using the side selection switch when approaching the platform. The door status can be seen from the T indicator (light on: doors open, flashing light: locking process). After departure, the side selection switch has to be returned to the lock position, as for SST.

2.7.3.5 TAV

With the train-based automatic door-closing system (TAV), the doors operate automatically, whereby light barriers ensure that the doors do not close if someone is standing in the way. Shortly before stopping, the train driver gives clearance for one side of the train to be opened, using the side selection switch (“Insert” and “Home” keys by default in Zusi). With some TAV systems, the doors have to be explicitly given clearance a second time using a special button (“T” key by default in Zusi). At the departure time, the train driver returns the selector switch to “Close”. A door that has been closed then remains locked,

and as soon as all doors are closed an indicator light goes on in the cab, the traction block on the vehicle is released, and the driver can proceed. A conductor is not needed in this case, and there is no order to proceed. Rather, the train driver departs autonomously at the scheduled departure time.

The train driver can initiate forced closure using a button provided for the purpose (“Z” key by default). This is used if someone is standing in the doorway and thus delaying departure, as the doors would never close otherwise in these circumstances.

Typical application: 423–426, 612, double-decker cars.

2.7.3.6 UIC-WTB

With this system, a rotary switch is used to select the exit side shortly before stopping. Under 2 km/h, a blue indicator light “T” illuminates. If the doors are open, a yellow indicator light illuminates and the blue one goes out. The conductor is responsible for the door-closing procedure. If all doors are closed, the yellow indicator light goes out and the blue one illuminates again. The train driver then turns the side selection switch to “Close” and can then move off after the all clear to depart is given. The blue indicator goes out again after moving off.

Typical application: Locomotives with ÖBB (Austrian Federal Railways) background, such as ER20 or TAURUS, also when used in Germany.

2.7.3.7 Operation of the side selection switch

A side selection switch with rotary switch construction can be rotated continuously through the settings (“Close” “Right” “Both” “Left” “Close” etc.), which cannot be recreated with the normal Zusi switch function. There is therefore a special way of operating side selection switch, using the two relevant keys (“Insert” and “Home” keys by default in Zusi). Each time the “Doors: Right” is pressed, the switch moves one position to the right, and vice-versa in the left-hand direction.

If this function is operated via a DirectInput hardware control, this method of controlling it is not possible. It can be useful to activate the hardware control mode for the door system in the simulator settings.



2.7.4 Safety systems

2.7.4.1 Sifa

The driver's safety device (DSD — or "Sifa" in Zusi) ensures that the train driver is conscious, by requiring that he or she presses the Sifa switch approximately every 30 seconds (space bar by default) otherwise the emergency brake is activated. The various systems, which differ somewhat in their details are explained in section 2.12.3.1 .

2.7.4.2 Train protection

The train protection system monitors whether the signals and maximum speeds are being heeded. There are numerous, widely differing systems, which are explained in section 2.12.

2.8 Railway operation

This chapter describes the main principles according to which the railways operate. In short, it is concerned with the question of when, where and at what speed a train/vehicle is permitted to drive. The set of regulations developed for this purpose is usually complex and country-specific.

2.8.1 Germany

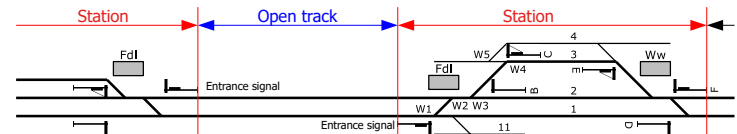
In Germany, Regulation no. 408 (Train Operating Regulations) and regulation no. 301 (Signal Code) are the two most important regulations relating to railway operation. The regulations are extremely complex, and what follows is a very much abbreviated and simplified overview. The basic principles are outlined here in an accessible way. For a more in-depth look at the subject, the regulations mentioned can be found on the website of the German Federal railway network, DB Netz AG.

2.8.1.1 Main signal

The subject of signals is dealt with in greater detail in a later chapter. However, in order to understand the sections that follow, a short introduction to the main signal needs first to be provided. In its default status, a main signal shows the stop aspect (depending on the construction, this is either shown by red lights or a horizontal semaphore arm); when in this aspect, it is not permitted for any vehicle to overrun the signal. When a vehicle is permitted to proceed into the track section behind the signal, this is indicated by yellow/green lights or a diagonal semaphore arm, depending on the construction type of the signal. fahrimulator/HV

2.8.1.2 Railway stations and open track

The German signalling system is conceptually based on the traditional mechanical signal box system with fixed signal placement. The traffic controller (Fdl) is responsible for the area of a railway station, and has an overview from his or her signal box of the trackage. If a station is too large for just one signal box, then there are additional signalmen who are subordinate to the traffic controller (or signallers, Ww), who have responsibility for their own signal boxes and areas of work. Access to the station area that is controlled from the signal boxes is restricted by main signals (entrance signals). From that point on, the open track begins, which runs all the way to the entrance signal of the next station. The differentiation between station and open track is fundamental, and has a great deal of bearing on the driver's driving behaviour.



The entrance signal protects the station in respect of the open track sections. As long as the signal is showing the stop aspect, the traffic controller can be sure that no vehicle will enter the "operational zone" of the signal boxes unexpectedly.

Two types of vehicle movement can take place on this basis, i.e. shunting movements and running movements. The rule is always that



no vehicle may move without the authorisation of the traffic controller. This rule ensures that no vehicles can present a risk by moving around the tracks in an uncoordinated manner. Ultimately, it is the traffic controller alone who has the overview of all vehicle movements.

2.8.1.3 Shunting movement

A shunting movement takes place only within a station, and basically operates without safety systems. It is operated freely in manual mode, so to speak. Owing to the minimal technical protection, these vehicles have to be driven on-sight and no faster than 25 km/h. The driver must therefore always be able to stop before any obstacles which may arise.

For example: A freight train that has entered track 3 as shown in the image above wants to stable a wagon on track 11. This concerns a movement within a station — in other words, a shunting movement. The traffic controller establishes in consultation with his/her signaller whether any other services would be jeopardised by this, then sets the points and gives authorisation to the driver over the radio for a shunting movement as far as points W1. The driver then drives through main signal C showing the stop aspect and over points W4, W3 and W2, up to points W1. The traffic controller then sets the points in the direction of track 11, gives the driver the all clear to proceed to track 11 etc.

If shunting movements take place on a more frequent basis in a station, shunting signals would normally be available, which give a greater level of protection against misunderstanding in comparison with communication by radio, and allow the operations to be carried out more quickly. The consultation at the beginning between the traffic controller and the driver, which must take place in any event, is of course still necessary in this case.

Typically, shunting involves:

- Regular consultation with the traffic controller but not with higher-level officials, and more extensive planning in advance is not necessary

- Driving only within the station
- On-sight driving, at a maximum speed of 25 km/h
- Authorisation from the traffic controller before every operation by a shunting is commenced, issued either by radio, shunting signal or hand signal
- Tracks may be occupied by other vehicles
- Other shunting gangs may be operating on the same track
- The locomotive can pull or push the wagons; if sight lines are blocked when pushing, escort shunting staff must stand at the front of the train and apprise the driver of the situation over the radio or by hand signals
- Points can be set in a different direction to what the driver is expecting, either because of an error on the part of the traffic controller or because of unclear communication, which is why points signals are installed at points

2.8.1.3.1 Shunting signals

Shunting signals provide the driver with instructions on how to proceed when shunting. On the one hand, there are the hand signals “Move away from me” (vertical arm movement) “Move towards me” (horizontal arm movement) and “Stop” (circular arm movement), which are used, for example, by an escort shunter when communicating instructions to the driver from the front of the train being shunted. In addition, there are the following mechanical and light signals:



Wait signal: A sheet-metal W-shaped sign that is only relevant for shunting. Shunters must wait in front of the signal until they have permission from the signal box to proceed. Permission is normally signalled using two white lights. This signal is called Sh 1 (West) or Ra 12 (East). If there is no such signal, permission must be verbally given instead. Drivers engaged in running movements can ignore this signal.



Mechanical block marker: Rotatable black bar across a white circle. This signal also applies to running movements. In contrast to the wait signal, therefore, a proceed aspect must be showing at the location of a main signal at the same time as the main signal is showing the proceed aspect.



Light block marker: One or two red lights, or two white lights (Sh 1/Ra 12). At a main light signal, the two white lights are normally integrated within the main signal screen. If the block marker is separate from the main signal, it will be dark when the main signal is showing a proceed aspect. If it is on its own on the track then it displays two white lights for running movements as well.



Limit-of-shunt signal: The limit-of-shunt signal, Ra 10, is located in the direction of the open track and identifies the point up to which shunting movements are permitted to drive in the direction of the entrance signal. Since the possibility exists of a train approaching from the open track, a shunting gang must keep a sufficient safety distance from the entrance signal.

Originally, main signals did not apply to shunting movements. This was changed in the Deutsche Reichsbahn in 1 January 1962, and nationwide on 18 December 1995. Since then, throughout Germany a shunting movement must stop in front of a main signal, or requires permission to proceed past it.

2.8.1.4 Running movement

Running movements generally drive on open track and at high speeds. Because of their relatively long braking times, more sophisticated technical and organisational measures are required for running movements than for shunting movements.

Running movement takes place in between main signals, and it must be ensured that all points are set correctly and the route is free as far as the next main signal, as the driver will not be able to stop within his/her range of vision because of the high speed being travelled at. Technical dependencies are therefore built into the signal box in order to guarantee this. Thus, a main signal will only show the proceed aspect when all relevant points are set correctly and the open track ahead has been vacated by the previous train. Conflicting routes cannot be set at the same time etc.

A timetable with a unique train number must be produced for a running movement. It is up to the train driver and all signal boxes on the route to make sure that the route is travelled correctly. In addition to the tracks to be used and the running times, the timetable must also contain details of maximum speed, train length, braking capacity etc.

Typically, a running movement involves the following:

- There must be a timetable with a unique train number, which must be drawn up in advance by the timetable office (even for all one-off special trains)
- Under normal circumstances, communication with the signal boxes is not needed (all movements are controlled by the timetable)
- Movement takes place on the basis of the main signal; the proceed aspect also represents the permission from the traffic controller for the train to proceed
- The movement begins in the station, runs on the open track and ends in the station
- The driver can be sure that his route is free and that all points are set correctly



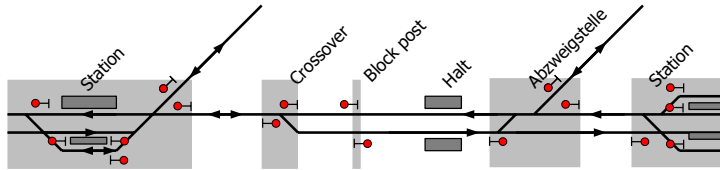
2.8.1.5 Main tracks/sidings

In the station, a distinction is made between main tracks and subsidiary tracks. On main tracks, running movements can take place (as well, of course, as shunting movements), for which the requisite main signals are in place. Sidings, on the other hand, are only for shunting movements. In the station diagram above, the sidings are shown with narrower lines. Sidings are typically used for stabling and for linking load transfer yards and freight sheds.

The main tracks that run through a station as an extension of an open track are known as “through tracks”.

2.8.1.6 Operating control points and signal locations

A distinction is made between the various types of operating control points in railway operations, depending on their function. The image below gives an example of this, in which the red circles indicate typical locations for main signals.



On the left and right-hand sides there is a station (Bahnhof — Bf), where running movements can start or end, and where there is normally at least one set of points. Stations and stops are named according to their function, the major ones being (with their German name and abbreviation in brackets) main station (Hauptbahnhof — Hbf), freight station (Güterbahnhof — Gbf), marshalling yard (Rangierbahnhof — Rbf, formerly known as Verschiebebahnhof — Vbf), locomotive depot (Betriebsbahnhof — Bbf — used only for internal railway operations such as train crossovers). Most stations have an entrance signal that faces in the direction of the open track, and exit signals at tracks that are intended to be used for leaving the station. This differentiation relates only to the function of the signals and not necessarily their technical construction. Longer stretches of track within stations may also have intermediate signals that are located between entrance and exit signals.

In a crossover (Überleitstelle — Üst) there are sets of points, protected by main signals, which (as shown here, for example) lead to a second track or allow a train to transfer from one track to another on double-track sections on the same route. These do not branch off to another route, however. A signal at a crossover is known as a block signal.

A block post (Blockstelle Bk) is a main signal (block signal) on an open track that serves to increase the capacity of a route by increasing the throughput of trains.

A halt (Haltepunkt — Hp) is a halt/platform for passenger trains on an open section of track without signals.

An Abzweigstelle — Abzw is a junction without platforms, not within a station, that is protected by the main signal. A signal at such a junction is known as a block signal.

2.8.1.7 Driving direction

In contrast to many other European railways, trains drive on the right in Germany. On double-track routes, the right-hand track is always the one that is driven on. This is known as uni-directional running, as a track can only be driven on in one direction owing to the signal set-up. From an operational perspective, there are only single and double-track routes. Where there are more than two tracks, these are considered to be multiple independent single tracks. Since harmonisation between West and East Germany, in the case of double tracks the right-hand track in the driving direction is referred to as the “regular track” (Regelgleis) and the left-hand one as the “opposite track” (Gegengleis). The term “wrong track” (falsches Gleis) used to be used for the opposite track in the Federal Republic of Germany, and “left track” in the GDR. The distinction between regular and opposite track is only made on open sections of track, and not in stations.

2.8.1.7.1 Single-line operation of the opposite track

A difficulty is presented on routes with unidirectional operation when, for example, only one track is available due to maintenance works. As previously mentioned, the signal box system will only allow running between one main signal to another. A signal showing the proceed



aspect cannot therefore be used to send a train onto the opposite track that does not have any signals. In order to allow running movements to take place in spite of this difficulty, there are various forms of single-line operation which permit the opposite track to be used even without main signals.

2.8.1.7.2 Bi-directional operation

As early as the 1950s, bi-directional operation was introduced on the north-south line north of Bebra in order to increase the capacity of the line. This means that both tracks on the route can be driven in both directions in normal operation. This requires additional signals at the route, including, in particular, entrance signals at the entries to the opposite track. This makes operation significantly more flexible, as a slower train can be overtaken by an express train if there is no traffic coming from the opposite direction at the time. These days, bi-directional operation is in place on many main routes.

Disruptions and construction sites are far simpler and safer to manage when routes are equipped for bi-directional operation.

2.8.1.8 Main lines and branch lines

In the German railway system, a distinction is made between main lines and branch lines. Branch lines are operated in a more simplified way, and so level crossings without active protection are allowed, stations do not necessarily have to be protected by main signals, distant signals are not mandatory, etc. For these reasons, a maximum speed of 80 km/h applies as a general rule on branch lines.

Even though important routes are normally on well-equipped main lines, and branch lines were built for less well-used routes, a branch line is not necessarily an insignificant one. There are some heavily used (and sometimes even double-track, electrified) branch lines, as well as single-track, less-frequented main lines. The distinction lies solely in the standard of the safety systems.

2.8.1.9 Speeds

The train driver must keep strictly to the permissible maximum speed. If there is a mandatory 60 km/h limit, then the driver must drive no faster than 60 km/h, and not at around 62 km/h. Since the introduc-

tion of electronically-generated and automated driving data, a train driver must be prepared for the consequences if he/she knowingly drives too fast. Exceeding the speed limit momentarily is tolerated, however.

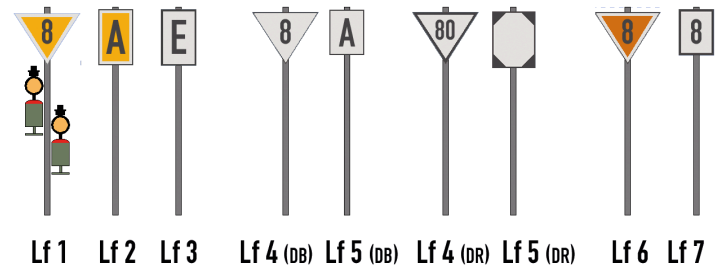
Very often, the train driver receives several pieces of information regarding maximum speed, in which case the lowest of all of the speeds is the one that applies.

The following speed information is typical of what needs to be taken into consideration:

2.8.1.9.1 Vehicle speed

Every vehicle has a maximum permissible speed, which is written on the outside of a wagon, and on the inside of the cab in a locomotive. The vehicle which has the lowest maximum speed determines the maximum speed for the whole of the train. The scheduled maximum speed is specified in the timetable for each particular train. When putting together a consist, care must be taken to ensure that all vehicles in the consist are permitted to run at this speed. When a change in the speed limit occurs, the driver must take the train length into consideration. If a higher speed limit applies, he/she must ensure that the entire train has passed the relevant point before accelerating. The driver is informed of the length of the train by the braking sheet that is produced when the consist is put together, and he/she can find out how far the train has travelled by looking at the mileposts along the route or at the hectometre boards.

2.8.1.9.2 Maximum speed for the route





Every route has a maximum speed which is determined by the bend radii and the permanent ways. The driver will find the line speed in the working timetable. The working timetable for the train already takes into consideration the maximum speed of the train. This means that a working timetable will have a maximum speed of 80 km/h for a train which itself has a maximum speed of 80 km/h, even if the actual line would allow higher speeds. Changes in line speed are indicated on signal boards along the line. Signals Lf 4, Lf 5, Lf 6 and Lf 7 are used. In the Bundesbahn, only reductions in speed used to be indicated, and the driver had to find out the increases in speed from the working timetable. In the GDR Reichsbahn, increases in speed were also signalled, which has now been adopted across the whole of Germany. The triangular board gives the relevant speed notification, and the square one indicates the place at which the new speed applies, in this case, for the new speed of 80 km/h.

2.8.1.9.3 Temporary speed limits

In places where there are construction works, severe defects in permanent ways etc. the line speed may be further restricted by temporary speed limits. These are indicated by the signal plates Lf 1, Lf 2 and Lf 3 and are also listed in the “La” (short for “Langsam” — slow), which is a booklet that is updated on a weekly basis and contains all exceptions and irregularities, and must be provided in the cab to provide supplementary information along with the working timetable.

2.8.1.9.4 Signal speeds

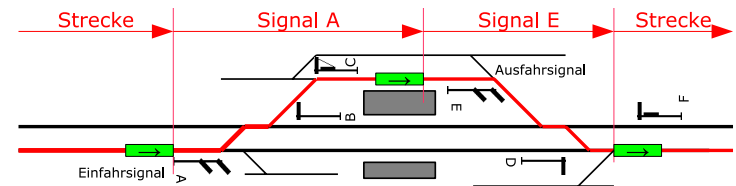
If the train has to branch off over a set of points, the speed limit is normally lower at this point than the line speed. These speeds are indicated by various signal aspects on main signals. For example, the signal may show that the line speed applies without further restriction when driving in a straight line over the points, and that a slow approach at 40 km/h applies when branching off.

The signal speeds apply from the entrance and intermediate signals until the next main signal. At junctions and for exit signals, the signal speed applies until after the last set of points (“end of points zone”). From then on, the line speed applies in accordance with the working timetable. The driver should know the status of the last points on the

route from his knowledge of the route. Nowadays this safety-related information is represented by the yen symbol (¥) in the working timetable. One exception is worthy of note: If a train makes a scheduled stop at a platform, then from the time that the train moves off again it is no longer the speed indicated on the entrance signal that applies, but rather, that shown on the exit signal.

The following diagrams provide some examples of the signal speeds that apply.

2.8.1.9.5 Entrance, scheduled stop and exit

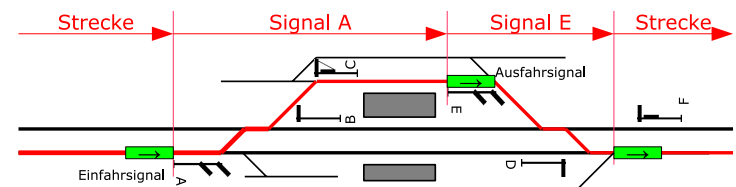


When entering the station, the speed shown on entrance signal A applies from that point (1st train position in the diagram) until the train arrives at the stopping point on the platform.

From there, after moving off, and irrespective of the length of the train, the speed shown on exit signal E applies, even if this is higher than that shown on signal A.

Once the train has driven over the last points in the route with the whole length of the train (3rd train position in the diagram), the driver can then accelerate to the speed given in the working timetable.

2.8.1.9.6 Passing through a station

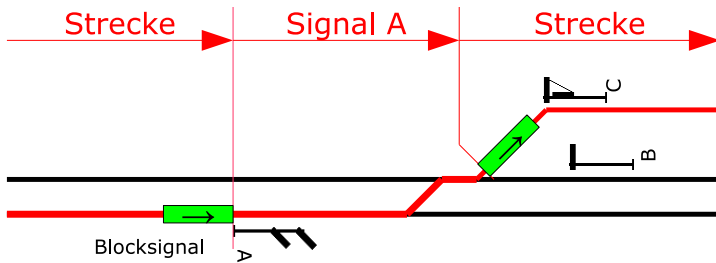


The same situation applies as in the previous diagram in the case of a



pass-through by a train, with the following difference: The change in speed to that of exit signal E does not take place at the platform, but comes into effect only when signal E is passed. If the permissible speed is higher than that indicated by signal A, then the whole train must have gone past signal E (2nd train position in the diagram) before the train can accelerate to the speed shown on signal E. In spite of the identical signals and identical route, the higher speed for a pass-through in comparison to that of a scheduled stop does not start until considerably later.

2.8.1.9.7 Pass-through at a junction or crossover



When driving through a junction or crossover, the speed indicated by the block signal applies until after the last points (“end of points zone”). After that, and taking the length of the train into consideration (2nd train position in the diagram), the driver can accelerate to the line speed again.

2.8.1.10 Timetables

In the railways system there is a large number of different types of timetables, e.g. (freight) schedule, graphic timetable, roster for traction units, and many more besides. For the locomotive driver, there is the working timetable, as shown in the example below for the Wolfsburg-Braunschweig line. Locomotive cabs contain shelves with timetables for the train services using that particular locomotive type. The driver must find his own working timetable amongst these before starting his journey. This timetable provides the driver with all the information he/she needs for driving the train according to the schedule. The example shown here is one taken from the Bundesbahn at the end of the 1980s. Nowadays, partly as a result of the railway

accident in Brühl, all main signal locations and the “end of points zone” are shown in addition.

2.8.1.10.1 Compilation of the working timetable

E 6034 Wolfsburg-Paderborn
Tfz 634-434 901
120 t/mw

1	2	3a	3b	4	5
140	Wolfsburg	080	A60	18:15	18:15
	Fallersleben	185.8	A60	18:19	18:20
		186.5			
		24.0			
23.9	80	Ehmen	20.0	18:25	
			13.6		
			13.4		
12.9	40	VZ	12.2	18:34	18:35
12.2	40	Lehre	12.2		
	60	Zsig	A60	11.5	
2.8	50	Braunschweig Ost	2.7	18:45	
			1.2		
6.8	60	Braunschweig	7.2	18:51	18:52
6.8	60	Abzw. Linsichtsch	6.2		
			5.2		
0.5	100	Braunschweig Hbf	0.1	18:59	19:01

The train number (E 6034) to which the timetable applies is shown in the top left-hand corner. The scheduled traction unit (Tfz) is class 634, and the train mass is up to 90 t.

Columns 1 to 5 contain information on the route: Column 1 gives the mileage for speed changes, column 2 shows the maximum permissible speed, column 3 the names of the operating control points (3a) on the route, and their position (3b), and in columns 4 and 5 are the scheduled arrival and departure times.

Now for the trip chronology for the E 6034:

140	Wolfsburg	E90	181.0	18:15
	Fallersleben	A60	185.8	18:20

The trip starts in Wolfsburg (this station is located at the 181.0 km-mark) at 18:15 with a maximum speed of 140 km/h. An exit signal, A60, is given, which means that at Hp 2 (signal aspect shows 40 km/h), by way of exception, a speed of 60 km/h is allowed.

The next station is Fallersleben at the 185.8 km-mark, the arrival time is 18:19, departure time 18:20.

	Fallersleben	185.8	18:19	18:20
		186.5		
		24.0		
23.9	80	Ehmen	20.0	18:25

After Fallersleben, the train turns off onto another route, as the mileage jumps from 186.5 to 24.0 (column 3b, horizontal line). After 23.9 km, a new maximum speed of 80 km/h applies (columns 1 and 2). At the 20.0 km-mark is Ehmen station, which the train scheduled to reach at 18:25. As there is no arrival time indicated here, the train passes through the station.

After another mileage change at 13.6 km/13.4 km, comes the Lehrestation. Owing to the somewhat unusual arrangement, the locations of some of the signals are also given in the working timetable:


12.9	40	VZ	12.2	18:34	18:35
12.2	40	Lehre	12.2		
	60	Zsig	A60	11.5	

VZ stands for the distant signal (Vorsignal) of the intermediate signal (Zwischensignal), Zsig at the 12.2



km-mark — the distant signal is actually located within a shortened braking distance (triangle) at the 12.9 km mark — and between the distant signal and the main signal there are only 700 m. Since that is unusually short, it is specifically set out in the working timetable, and the route mileage is also given again in column 1. Moreover, from the 12.9 km-mark, there is a maximum speed of 40 km/h. There is a scheduled stop in Lehre from 18:34 to 18:35. From the intermediate signal at the 12.2 km-mark, a maximum speed of 60km/h applies. For the exit signal, a similar exception applies as in Wolfsburg, and 60 km/h is permitted at Hp 2 (A60).

Following the Brühl rail disaster in 2000, the railways switched to writing all signal locations in the timetable, and although this makes the timetables longer, it does also enable the driver always to clearly identify the signal function.

 The rest of the timetable does not show any new functions, so further detailed explanation is not necessary. A second place with a shortened braking distance should also be mentioned: The distant signal at the Abzw. Lünischteich (Lünischteich junction) is similarly shortened, which is identified on the triangle at the 6.6km-mark.

2.8.1.10.2 Speed Book (Geschwindigkeitsheft) and Departure Times Book (Fahrzeitenheft)

Since all the same route information for all trains is taken everywhere in the form of the working timetable, far more paper is printed than is actually necessary. For this reason, the Bundesbahn decided in the 1980s to split the information into a booklet that related to the routes themselves (the Speed Book — Geschwindigkeitsheft), of which only one copy is needed, and one containing the details for each train (Departure Times Book — Fahrzeitenheft).

2.8.1.10.3 Electronic working timetable

Since 2002, traction units in the DB have been operating with the electronic working timetable and catalogue of restricted speed zones, known as the “EBuLa”, although the project was initiated years earlier and dragged its heels before being finally implemented. EBuLa is an integrated computer terminal in the cab, which displays driving

data and does away with the need for the large amounts of printed documentation of earlier years. The original intention to also include the restricted speed zone data, irregularities etc. from the “La” was abandoned in 2014.

2.8.2 All clear to depart

Generally speaking, the locomotive driver is not allowed simply to leave a station she/he has stopped at when a signal is showing the proceed aspect, but must wait for the all clear to depart. The conductor stands on the platform, closes the doors, and give the driver the all clear with the green and white Zp 9 signal. Only then can the locomotive driver move off. Exceptions to this rule are trains with SAT (door-closing procedure operated by the driver) or with fully automatic doors, when the driver also takes on the conductor’s tasks.

2.9 Drive Technology

2.9.1 Electric Series-Wound Motor Drive

The electric series-wound motor operates with alternating current drawn from the overhead line via a pantograph. The power controller (throttle) in the cab operates a stepping mechanism on the vehicle transformer, with which low or high voltages in the transformer can be selected in order to control the power of the electric motors as required. During operation, there are two essential thresholds that must not be exceeded: Firstly, the intensity of the current drawn from the overhead line (overhead current), and secondly, the current intensity in the electric motors (motor current). In the case of older vehicles, the driver has to manually ensure that these thresholds are complied with by operating the power controller himself in the correct way, otherwise, the motors will be disconnected from the current (via the motor-isolating contactors), or the current disconnected from the whole vehicle (via the main switch), for safety reasons. Newer vehicles have limit monitoring devices that restrict the step-up in such a way that the current intensities automatically remain



within the thresholds. Another reason for the main controller shutting off while the train is moving is if a track section without a live overhead line is entered by mistake. In the event of wheel slip, the train driver has to take action himself to change down the power controller, as the wheel slip control in series-wound vehicles is usually limited to an anti-wheel-slip brake.

2.9.2 Electric Drive (Three-Phase Current)

This type of traction system has completely replaced the series-wound drive in all vehicles built since the early 1990s. With this traction system, the alternating current supply from the overhead line equipment is transformed initially into three-phase current in the vehicle. Three-phase motors are comparatively lightweight and need comparatively less maintenance in high performance conditions. The fundamental considerations that apply to motor current and overhead current also apply here, although most three-phase vehicles have inbuilt automatic limit-monitoring systems. In addition, this type of vehicle normally has automatic traction control, which prevents wheel slip by continuous brake interventions (or, more specifically, only a minimal amount of slip is normally permitted, in order to obtain maximum possible traction). The role of the train driver is thus restricted to simply predefining the desired maximum traction using the power controller. Should it not be possible to produce the desired amount of traction on the rails, the traction control creeps little by little up to the peak traction value.

2.9.3 Diesel-Hydraulic Drive

With this type of drive, a diesel motor transfers power to a hydraulic drive unit, which consists of torque converters and clutches in which oil is driven at high speed against a turbine wheel. Before the stationary vehicle starts to move, the converter must first be filled with oil, which takes around one to two seconds. Some vehicles have an indicator light that switches off to indicate that the filling process has been completed. If such an indicator is not present, then the driver should initially switch from speed level 0 to no higher than speed level 2, then wait approximately two seconds before switching

to higher speed levels. Since hydraulic drive units are always automatic transmission, subsequent gear changes after initial moving off will always occur automatically, determined by the speed and the engine load. In this process, the oil from each previous converter is drained out and the new converter or clutch is filled, so that the gear changes occur without the traction being interrupted. In the event of wheel slip, the train driver must change down the power controller, as, although throttling down as an immediate countermeasure normally achieves grip, the effect of this diminishes over time and the wheels would therefore start to slip again.

2.10 Braking technology

2.10.1 Introduction

In the earliest days of the railways, widely differing braking systems were developed. Brakemen were employed to sit in small, elevated cabs located in every other wagon, and apply or release the brakes on a whistle-signal from the engine driver.

The major breakthrough in terms of safety and rationalisation came in 1869 with the invention of the air brake by Westinghouse. This system allows the engine driver to apply the brakes on all wagons remotely from the driver's compartment by means of an air pipe running the length of the train. It is the air brake which is used as the standard braking system on railways today. However, there were some interesting niche developments along the way, including systems with mechanically operated cable pulls that ran the length of the train. On many narrow-gauge and light railway lines, trains were fitted with vacuum brakes (similar to air brakes, but using a vacuum).

Zusi is based on air brakes used as standard across Europe.

2.10.2 Braking efficiency

The braking capacity of vehicles and trains is expressed as braked weight percentage, which is calculated using the following formula:



$$\text{Braked weight percentage} = \frac{\text{Braked weight}}{\text{Train mass}} \times 100$$

The train mass is the total combined mass of all vehicles in a train, while the braked weight is a somewhat “imaginary” value that is calculated using the following formula:

$$\text{Braked weight} =$$

whereby k is a factor that takes account of the response behaviour etc. of the brake construction type in question, total braking forces are all of the effective braking forces between the train and the track, and g is gravitational acceleration.

With the value for performance expressed as braked weight percentage, this in turn also establishes the relationship between train weight and the braking forces that can be applied, resulting in a value that represents the braking efficiency independent of brake construction type or train mass.

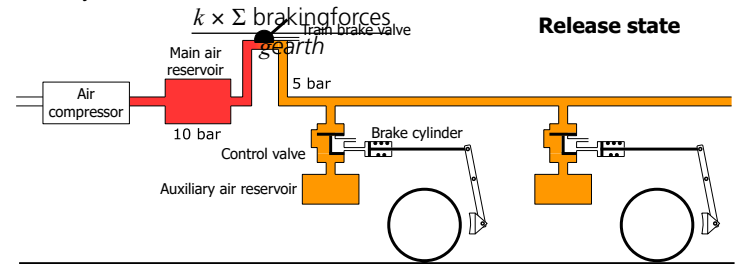
A specified braking efficiency is required for any given timetable on a route, so that the train can come to a halt within predetermined braking distances on slopes and before distance signals. This minimum value which must be achieved is referred to as the minimum braked weight percentage. If a train does not meet the minimum braked weight percentage (for example, if the train includes rolling stock with less effective brakes), then the maximum speed must be reduced to ensure that the braking distance is adhered to.

2.10.3 Air brake

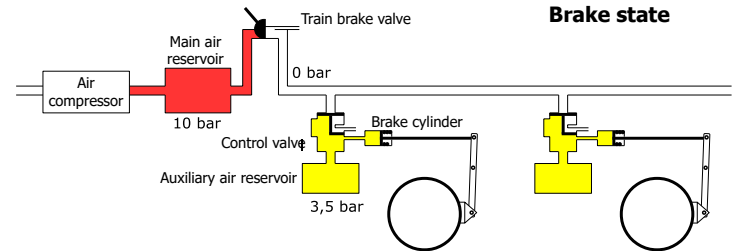
The air brake is the standard train brake used for railway vehicles throughout Central Europe. The main components of the air brake system include an air compressor on the locomotive, which maintains an air pressure of around 10 bar in the main reservoir. The main brake pipe runs the length of the train and is connected to the main reservoir via the driver’s brake valve. The driver operates the brake

using the driver’s brake valve. The following two diagrams provide a highly simplified overview of the system:

In the driving position (released state), the driver’s brake valve keeps the pressure at 5 bar. As a result, the auxiliary reservoirs located on each wagon are filled to a pressure of 5 bar via the main brake pipe. The brake cylinders are vented to the ambient air, and the brakes are thereby released.



The scheme below shows the brake in full application position: The air in the main brake pipe is released through the driver’s brake valve. The control valve switches due to the pressure from below and air from the auxiliary reservoir feeds into the brake cylinder, establishing a pressure of approx. 3.5 bar.



Should a wagon or train section break away from the rest of the train, the main brake pipe will become uncoupled, and emergency braking then occurs automatically as a result of the loss of pressure. The same thing happens if the emergency brake is pulled.



In normal braking, the pressure is 10 bar in the main reservoir and 5 bar in the main brake pipe in driving position, with full braking performance being achieved at 3.5 bar. The pressure in the main brake pipe only ever falls below 3.5 bar during emergency braking or automatic train stop situations, when the air in the pipe is completely vented within a short period of time through exceptionally large cross-sectional vents.

Venting the main brake pipe also allows the braking force to be adjusted to intermediate levels of pressure between 5 and 3.5 bar.

2.10.3.1 Operation of air brakes

The driver has two interfaces with the brake system — one in the form of the aforementioned driver's brake valve, and the other in the form of a pressure gauge in the cab for controlling the braking force.



The pressure in the main brake pipe is set by means of the train brake valve. There are various designs of train brake valve, which are explained under section 2.7.1.2. When the driver wants to apply the brakes, he sets the train brake valve to the desired pressure (between 5 and 3.5 bar) in the main brake pipe.

Even the best air brake or dynamic brake cannot brake the train more forcibly than the friction coefficient between wheel and rail will allow. An increase in brake force would, in that case, simply result in skidding, or, in other words, the sliding of the non-rotating wheel on the rail, which would very quickly wear flat areas on the wheel.

2.10.3.2 Direct-release brake

The direct-release brake is the oldest and simplest system, which has more or less been superseded now in Germany. What is interesting about this system is that although the brakes can be applied in increments, they cannot be released gradually. As soon as the pressure in the main brake pipe increases slightly, the brake is released completely. After repeated braking and filling, the supply in the auxiliary reservoirs can be exhausted, and the train will no longer brake at all. For this reason, the direct-release brake demands especially prudent driving and braking behaviour.

2.10.3.3 Graduated brake

In contrast to the direct-release brake, the graduated brake can be released incrementally, and is practically inexhaustible. This makes sloping gradients easier to deal with, as well as making it significantly easier for the train to come to a precisely controlled stop at a platform. All newly-built vehicles in Germany are fitted with graduated brakes.

2.10.3.4 Brake setting

Swift application of the brake after a fall in pressure in the main brake pipe can be a problem in long trains. The coaches at the front respond more quickly than the coaches at the back, as the reduction in pressure takes longer to reach the end of the train. So, in order to prevent, for example, a strongly banking back end pushing the front wagons off the track on a bend, there must be a way of adjusting the change rate of rotational speed [rpm per s] to suit the particular consist.

This is done by setting the brake type at the control valves for each wagon, which must be carried out by railway staff at the time the consist is assembled. The possible brake settings are G (goods/freight train, with very slow application and release of the brake cylinders), P (passenger train) and R (rapid) as well as R+Mg (Magnetic brake). Freight trains are often run in the P setting, if the consist permits it.

2.10.3.5 Overloading

If the driver fills the main brake pipe to pressures of well over 5 bar as a result of holding the train brake valve in the "Fill" position for too long, the brake can reach a point at which it can no longer be released. This is known as overloading. If such a misfortune befalls the driver, he must then go through the whole train and manually vent the brake in each wagon.

2.10.4 Wear-resistant brakes

It is recommended that the wear-resistant brakes are the first ones to be applied, and that the air brake is only resorted to if the braking capacity of the wear-resistant brakes is insufficient.



2.10.4.1 Electric brake

In the case of traction units with electric drive, there is an option to deploy the electric motors for braking, as it is well known that when powered, an electric motor can also act as a generator. The braking power thus generated must then be discharged afterwards, e.g. via large resistors on the (well-ventilated) roof of the locomotive. Typical examples of this are classes 110 and 139 in the DB. The advantage of this method is the very low amount of wear in comparison to the block brake.

With the introduction of three-phase technology in the 120 class, it also became possible to feed the power generated by electric braking back into the overhead line, which has a positive impact on the overall electricity consumption.

2.10.4.2 Hydro-dynamic brakes

Primarily in the case of diesel locomotives with hydrodynamic drive, there are also hydrodynamic brakes (also known as retarders), in which the braking power is converted to heat.

2.10.4.3 Eddy current brake

With the eddy current brake it is possible to increase the brake force to above the friction coefficient, whereby eddy currents are induced in the rails by electromagnets in the vehicle, which slows the vehicle. The big advantage with this type of brake is that it is not dependent on friction coefficients, and so the same brake force is applied even when rails are slippery.

2.10.5 Magnetic brake

Another type of brake which can slow down a vehicle above the normal friction threshold is the magnetic brake. Here, electromagnets are lowered onto the rail head and perform a mechanical braking action. Because of the high level of wear with this type of brake, they are, however, only used in emergency braking situations, and regular braking is carried out using other systems. This brake is automatically released when the pressure in the main brake pipe falls below 3 bar. At speeds of under 50 km/h, the magnetic brake is released again

automatically. Some traction units also allow manual release of the magnetic brake via a switch in the cab.

2.11 Signals

Signals convey information visually (and some, also aurally) to the train driver. There are countless variants in terms of their meaning and design, depending on the country, historic period and intended function. The explanation of signals that follows will be restricted to the ones that are relevant to Zusi.

Main signals serve the purpose of safety for running movements, and communicate to the driver whether and at what speed he/she is permitted to drive on the section of track ahead. In their default position, main signals show the stop aspect, and are only switched to show the proceed aspect for a running movement. An exception to this is the automatic block signal, which shows the proceed aspect by default, and only switches to the stop aspect after a train has passed, until the block section is clear again.

As the braking times of trains are too long for the driver to come to a standstill after seeing what aspect the main signal is showing, the main signal aspect is indicated by a distant signal located at the braking distance away from the main signal (usually c.1000m).

There are also simple sheet metal signals, some with lights, that communicate a wide range of other information, such as a stopping point or a speed restriction. All signal aspects have an abbreviation, which are shown below in detail.

2.11.1 Germany

A harmonised signalling system was introduced in Germany at the end of the 19th century, and most signals work on the same principles even today.

Before this uniform system was introduced, most of the regional railways in Germany had their own signalling systems. These have not yet been included in the documentation. After the two German states



were formed after the Second World War, the signalling system once again diverged into two systems. Since reunification, efforts have been underway to harmonize the two, but this is likely to be ongoing for quite some time.

With just a few exceptions, generally speaking, signals are located on the right-hand side next to or above the corresponding track. Those wishing to explore this topic in greater depth can read about it at <http://www.sh1.org>, for example.

2.11.1.1 Historic regional railway styles

This era is not covered by Zusi at present.

2.11.1.2 Semaphore signals in the Deutsche Reichsbahn



When the regional railways were subsumed into the Deutsche Reichsbahn, the semaphore signals outlined below were introduced across the whole of East Germany from the 1920s onwards. They are still in common use today. The signal aspect is shown by one/two semaphore arms, and at night by one/two lights. There are three signal aspects that can be shown:

Stop (Hp 0, horizontal arm, night aspect:

red light); proceed without speed restriction (Hp 1, diagonal arm or green light); proceed with 40 km/h speed restriction (Hp 2, two diagonal arms or green and yellow light). The 40 km/h restriction arises from the way in which points are generally constructed, which allows a train to travel at 40 km/h on the branching-off switch rail, while the straight track can be driven on without speed restriction.

The driver can thus immediately identify from the signal whether he/she is going to branch off at a set of points. Signals that only apply to routes without speed restrictions do not have the second semaphore arm, which will also not be present on the distant signal in this case.

The distant signal consists of a disc that is shown face-on to the driver in its warning aspect (Vr 0, Vr 2), and for unrestricted running (Vr 1) is flipped up 90° and is thus barely visible. The corresponding night signal consists of two orange or two green lights.

Main signals with two semaphore arms normally have a distant signal with a supplementary semaphore arm — a main signal with a 40 km/h restriction is indicated in advance by a distant signal showing the disc plus a diagonal semaphore arm.

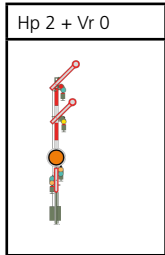
There are of course situations in which other speeds besides 40 km/h apply at main signals. These are indicated by means of supplementary signals, which are explained in greater detail under Speed Indicators in section 2.11.1.7.

The distant signal with supplementary semaphore arm was introduced quite late on in the 1930s. Up until that time, Hp 2 was always indicated by a distant signal without an additional semaphore arm. The driver therefore had to be prepared at a Vr 1 aspect at the distant signal for Hp 2 at the main signal. Occasionally, an instruction regarding a diversion over junction points for a train that is scheduled to travel along the main continuous track is communicated via the distant signal Vr 0. All-in-all, such an arrangement is not only questionable from a safety perspective, but also hinders the flow of traffic. More advanced distant signals with supplementary semaphore arms also had an extra, special distant signal board. When this board is present, the driver can safely assume that with the distant signal Vr 1 he can also expect Hp 1 at the main signal.

	Daytime signals				Night time signals	
	Distant signal		Main signal		Distant signal	Main signal
Stop (Vr 0/Hp 0)						
Proceed (Vr 1/Hp 1)						
Proceed with 40 km/h (Vr 2/Hp 2)						

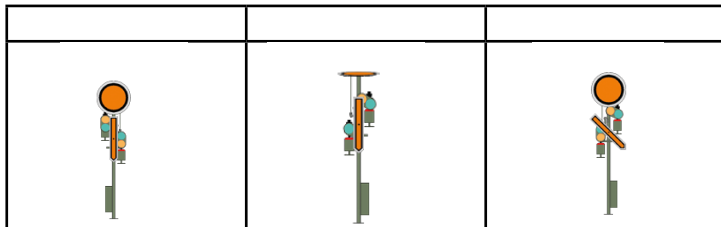


When a main signal is followed by the next main signal within the braking distance, then the distant signal for the second main signal will be located in the same place as the first main signal. The following signal combination thus means: From this point onwards 40 km/h; the next main signal is showing the stop aspect.



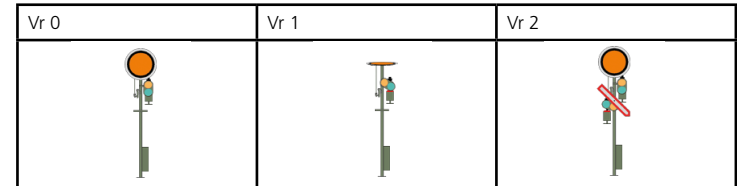
2.11.1.2.1 Differences in the case of the Deutsche Bundesbahn

In the post-war period, the red and white supplementary semaphore arm at the distant signal was exchanged for an orange one, as shown in the images below. Moreover, (in contrast to the GDR Reichsbahn) the somewhat suspect configurations from a safety perspective were redesigned in a new arrangement, whereby Hp 2 can be communicated at the distant signal using just two aspects. In the Bundesbahn area therefore, drivers do not have to be prepared to find speed restrictions at the main signal that have not already been indicated at the distant signal. As a special distant signal board for triple-aspect signals became superfluous, the normal distant signal board is found in front of every distant signal on the Bundesbahn.



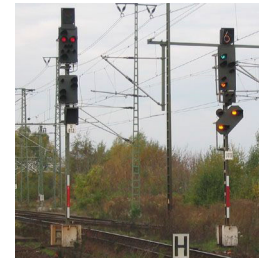
2.11.1.2.2 Differences in the case of the Deutsche Reichsbahn (GDR)

With the GDR Reichsbahn there was a danger with the original set-up for Vr 2 of confusing it with the HI 3a of the HL light system (section 2.11.1.4). For this reason, the triple-aspect distant signals were changed to a light signal (green light underneath, yellow light above). Similarly, a set-up with just one green and one yellow light for proceed and stop was introduced at standalone signals.



After the Deutsche Bahn AG was founded, the Bundesbahn-type supplementary orange semaphore arm was also allowed in the former GDR, gradually replacing the original type from around 2010 onwards.

2.11.1.3 Light signals in the H/V (Main/Distant) Signalling System (Bundesbahn)



The first light signals in the H/V System began to be trialled by the Reichsbahn as early as 1927. The night-time aspects of the H/V semaphore signals were adopted for these light signals. However, light signals were not used extensively until after the Second World War.



	Distant signal	Main signal
Stop (Vr 0 / Hp 0)		
Proceed (Vr 1 / Hp 1)		
Proceed with 40 km/h (Vr 2 / Hp 2)		

The signal screens vary in their design. There are the 1951 and 1969 types, as well as the most recent designs known as compact signals. Moreover, different signal screens are used according to the function of the signal. For the train driver, what the screen or housing looks like is, of course, irrelevant. The particular function of the signal (block signal, entrance signal, intermediate signal or exit signal) must be deduced by the driver on the basis of his/her knowledge of the route.

It is only more recently that drivers have been able to rely completely on the information given in the working timetable.



Speeds that differ from 40 km/h are notified in advance on the speed indicatorZs 3 (section 2.11.1.7), and byZs 3v as required.

Exit and intermediate signals must also have the facility to give permission for shunting movements. In the case of 1951-type signals, the H/V main signal and the switch signal for shunting were shown separately at the same location. Later on, the switch signal was integrated into the signal screen of the main signal. In accordance with the rulebook of the time, theHp 0 signal only applied to running movements, and so a second red light signalled a stop aspect for shunting movements. The two red lights together formed the signal aspect. Hp 00. Since then, theHp 0 has been introduced to apply to shunting movements, and Hp 00 no longer has any additional significance. Retrofitting of the double red light signals was not carried out.


Hp 00 (today: Hp 0) — stop for running and shunting movements	
Hp 0 + Sh 1 - stop for running movements, movement restriction lifted for shunting movements	






When a light signal is not needed for a particular route, it is deactivated. In order to be able to distinguish a deactivated light signal from a defective one, a white marker light is displayed. Signals showing the marker light are treated as non-existent.

	Distant signal	Main signal
Marker light		

Where there is only a short distance to the next main signal, the distant signal can be mounted on the post of the previous main signal. Such a set-up has the peculiarity of the distant signal being dark-switched as long as the main signal is showing Hp 0 .

Hp 0, distant signal dark-switched	
------------------------------------	---

Where the braking distance is reduced by more than 5%, H/V distant signals show an additional white light. The same white light is shown in the case of distant signal repeaters. The driver can distinguish between the two cases by means of the Ne 2 distant signal board. When a distant signal board is present (or when there is a distant signal mounted on a main signal) then the braking distance is reduced. Signal repeaters, on the other hand, do not have a distant signal board.

Vr 0, reduced braking distance (on the right together with Hp 1 on the main signal)		
Vr 0 as distant signal repeater		

For an explanation of the meanings of the post-mounted signs on H/V main light signals, see the separate section section 2.11.1.6.

2.11.1.4 Light signals in the HI system (GDR Reichsbahn)



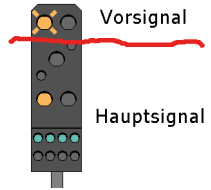
The HI-signal system was developed jointly by a number of railways in the former Eastern Bloc, and was introduced by the GDR's Deutsche Reichsbahn from 1959 onwards.

HI signals combine the functions of the main signal and the distant signal in one signal screen. Combining the lights for main and distant signals, as well as light bars that increase the main signal aspect to a higher speed, results in a possible 17 different signal aspects. Beginners should therefore not attempt to memorise the signal pictures, but instead should learn the system behind them in order to be able to understand the signal aspects.

Up to two lights are shown on the signal screen. The lower half of the signal screen represents the main signal function of the signal and shows the speed which applies from this signal, while the upper half has the function of the distant signal for the next main signal. If no yellow light is visible in the lower half, then the train is permitted to pass this signal at the maximum route speed. If there is a yellow light



in the lower half together with a bar of yellow lights, then a speed of 60 km/h is allowed, and with no yellow bar a speed of just 40 km/h is permitted. A green light-bar together with a yellow light permits a passing speed of 100 km/h.



A steady green light in the top part of the signal screen means that the next signal allows a train to proceed at the maximum route speed. A flashing green light means that the train is allowed to proceed at a speed of 100 km/h at the next signal. A steady yellow light in the top part means that the next signal will be showing the stop aspect. A flashing yellow light

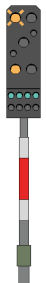
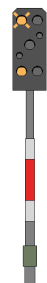
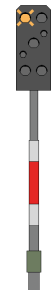
in the top part indicates that the next signal will be showing either 40 or 60 km/h. Which of the two speeds is meant can only be determined from one's knowledge of the route. In the event of doubt, the driver must err on the side of caution and assume that 40 km/h is meant.

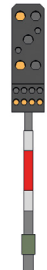
HI 1 Proceed — maximum speed, Expect proceed — maximum speed		HI 2 Proceed — max. speed 100 km/h, Expect proceed — maximum speed		HI 3a Proceed — max. speed 40 km/h, Expect proceed — maximum speed	
Distant signal	Main signal	Main signal	Main signal	Main signal	Main signal

HI 3b Proceed — max. speed 60 km/h, Expect proceed — maximum speed		HI 4 Proceed — maximum speed, Expect proceed — max. speed 100 km/h		HI 5 Proceed — max. speed 100 km/h, Expect proceed — max. speed 100 km/h	
Main signal		Distant signal		Main signal	

HI 6a Proceed — max. speed 40 km/h, Expect proceed — max. speed 100 km/h		HI 6b Proceed — max. speed 60 km/h, Expect proceed — max. speed 100 km/h		HI 7 Proceed — maximum speed, Expect proceed — max. speed 40 or 60 km/h	
Main signal		Main signal		Distant signal	

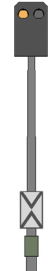
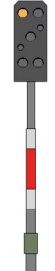
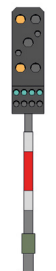
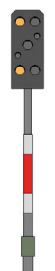


<p>HI 8</p> <p>Proceed — max. speed 100 km/h, Expect proceed — max. speed 40 or 60 km/h</p>	<p>HI 9a</p> <p>Proceed — max. speed 40 km/h, Expect proceed — max. speed 40 or 60 km/h</p>	<p>HI 9b</p> <p>Proceed — max. speed 60 km/h, Expect proceed — max. speed 40 or 60 km/h</p>
Main signal	Main signal	Main signal
		

<p>HI 12b</p> <p>Proceed — max speed 60 km/h, Expect stop</p>	<p>HI 13 (today Hp 0)</p> <p>Stop</p>
Main signal	Main signal
	

HI signals can only show speeds of 40, 60, 100 and unrestricted, which is clearly a disadvantage in comparison to other signalling systems, and is the biggest shortcoming of the HI system.

For an explanation of the meanings of the post-mounted signs on HI signals, see the separate section section 2.11.1.6.

<p>HI 10</p> <p>Proceed — maximum speed, Expect stop</p>	<p>HI 11</p> <p>Proceed — max speed 100 km/h, Expect stop</p>	<p>HI 12a</p> <p>Proceed — max. speed 40 km/h, Expect stop</p>	
Distant signal	Main signal	Main signal	Main signal
			

2.11.1.5 Ks light signal system (nationwide in Germany)



After German reunification, a common signalling system was developed for the new and old Federal States, namely the Ks (combination signal) system. This is implemented in conjunction with electronic signal boxes only. The first Ks signals were put into operation in 1993.

The main feature of the Ks system is that there is only one light on the signal screen. The proceed aspect Ks 1 is used at distant signals as well as main signals. Purely distant signals do not have a post-mounted sign, but a distant signal board Ne 2. Main signals are identified by a post-mounted sign.

Speeds are notified entirely via speed indicators Zs 3 (section 2.11.1.7), and notified in advance via Zs 3v as required.



	Distant signal	Main signal
Stop (Ks 2 / Hp 0)		
Proceed (Ks 1 / Ks 1)		

A special feature of Ks 1 is that if there is an additional distant speed display Zs 3v at the signal, the green light of the Ks 1 will be flashing.

Main and distant signal functions can be brought together into one signal screen. Such signals are indicated by an additional post-mounted sign that shows a yellow triangle standing on end:

Stop (Hp 0)	Proceed, Expect proceed (Ks 1)	Proceed, Expect stop (Ks 2)

Where the braking distance is reduced by more than 5%, Ks signals

show an additional white light above the signal light. An additional white light underneath the signal light is a distant signal repeater.

Expect stop (Ks 2), reduced braking distance	
Expect stop (Ks 2) as distant signal repeater	



And finally, a comparison of the same signal aspect in the H/V, HI and Ks systems (60 km/h permitted, Expect 100 km/h):



2.11.1.6 Post-mounted signs

If the night-time versions of the semaphore signals are suspect or not working, a temporary solution can be to ascertain the signal aspect from the daytime signal. This fallback does not exist for any type of light signal, so the driver needs information on how he should drive at a malfunctioning or impaired light signal. There must also be a solution to cover the eventuality of a signal permanently showing the stop aspect and communication with the relevant traffic controller not being possible at the location of the signal. If the signal is not protecting a danger zone (in particular, at a set of points for an incoming track), then the post-mounted sign can allow a train to overrun a signal showing the stop aspect.

If a light signal that has a post-mounted sign is found to be not working or is faulty, the driver must first stop. His/her next move depends on the post-mounted sign:



<p>White-red-white post-mounted sign:</p> <p>Pass only with a command, substitute signal, caution signal, opposite-track running substitute signal or verbal order together with M-board. Shunting movements require permission before they can pass.</p>	
<p>White-yellow-white-yellow-white post-mounted sign:</p> <p>On-sight passing allowed until the next main signal if communication with the traffic controller is not possible.</p>	

<p>Speed indicators and advance speed limit signals in the form of sheet metal signs: at the top,Zs 3 with the number 6, and at the bottom,Zs 3v with the number 3. If the signal is showing the proceed aspect, a speed of 60 km/h is permitted at the signal, and 30 km/h from the next signal.</p>	
<p>Speed indicators and advance speed limit signals in the form of light signals: at the top,Zs 3 with the number 6, and at the bottom,Zs 3v with the number 3. Here, a speed of 60 km/h is permitted at the signal, and 30 km/h from the next signal.</p>	

Note on current deployment in Zusi: Passing a signal showing the stop aspect with a white-yellow-white-yellow-white post-mounted sign is not advised, as this is not due to a simulated disruption but to a route that is in reality not available. If the user ignores the signal and drives past it, the train will drop out of the simulator's signal box logic and will not be assigned any more regular routes in future.

H/V semaphore signals also carry red and white painted post-mounted plates, however, these are only for the purposes of improving noticeability, and are not signs that have any operational significance.

2.11.1.7 Speed indicators

Speed indicators (Zs 3) and distant speed indicators (Zs 3v) are used in conjunction with H/V semaphore and light signals as well as Ks (combination) signals. They come either in the form of a sheet-metal sign (when the same speed applies to all routes that depend on the signal) or as changeable light indicators (when different speeds have to be indicated). They show a speed limit code number between 1 and 15, which represents 1/10 of the speed that is permitted in the points zone beyond the signal. The numbers on the speed indicator Zs 3 are in white. Within the braking distance before the Zs 3 (typically at the distant signal) there may be an advance speed limit signal Zs 3v, which will show the same number as the upcoming Zs 3 but in yellow.

Speed indicators are found in isolation along the track, or at the location of a main signal. They change the maximum speed that applies from the signal. In particular, at the Hp 2 signal, the standard 40 km/h no longer applies if a Zs 3 is showing a different speed. In the case of H/V semaphore and light signals, up to and including Zs 3 number 6, the signal aspect Hp 2 is shown, and from number 7 upwards, Hp 1.

2.12 Train protection

The purpose of train protection systems, among other things, is to recognise when the driver is incapacitated or when errors are being made such as driving over the speed limit or responding incorrectly to signals, and to brake if necessary. Numerous country-specific systems have been developed over the last few decades. There are basically two types of train protection system: PZB (Punktförmige Zugbeeinflussung, or intermittent train protection) is the umbrella term for all safety systems that exchange information between train and track at certain points along the route. Continuous systems, on the other hand, maintain continual contact between the locomotive and the track/signal box. The first system of this kind to be installed in Germany was LZB (Linienzugbeeinflussung). Since LZB is the only system of this kind in Germany, there is no umbrella term for in



German railway terminology as a counterpart to PZB. The abbreviation CTC (Continuous Train Control) is used by the safety system manufacturer Siemens.

2.12.1 Europe-wide systems

2.12.1.1 ETCS

In a move to harmonise the numerous different train protection systems in Europe, a unified, territory-wide system has been undergoing development since the 1990s that is designed to be a successor to the existing technologies. The European Train Control System (ETCS) is expected to simplify cross-border rail travel significantly in the future. Three different levels of application have been defined for the system, of which Levels 2 and 3 can be considered to be the most forward-looking. An initial test programme for Level 2 has been ongoing since the beginning of the 21st century, in which the SBB route between Olten and Lucerne has played a major role as the first large-scale practical trial. So far (in 2014), Level 3 has not yet been deployed in the field, and is not expected to be implemented in the foreseeable future. Communication is carried out by means of radio and balises, with Euroradio providing a continuous radio link between train and signal box. The Eurobalise transmits data intermittently to a passing train, and this can consist of static information such as a speed profile, or changeable information e.g. in connection with signals.

2.12.1.1.1 ETCS Level 1

At the simplest level — Level 1, Eurobalises are installed in connection with signals. The balises transmit the signal aspects to the vehicle-side system, which monitors the journey as it progresses. The speed profile of the route is also transmitted, making it possible to monitor a train's speed continuously. Since the information is only transmitted to the balises at regular intervals, Level 1 is a type of intermittent train protection system.

2.12.1.1.2 ETCS Level 2

At Level 2, contact between the train and signal box is maintained on a continual basis via Euroradio, which makes Level 2 an example of a continuous train protection system. The train determines its position by means of distance measurements, and communicates the results to the signal box via Euroradio. To avoid the risk of cumulative errors, this information from the train is regularly cross-checked with the help of Eurobalises. The balises are only able to assist with positioning information, however, and do not transmit any movement data, which is received by the train from the signal box via Euroradio. This ensures that the train's movement is continually monitored.

In order, for example, to be able to identify train separations, track-side axle counters and clear-track signalling are also required. The track is divided into block sections, in which only one train is allowed in one block section at a time. Signals are no longer required along the track.

In Germany, timetabled operation of ETCS Level 2 was implemented along a short section of track near Dessau at the end of 2005, and an initial, small number of electric locomotives were equipped with the system. The system is expected to be deployed in the next phase on a north-south corridor as well as an east-west corridor, which, it is hoped, will facilitate transit traffic.

2.12.1.1.3 ETCS Level 3

Level 3 does not work at all with fixed block sections, but trains are permitted to run one after the other continuously, with a headway of their respective braking distance. In a step up from Level 2, however, this requires a system whereby the train itself can monitor its own integrity, so that a following train can be stopped in the event of a train separation. This obviates the need for costly track-side axle counters, which makes implementation of the track-side infrastructure much more economical.



2.12.2 ETCS

In a move to harmonise the numerous different train protection systems in Europe, a unified, territory-wide system has been undergoing development since the 1990s that is designed to be a successor to the existing technologies. The European Train Control System (ETCS) is expected to simplify cross-border rail travel significantly in the future. Three different levels of application have been defined for the system, of which Levels 2 and 3 can be considered to be the most forward-looking. An initial test programme for Level 2 has been ongoing since the beginning of the 21st century, in which the SBB route between Olten and Lucerne has played a major role as the first large-scale practical trial. ETCS also sees growing usage outside of Europe, e.g. in Mexico, Saudi-Arabia, China, Sweden, Taiwan, New Zealand, and India.

The ETCS device in the trains can also control the older national systems. This way, the systems of the respective countries can still be used before only ETCS will be used in the distant future. If a train enters an ETCS section, it will switch to ETCS and, at the end of the section, switch back to the old national system.

2.12.2.1 Terms and components

2.12.2.1.1 Baseline

The baseline is the development status of the ETCS. There are baseline versions 1 (obsolete), 2 and 3, as well as sub-versions such as 2.3.0 d etc. Baseline 3 has existed since approx. 2018. Rolling stock and route must be fitted with compatible systems; a number of backwards compatibilities exist.

2.12.2.1.2 Balises and radio



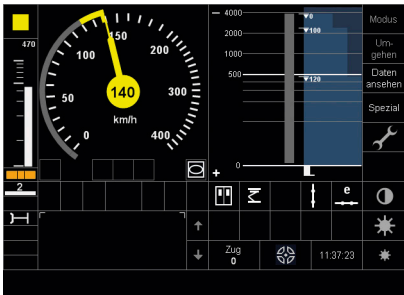
Eurobalise

Communication is carried out by means of radio and balises, with Euroradio providing a continuous radio link between train and signal box. The Eurobalise transmits data intermittently to a passing train, and this can consist of static information such as a km location (static data balise), or changeable information in connection with signals (switchable data balise). For direction-specific information, a balise group of 2 balises is required. Possible functions of the balises are:

- Main balise groups at the main signal (Level 1)
- Infill balises as approach signal function (Level 2)
- Positioning balises (“km stone”)
- Level-change balises
- Balises for “national values” (e.g. permitted speeds when driving on sight)



2.12.2.1.3 Display



ETCS is only available with displays using either touch displays or displays with key frames. The display uses the reference variables (target speed, route to destination and speed) to continuously display the current permitted speed monitored by ETCS. The structure of the display is mandatory, and consists of

the following sections:

Speed display Displays the actual speed (indicator) and the target speed (maximum speed permitted by ETCS) as a mark on the outside of the speed scale, here 140 km/h.

Route to destination: The route to the destination is displayed as a figure to the left of the speed display (470 m) and as a descending bar. It displays the distance to the next speed reduction. The new speed permitted from there is shown as a coloured contrast in the target speed, here 120 km/h.

Level: The active level is displayed under the route to destination, here level 2.

Radio: The Euroradio status is displayed under the level. There is an active radio connection here.

Mode: The square symbol at the bottom right of the speedometer displays the ETCS mode, here Full supervision.

Planning level: The planning level can be seen to the right of the speedometer that displays the speed profile of the route ahead.

Messages A range of messages can be shown at the bottom of the display. Some need to be confirmed, which can be done with the display button or with the ETCS confirmation key on the control panel.

2.12.2.1.4 Level

The operating method (wayside equipment) is known as a level. There are the following levels, which are described later in more detail:







Level STM (also NTC): National legacy system active, here PZB/LZB	
Level 0 (no ETCS wayside equipment)	
Level 1 Limited Supervision	-
Level 1 Full Supervision	
Level 2 (only Full Supervision available)	
Level 3 (vision of the future)	

2.12.2.1.5 Modus

The current status of the system is known as the mode. Exactly one mode is always active, shown as a symbol in the display:

FS: Full Supervision (FS is the normal operating mode when driving: full reference variable and continuous monitoring of the maximum speeds by ETCS)	
OS: On Sight (travelling by sight)	
SR: Staff Responsible (ETCS cannot monitor the rolling stock, the train driver is responsible)	
SH: Shunting	
UN: Unfitted (Level 0, rolling stock vMax is monitored, max. 50 km/h in Germany)	



SB: Standby (starting status after switching on)	
TR: Trip (pass through ETCS stop)	
PT: Post-trip (status after ending the trip)	
SF: System Failure	
IS: Isolation (system switched off)	Kein Symbol
NP: No Power (system switched off)	Display aus
NL: Non Leading (rolling stock is not at the front of the train)	
SN: STM National (national legacy system active)	

2.12.2.1.6 Movement Authority

ETCS works with Movement Authorities. The concept of a Movement Authority (MA) is that a train does not have a driving permit in its basic state. The ETCS system issues it with an MA, i.e. the authority to travel to a destination. For instance, it will receive an MA at the main signal to travel to the next main signal. This means the rolling stock knows how far it may travel and can monitor this itself. Once at the destination, the next MA is required before it may continue.

2.12.2.1.7 Stop Marker



The Stop Marker (yellow arrow on a blue background, DB designation: Ne 14) identifies loosely named locations "that actually have a main signal", i.e. entrances to railway stations or other places secured by a main signal. Fitted with both ETCS and main signals, these locations usually coincide, as pictured here. For the train

travelling under ETCS, the Stop Marker means "Stop" if no MA or command has been given. The signal means nothing to trains without ETCS.

2.12.2.1.8 Start process

Once the system has been switched on (SB mode), ETCS requires a start process. Only then is the downtime monitoring, which uses forced braking to prevent the train from moving, over. The train driver must provide at least his Tf number in order to be able to shunt. The train number, braking percent, train length etc. are required for a train journey. The ETCS level for the route must also be provided.

If the requirements for the journey are in place and with the approval of the dispatcher (for example signal to ride), then the train driver may select journey start on the display, which ends downtime monitoring.

The exact location of the train is usually not yet known after starting, so ETCS is not able to monitor the speed immediately, but switches to SR mode. The responsibility lies with the train driver until the first MA is received. Only once the first balise has been passed can ETCS locate the train precisely and shift to FS mode.

2.12.2.1.9 Release speed

The summation of measuring errors may result in a shifting of an ETCS stop in the display compared to the external signal. In order for the train to drive to the desired location in such a case, the monitored speed is not reduced to 0 km/h at the ETCS stop, but only as far as a release speed of, for example, 20 km/h. This figure is determined by the situation.

2.12.2.1.10 Forced braking

If the speed limit is exceeded, ETCS automatically issues an optical and acoustic warning by forced braking until the train is once more travelling at the required speed. The forced braking is automatically deactivated.

If an ETCS stop is missed, forced braking will also be initiated and the system will switch to TR mode (Trip). The train driver must confirm (ETCS key or on the display), which puts ETCS into PT mode, and if

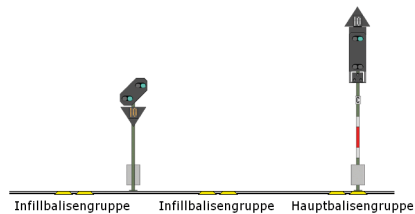


permitted, the driver may continue the journey by activating “Start” (on the display). ETCS then switches to SR mode until, for example, changing back to FS mode at the next balise.

2.12.2.2 ETCS Level 1 LS

Level 1 limited supervision has not yet been implemented.

2.12.2.3 ETCS Level 1 FS



At Level 1 full supervision, Eurobalises are installed in connection with signals. The balises transmit the signal aspects to the vehicle-side system,

which monitors the journey as it progresses. The speed profile of the route is also transmitted, making it possible to monitor a train's speed continuously. Since the information is only transmitted to the balises at regular intervals, Level 1 is a type of intermittent train protection system.

The picture shows a possible arrangement of the balises. As a train approaches one, its MA will suffice until the next main signal. If this already indicates movement on approaching, then the train will be given a new MA at the first balise group so it can continue on its way without braking. For this, the balise locations must be chosen so that the balises can be passed before the braking curve reduces in the direction of the main signal. Optionally, a further group of balises may be set up as a repeater. If the main signal also shows stop on passing this balise, the train will brake as far as the main signal with destination 0. Even if the main signal changes over, the on-board equipment will know nothing of this. Only the group of balises situated directly above the main signal can obtain a new MA once the main signal has changed over to drive.

2.12.2.4 ETCS Level 2

At Level 2, contact between the train and signal box is maintained on a continual basis via Euroradio, which makes Level 2 an example of a continuous train protection system. The train determines its position by means of distance measurements, and communicates the results to the signal box via Euroradio. To avoid the risk of cumulative errors, this information from the train is regularly cross-checked with the help of Eurobalises. The balises are only able to assist with positioning information, however, and do not transmit any movement data or MAs, which is received by the train from the signal box via Euroradio. This ensures that the train's movement is continually monitored.

As opposed to level 1, MAs will be transferred to the train immediately over radio, preventing unnecessary brakes before the next balise.

In order, for example, to be able to identify train separations, track-side axle counters and clear-track signalling are also required. The track is divided into block sections, in which only one train is allowed in one block section at a time. Signals are no longer required along the track.

In Germany, timetabled operation of ETCS Level 2 was implemented along a short section of track near Dessau at the end of 2005, and an initial, small number of electric locomotives were equipped with the system. Starting in December 2015, the high-speed railway line Erfurt-Halle/Leipzig was the first regular ETCS line in Germany (level 2 without approach and main signals), followed by the extension of the newly built line to Bamberg.

2.12.2.5 ETCS Level 3

Level 3 does not work at all with fixed block sections, but trains are permitted to run one after the other continuously, with a headway of their respective braking distance. In a step up from Level 2, however, this requires a system whereby the train itself can monitor its own integrity, so that a following train can be stopped in the event of a train separation. This obviates the need for costly track-side axle counters, which makes implementation of the track-side infrastructure much more economical. It will not see practical usage in railroad operation in the foreseeable future.



2.12.3 Germany

2.12.3.1 Sifa — Driver's Safety Device

In order to monitor whether the driver is conscious and capable of driving, he/she has to operate the Sifa DSD at regular intervals. On most traction units there is a special foot pedal for this purpose underneath the cab console, and a hand button at each of the side windows for departure at a platform, for when the driver is watching the doors and the platform. A Sifa switch is often integrated into the power controller, which involves pushing down on the knob of the throttle.

If the driver takes too long before pressing one or other of these buttons, the Sifa warning light illuminates in the cab. If there is no reaction to this, the Sifa horn sounds in the cab. If there is still no reaction, this results in the emergency brake being applied, which is released again as soon as the Sifa button is activated.

The driver has to press down the foot pedal or one of the alternative manual buttons continuously and quickly release it at regular intervals. When the driver releases the foot pedal or manual button, the Sifa response test sequence (light, horn, forced braking) is triggered.

There are various systems in Germany that differ somewhat in their response test sequence, as outlined below:

2.12.3.1.1 R.Z.M. Sifa

R.Z.M. stands for Reichsbahn-Zentral-Maschinenamt, the name of the company in the GDR which developed this Sifa system. This also works with certain tolerances (so, for example, the time measurement is carried out by venting an air container using a throttle). This Sifa is only operational at 15 km/h or above, and is entirely time-dependent. After 40–60 seconds, the warning indicator comes on, and after a further three seconds the Sifa horn sounds in the cab, then three to six seconds after that, forced braking is activated. Early Bundesbahn vehicles such as VT08/VT12, V80, and V200-prototypes were still being fitted with the R.Z.M. Sifa.

2.12.3.1.2 Time-distance Sifa

A typical example of the time-distance Sifa is the mechanical BBC Sifa, which was installed in Bundesbahn locomotives from the mid-1950s. (Electronic versions of this include the BBC L45a and Deuta ES66.)

With this type, if the driver has not activated any of the Sifa buttons for 30 seconds, the Sifa indicator lights up.

After a the train has driven another 75 metres without Sifa activation, the Sifa horn sounds in the cab, and after a further 75 metres the emergency brake is applied. The emergency brake can be cancelled at any time by pressing the Sifa button. In the Bundesbahn, the following vehicles are fitted with this type of Sifa: 110, 140, 141, 150, 211, 212, 213, 216, 217, 219, 220, 221, V36, V60, VT11, 624, 634.

2.12.3.1.3 Time-time Sifa

This type has been the standard system on the Bundesbahn since the end of the 1960s. If the driver has not activated any of the Sifa buttons for 30 seconds, the Sifa indicator lights up. After another 2.5 seconds without Sifa activation, the Sifa horn sounds in the cab, and after a further 2.5 seconds the emergency brake is applied. The emergency brake can be cancelled at any time by pressing the Sifa button. Existing designs based on this principle using microprocessor technology are the L44s (BBC), STG205 (Schaltbau) and ES70 (Deuta). Older vehicles have also been retrofitted with the time-time Sifa when being overhauled.

In the Bundesbahn, the following vehicles are fitted with this type of Sifa: 111, 210, 215, 218, V90, 602, 614, 627, 628, 701, 702

2.12.3.1.4 Sifa 66

The response test sequence for Sifa 66 is the same as for the aforementioned time-time Sifa, except that with this type, the driver is given a prompt in the form of a light, to which he/she must react. If the button is pressed before the light is illuminated, this will be ignored. The principle of the prompt-type Sifa was an attempt to augment the driver's concentration. The Sifa 66 was developed by the GDR Reichsbahn.



2.12.3.1.5 Sifa 86

This type of Sifa comes in two different modes — 400 m and 800 m. The 400 m-mode is for vehicles with a maximum speed of less than 100 km/h. The driver has to press the Sifa button every 400/800 metres, or every 40 to 50 seconds, whichever comes first. The time lapse between 40 and 50 seconds is determined by a random generator. Sifa 86 is a prompt-type Sifa, which means that pressing the button before the light is illuminated will be ignored.

After the 40 to 50 seconds or 400/800 metres have passed, the Sifa indicator light goes on. Once the light is illuminated, the button has to be pressed.

After a further four seconds, the horn is sounded, and two seconds after that, the emergency brake is activated. The emergency brake can be cancelled at any time by pressing the Sifa button.

Sifa 86 was developed by the GDR Reichsbahn and was installed in a large number of Reichsbahn locomotives.

2.12.3.2 Inductive train protection system (Indusi)

The need for a train protection system arose as a result of the increasing driving speeds of trains from the 1920s onwards, when the hitherto normal speeds of 100 km/h were being exceeded by a large margin by increasingly powerful, express steam locomotives and the newly emerging express traction units. The aim of the system was to prevent overrunning a stop signal and driving over branching-off points at excessive speeds.

2.12.3.2.1 Development and deployment

After various trials, including the use of visual communication of information, the Reichsbahn decided in the 1930s to introduce the inductive train protection system (Indusi), which is an intermittent-type system. Indusi was initially designed for the high-speed vehicles, but there was little further expansion of it, owing to the Second World War. The decision to opt for the inductive system should be regarded as one of considerable foresight as it meant the introduction of a system that was so simple and at the same time so reliable that it still measures up to all requirements even after almost 100 years, and with very few modifications since.

The Bundesbahn and GDR Reichsbahn adopted the inductive train protection system with barely any modifications, and proceeded to equip their networks and vehicles with it. At the end of the 1950s, the system was installed on the major main lines in West Germany (which today form the IC/ICE network). After a few serious railway accidents due to excessive speed in the 1970s, all speed changes on the Bundesbahn with a speed reduction of more than 20% were protected with Indusi. Practically the whole of the West German network has been equipped with Indusi since the 1970s. In the case of the GDR Reichsbahn, many lines, including important main lines, were not equipped with the system, which was largely still the case even at the start of the 21st century. It was not until the serious accident in Hordorf in 2011 that comprehensive retrofitting took place.

PZB systems are permitted in Germany up to speeds of 160 km/h. Faster trains are required to have continuous monitoring systems.

2.12.3.2.2 Operating principle

On the traction unit is an electrical oscillatory circuit, and on the track is a passive oscillatory circuit with the same resonant frequency, which operates without a power source. When the locomotive passes the so-called track magnets (from a physics perspective, this term is not strictly correct, as it is actually an electrical oscillating circuit), the voltage in the train's oscillator drops due to the resonance of the two circuits. A transmission of information has thereby taken place, which can then be interpreted and acted on accordingly by the locomotive-side system.



Train magnet passes over track magnet

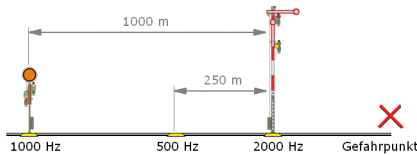


When train protection is not necessary, for example when the signal is showing unrestricted running, the track-side oscillatory circuit is short-circuited and therefore inactive. This simplified system can of course only transmit an On/Off status. As that would not be sufficient for the purposes it was intended for, there are three control frequencies (1000, 500 and 2000 Hz — triple-frequency type), each of which triggers its own response test sequence on the locomotive.

2.12.3.2.3 Operating program

The response test sequence for Indusi I54, train type O is described below. The Indusi I54 is the oldest type on the Bundesbahn and lends itself well as an introductory example. Although they have the same track-side equipment, more recent designs have other functions besides — which will be explained in more detail later on. In its default state, a blue indicator light is illuminated in the cab, showing that the system is operational.

The image below shows the how the magnets are typically installed:



When a train approaches a signal that is showing the stop aspect, all three magnets are armed. The safety system must ensure to a high degree of reliability that the train is prevented from entering the danger zone.

To this end, the following response test sequences are carried out at the different control locations:

2.12.3.2.3.1 1000 Hz inductor

At about 1000 metres before the main signal, the distant signal shows the stop aspect, and the train receives a 1000-Hz interference. The driver must then activate the vigilance button within four seconds in order to confirm to the system that he has seen the signal. The horn then sounds in the cab, and the yellow 1000 Hz indicator light is illuminated.



Indusi I54 installation with command, release and vigilance buttons and the two light indicators

If the driver fails to do so, the train will be brought to an emergency stop without any prior warning. In order to ensure that braking does actually take place after the vigilance button has been pressed, a corresponding speed test starts at the 1000 Hz inductor, running for 20 seconds. After the 20 seconds have passed, the current speed is checked at that point. If it is over 95 km/h, immediate emergency braking is triggered. The yellow indicator light goes out after the 20 seconds are up, and the system returns to default position.

2.12.3.2.3.2 2000 Hz inductor

Next comes the 2000 Hz inductor. This triggers immediate emergency braking and is therefore operational at a main signal showing a stop aspect.

2.12.3.2.3.3 500 Hz inductor

The 1000 Hz inductor only prevents the train from continuing to travel towards the main signal at high speed without slowing down after the distant signal. In actual fact, the 95 km/h threshold that is tested for is such a high speed that after the 2000 Hz emergency braking at the main signal the train would still overshoot the main signal by a long way. In many situations, the danger point is actually a long way back from the signal.

For this reason, in the case of critical signals, a 500 Hz magnet is placed approximately 200–250 m before the main signal, and is linked to the circuit of the main signal. When this magnet is passed, the maximum permissible speed of the train is 65 km/h, otherwise emergency braking will again be triggered. The 500 Hz magnet is also armed when the



maximum permissible speed at the main signal is less than 40 km/h.

Thanks to these three inductors, it can be ensured to a high degree of reliability that an approaching train will be brought to a standstill in time, should the driver misinterpret or fail to notice the distant signal, or not apply the brakes sufficiently for any reason. It goes without saying that the driver must never deliberately act incorrectly on a signal.

The same process applies when the main signal aspect or the new line speed is below 100 km/h. At 40 km/h and over, the 500 Hz magnet is no longer activated, as otherwise it would initiate unnecessarily hard braking.

2.12.3.2.3.4 Speed checking sections

With the procedure described above, speeds above 100 km/h cannot practicably be controlled, as the Indusi system would require unnecessarily sharp braking.

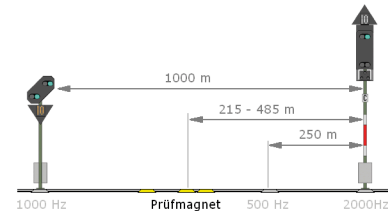
This is where the speed monitoring section comes in, which consists of an activation point, a 2000 Hz magnet beyond that, followed by a deactivation point. At the activation point, the train arms the 2000 Hz magnet. A delay switch deactivates the 2000 Hz magnet again as appropriate, so that a train travelling at the permissible speed will travel over the magnet in its deactivated state, whereas a train travelling at excessive speed will reach the magnet while it is still armed, and will thus be subject to an automatic emergency stop. This arrangement together with the very simple triple-frequency PZB allows all speeds to be monitored and controlled.

According to the same principle, for notifications of 80 and 90 km/h, the 1000 Hz inductor is not activated if the train is travelling sufficiently slowly.

The image below shows the set-up for speed restrictions of 100 km/h or more. At the speed notification, the 1000 Hz magnet is not active. Depending on the monitoring speed limit, the speed will be checked at a point between 215 and 485 m before the speed restriction point, along a 2000 Hz monitoring section. The speed at that point will still be above the target speed, as the train still has some way to go before reaching the restriction point. The 500 and 2000 Hz magnets are not active.



Monitoring section with activation, test and deactivation magnets



2.12.3.2.3.5 Releasing an emergency brake

If the emergency brake is activated, the air in the main brake pipe is completely vented, the blue "ready" light goes out, the yellow indicator flashes and the horn in the cab sounds. Only when the train has come to a standstill can the emergency braking be deactivated by pressing the "Frei" (release) button, which will cause the main brake pipe to be replenished, after which the train can move on again. Since the beginning of the 21st century on the Deutsche Bahn AG, the locomotive driver is obliged to always make contact with the traffic controller in the relevant signal box in the event of PZB emergency braking. This rule was put in place after it was apparent that drivers were continuing on their journey after an emergency braking at a main signal because they were assuming that there had not been a critical issue behind the emergency braking.



2.12.3.2.3.6 Function of the “Befehl” (command) button

By holding down the command button, an emergency braking activated by a 2000 Hz inductor can be overridden. This is employed when driving over a 2000 Hz magnet, for example in shunting movements or movements on command or substitute signal. In this case, the train is not permitted to drive over 40 km/h. While the button is being held down, the horn sounds in the cab.

2.12.3.2.3.7 Overview of arming the PZB magnets

The PZB magnets are armed in the following circumstances:

1000 Hz (Vigilance button pressed):

- Notification of a maximum speed of 70 km/h or less
- Notification of 80 km/h and the train passes at a speed of 95 km/h or more
- Notification of 90 km/h and the train passes at a speed of 105 km/h or more
- Distant signal on its own
- Level crossing monitor signal indicates defective crossing

500 Hz (driving under the monitoring speed limit):

- Main signal shows stop aspect or maximum speed less than 40 km/h
- Restriction of the line speed to less than 40 km/h
- Safeguarding entrance to a station when driving on the opposite track

2000 Hz (immediate application of emergency brake):

- Main signal shows stop aspect
- Speed monitoring section driven too fast over
- Ne 1 board on the opposite track

2.12.3.2.3.8 Activation by the locomotive driver

The driver must perform the following operations:

- When passing a distant signal or a speed board with a notification of between 0 and 90 km/h, he/she must press the vigilance (Wachsamkeit) button within 4 seconds, and then brake to bring the train's speed down to under the maximum permissible speed (95 km/h) within the test time. This braking action must be taken under all circumstances, even if the main signal changes to unrestricted straight after the 1000 Hz inductor (ultimately, the Indusi system cannot know about this change, given the absence of further information channels, and so it has to work on the basis of the red signal). The yellow 1000 Hz indicator lights up during the test time.
- When approaching a main signal or when the maximum permissible speed is changed to below 40 km/h, keep within the maximum permissible speed (65 km/h) at the 500 Hz magnet.
- In the case of speed restrictions of 100 km/h or more, take account, when braking, of the test section located before the speed limit change.
- Stop before a main signal that is showing the stop aspect.
- If it is permissible to pass a signal at danger, press the Command button before driving over the 2000 Hz magnet and keep it held down until the signal has passed.

2.12.3.2.4 Indusi I36

Information on the operating program for this type of Indusi from the 1930s would be welcomed.

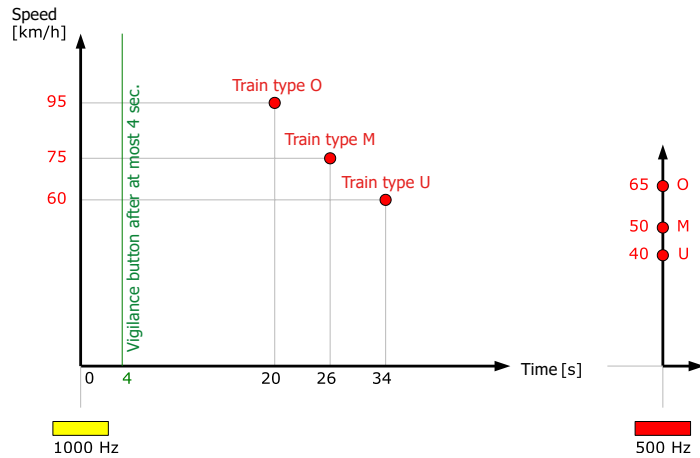
2.12.3.2.5 Indusi I54

The functions of Indusi I54 have largely been covered by the explanations in the previous chapter. Two further operational modes for trains with low braking capacity can be added here. In addition to train type O explained above there are also train types M and U, with lower thresholds. The I54 system can only be set to one fixed mode,



however. Typical freight train locomotives are therefore set permanently to M.

Monitoring function Indusi I54/I60



With Indusi I54, whether the train actually stops in the event of an emergency braking is not verified. The emergency brake can be released as soon as the brake pipe has been vented. Technically speaking, a driver can therefore cancel an emergency braking against the regulations if he/she reacts quickly, and prevent the train from stopping.

2.12.3.2.6 Indusi I60



Indusi I60 differs from the I54 primarily in the fact that the train type can be set on the locomotive. This means that the operating program can be set for the actual braking capacity of the train in question. The driver can see which train type the system is set for from the corresponding blue indicator — 95/75/60. The test values are identical with those of I54. Indusi I60 is the standard Indusi of the Bundesbahn, and was deployed in a large number of vehicles.

2.12.3.2.7 Indusi I60DR

This is a variant of the GDR Reichsbahn, with monitoring speed limits that differ somewhat from those of the Indusi I60. For train type O 90 km/h applies; for M, 65 km/h and for U, 50 km/h. The Indusi I60DR was deployed on a wide range of express locomotives.

2.12.3.2.8 Indusi I60M

The Indusi I60M was developed from the Indusi I60 in order to bring shunting locomotives up to the safety standards of the PZB90 (see next chapter). This differs from the I60 only in terms of its testing parameters, which avoids having to convert to the expensive PZB90 hardware. The new monitoring speed limits are 25 km/h after 45 seconds at a 1000 Hz magnet, and 10 km/h at a 500 Hz magnet.

The Indusi I60M has been deployed on Bundesbahn-V60 locomotives since 2006, which only consist of type-U trains anyway.

2.12.3.2.9 Indusi I60R/Indusi I80

There are certain safety issues with the Indusi I60. When the driver activates the vigilance button but does not then activate the brakes, a train travelling at, say, 140 km/h during the 20-second monitoring time would have already travelled approximately 770 metres before the associated speed test activated the emergency brake. In most cases, this would not be sufficient to prevent overrunning into the danger zone. Another loophole is the lack of distance dependency. If the 1000 Hz magnets are passed very slowly, then only a short distance will be travelled during the speed monitoring time. The driver, perhaps because he has wrongly interpreted the changing of a different signal as being related to the track he is driving on, could then subsequently accelerate to the 500 Hz magnets at high speed without the Indusi I60 intervening.



Indicators on the Indusi I60M (Photo: Timo Albert)

The Indusi I60R solves these issues by monitoring continuously. The Bundesbahn introduced this microprocessor-based system in 1985 (in combination with LZB80) and in 1990 (also independently without the LZB function) as a new standard PZB for all newly acquired vehicles as well as retrofitting it to class 111, 112 and 181.2 vehicles. Indusi I60R made it possible to drive 160 km/h express trains without an assistant driver, which was only permitted up to 140 km/h with the Indusi I60. When the system is integrated into the LZB80, the system is referred to as Indusi I80 (and can also be used with speech output in this case). The operating program is the same as that of the Indusi I60R, and so no further description of the Indusi I80 is given here.

2.12.3.2.9.1 1000 Hz inductor

In addition to the program for the I54, the train's braking curve is continuously monitored against a prescribed braking curve after the 1000 Hz inductor. If this model braking curve is exceeded at any point during the braking process, prior warning of an emergency braking is given.

Furthermore, the associated speed test is not only dependent on the monitoring time, but also on a monitoring distance of 700 metres.

If a further inductor is activated during the speed test, the distance-dependent test will be extended to run for a further 700 metres after the second inductor.

2.12.3.2.9.2 500 Hz inductor

In the case of Indusi I60R, at the 500 Hz magnet a braking curve is activated which is purely distance-based, thereby ensuring that a train can travel at no more than a maximum speed of 45 km/h over a main signal that is showing the stop aspect, which would mean that it should come to a standstill before the danger zone. While the test curve is activated, the red 500 Hz indicator lights up on the cab console that has newly been fitted with Indusi I60R.



Indusi I60R indicators (here without train type U), design and arrangement can vary from class to class (retouched image)

2.12.3.2.9.3 Emergency braking

In contrast to Indusi I60, with Indusi I60R the speed is in fact controlled by pressing the release button after the emergency brake is activated, but not all the way until the train has come to a stop, as the replenishment of the empty main brake pipe can take quite a long time. In order to be able to move off more quickly after the emergency brake has been applied, with the Indusi I60R the emergency brake can be cancelled at below 30 km/h by pressing the Release button, and the replenishment of the main brake pipe thereby initiated. The train must then come to a standstill within the next 15 seconds at the most, otherwise the emergency brake will again be activated.

2.12.3.2.9.4 Control of maximum speed

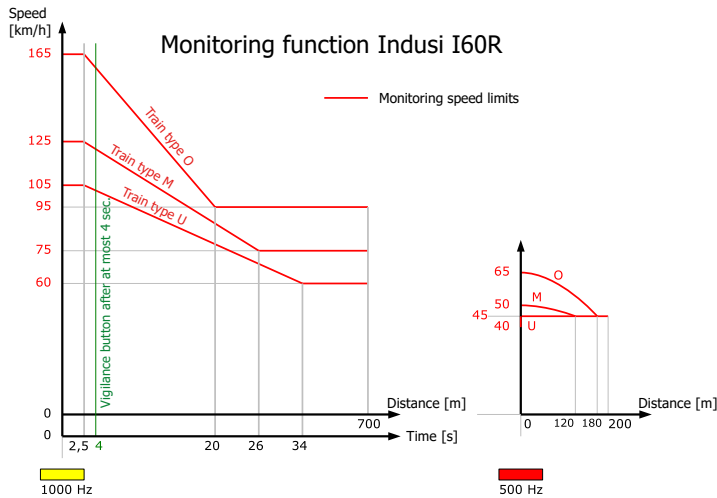
A further innovation with the Indusi I60R is the continuous monitoring of the maximum speed of the train or locomotive. Depending on the train type, a horn in the cab is activated above 165/125/105 km/h. From 169/134/119 km/h the emergency brake is activated. The emergency brake is not applied all the way to standstill, however, and the brake pipe is refilled automatically as soon as the maximum speed is not being exceeded.



2.12.3.2.9.5 Command button

The command button only works below a speed of 45 km/h with Indusi I60R, so that a 2000 Hz magnet cannot be driven over faster than is allowed. When the 2000 Hz magnet is passed, the white indicator introduced with Indusi I60R lights up and tells the driver that he can release the command button.

2.12.3.2.9.6 Diagram of test curves



Note on diagram of curves for all Indusi versions: In most of the official documentation, the test curves are not shown correctly. What is correct is a linear decrease over time, and a parabolic decrease over distance, as shown here.

2.12.3.2.9.7 Train data and replacement train data

The train type is not entered directly into Indusi I60R. Instead, the braking percentage and brake type are entered into the system, and Indusi I60R then identifies the correct train type from this information. The driver ascertains the braking percentage from the braking sheet and enters it as the BRH value into the train data settings. The brake type is entered as the BRA value. It is specific to the vehicle and is listed in the documentation under the relevant vehicle type.

For Indusi I60R (without LZB) only brake types 1 (for brake setting G) and 8 (for brake settings P and R) are used. At initial start-up, the fixed replacement train data that have been stored in the Indusi I60R device are active, as the system has to have a value to be going on with. The replacement data tend to err on the side of caution for the typical uses of the vehicle, so can be rather restrictive. A train-type indicator flashes to prompt the driver to enter the train data. If the driver is not in a position to enter the train data, for example if there is a malfunction in the input device, then the train can be driven with the replacement data as a temporary measure. These replacement data automatically become active if the train moves off without train data having been entered. Train data can only be entered in Zusi using external software such as Zusi Display. Manual setting of the train protection must then be activated in the simulator settings.

2.12.3.2.10 PZB90

The S-Bahn disaster in Rüsselsheim in 1990 brought to light another loophole in the existing safety system, namely a train unintentionally passing through a Signal at Danger, which the Indusi I60 hardly prevents at all, and the Indusi I60R only prevents at speeds of over 45 km/h. Where the overlap at a signal is rather short, as is the case at station exits, the train may not come to a standstill until after the danger point, even when the 2000 Hz emergency brake is applied. The PZB90 therefore extends the functions of the Indusi I60R, in particular with the provision of restrictive mode, which stipulates very low monitoring speed limits after a stop has taken place.

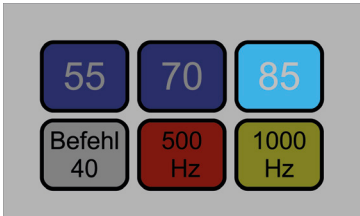
The PZB90 was introduced in the mid-1990s, and has been in nationwide operation since around 2002. With a very few exceptions, it is mandatory for driving on the rail network of the Deutsche Bahn AG. As part of the PZB90 roll-out, the positions of all 500 Hz magnets were changed in line with the new monitoring regime, and countless new magnets were also installed.



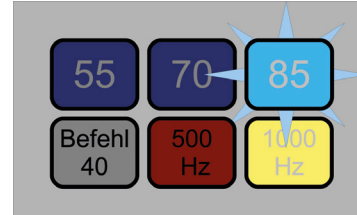
PZB90 indicator block — in some cases, indicators from the I60 and I60R are also still used or supplemented.

2.12.3.2.10.1 1000 Hz inductor

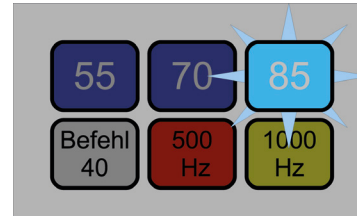
The 1000 Hz speed control inductor is associated with a 1,250 metre-long speed monitoring stretch where the PZB90 is concerned. After 700 m, the driver can press the release button to release the train from this speed control, but he can only do so if he has unmistakably acknowledged the changing of the main signal, otherwise the PZB90 would enforce a lower speed than the maximum permitted speed. In comparison to the Indusi I60R, somewhat tougher monitoring speed limits are applied — although slightly more time is given to achieve these. For train type O this speed is 85 km/h, for train type M 70 km/h, and for train type U 55 km/h.



The indicator lights display the same configuration as the Indusi I60R before the 1000 Hz inductor:



After the driver has pressed the acknowledgement (vigilance) button, the yellow indicator illuminates with a steady light, and the train-type light flashes (train type O in this case):



After 700 m, the yellow light goes out and the flashing train-type light indicates that monitoring is continuing. Release:

When the release button is pressed, the train-type light will light up continuously, and the test curve will no longer be active. The monitoring along the 1250 m stretch is still ongoing in the background however, and can become active again. Release is only permitted if the driver is allowed to drive faster than the PZB90 stipulates — if, for example, the announced main signal has changed in the meantime.

If a further speed control (superimposed speed control) is activated during the speed monitoring, the distance-dependent test will be extended to run for a further 1250 metres after the second speed control. If the driver releases the train from the first speed control before the second speed control has been activated, the first braking curve that is still running in the background will immediately become active again, in which case the target speed will immediately be

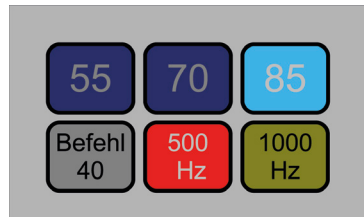


85/70/55 km/h. The basic principle of the PZB90 is that: All speed limiters will be activated, and the most critical case will always apply. It is only the latter that will be shown in the indicator unit.

2.12.3.2.10.2 500 Hz inductor

If a 500 Hz inductor is activated within the 1250 m distance after releasing the train from the 1000 Hz inductor, this results in an immediate emergency braking, as the signal is not yet showing the proceed aspect, and the driver has obviously pressed the release button inappropriately. The driver must pay particular attention to proceed aspects with speeds under 40 km/h, as the 500 Hz magnet will also be active if this is the case.

Otherwise the distance-dependent test braking curves are activated at the 500 Hz magnet, as shown in the diagram below. If the speed is exceeded, immediate emergency braking ensues. While the 500 Hz braking curve is active the red indicator light will illuminate, as is the case with the Indusi I60R:



After the end of the 500 Hz braking curve, the 1000 Hz monitoring that is continuing for the 1250 m-stretch may in some circumstances become active again.

2.12.3.2.10.3 Restrictive monitoring

Within the 1250 m stretch after the 1000 Hz inductor, if the train drives slower than 10 km/h for 15 seconds, the restrictive mode will be activated straight away, and the maximum permitted speed will then be 45 km/h. If the 45 km/h limit is exceeded, then emergency braking is immediately activated. This function should recognise a stop at a platform. The fact that restrictive mode is not activated when the train is stopping is due to the fact that it is difficult

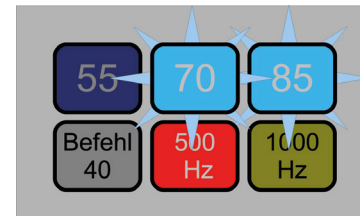
metrologically to distinguish a stop from very slow movement, and, moreover, a driver should be prevented from trying to circumvent the restrictive mode when approaching a stop signal by driving at a crawl.

Restrictive monitoring is indicated by the alternate flashing of the 70 and 85 train-type lights.



In this case also, the train can be released from this mode by using the release button from 700 m after the 1000 Hz inductor (when the yellow light goes out). This is of course only possible if a higher speed is permissible.

Within the 500 Hz braking curve zone, a permissible maximum speed of 25 km/h applies under restrictive monitoring.



In order to prevent crawling speeds for very long distances, the restrictive 500 Hz monitoring is only active for 200 m if restrictive mode is already active on release of the 500 Hz speed control, or if the train switches to restrictive mode within a maximum of 100 m after the 500 Hz speed control. Otherwise, monitoring will take place for 250 m.



2.12.3.2.10.4 Versions 1.5, 1.6 and 2.0

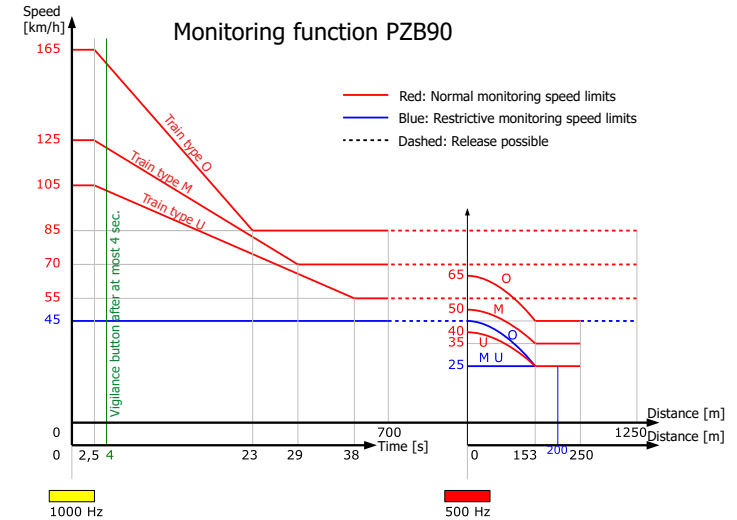
When the PZB90 went into series production, it was initially used with software Version 1.5. This still had the same 1000 Hz braking curves as the Indusi I60R (monitoring speed limit of 95/75/60 km/h). While installation was being rolled out, the software was upgraded to Version 1.6, as detailed here. Those vehicles which had already been fitted with Version 1.5 were subsequently retrofitted with Version 1.6 through a software update and changing of the indicator lights. Other innovations that came with Version 1.6 included a short horn sound at the end of the restrictive 500 Hz speed control and momentary extinguishing of the 1000 Hz indicator after acknowledgement of a superimposed 1000 Hz speed control.

A further change was introduced with Version 2.0: The system remembers the monitoring programme that has been running, even after the reverser has been set to neutral. With Version 1.6, the driver was able employ this move to cancel the unwelcome monitoring curves when stopping at a platform, which is of course not permitted, but was certainly practised.

2.12.3.2.10.5 Monitoring curves — displayed in tabular and graph form

Prüfgeschwindigkeit PZB90 V1.6 und 2.0				
	Zugart O	Zugart M	Zugart U	Befreiung möglich
	165→85 km/h	125→70 km/h	105→55 km/h	nein
	85 km/h	70 km/h	55 km/h	ja
	65→45 km/h	50→35 km/h	40→25 km/h	nein
	45 km/h	45 km/h	45 km/h	nein

	45 km/h	45 km/h	45 km/h	ja
	45→25 km/h	25 km/h	25 km/h	nein



2.12.3.2.11 PZ80R

The vehicles which are fitted with the PZ80, which is explained in the next section, are being retrofitted with PZB90 functionality, but in the process are fitted with an indicator device that is appropriate for the PZ80 construction. Given that its operational functionality is consistent with the PZB90 Version 1.6, the PZ80R is not explained separately here, but should be regarded as being the same as the PZB90 V1.6.

- The former PZ80 “LM” indicator now signifies “Befehl” (command), with the functionality of the “Befehl” (command) indicator in the conventional PZB90.
- The former PZ80 “40” indicator now signifies “500 Hz”, with the functionality of the “500 Hz” indicator in the conventional PZB90.



- The former PZ80 “60” indicator now signifies “1000 Hz”, with the functionality of the “1000 Hz” indicator in the conventional PZB90.
- The former PZ80 “PZB on” indicator assumes the function of the three train-type indicators. It illuminates when the PZB is in a state of operational readiness, goes out when emergency braking is taking place, and flashes during the 1000 Hz braking curve. It does not indicate the train type, which is shown by the following instrument:



Display unit for the PZ80R

- The monitoring speed limit is indicated clearly by a digital display whilst speed control is ongoing. The display shows a speed of 85/70/55/45/35/25, depending on which train type is selected and on whether restrictive mode is active. The PZ80R therefore does not feature alternately flashing indicators.
- The current driving speed is shown, as with the PZ80, as a central digital display.

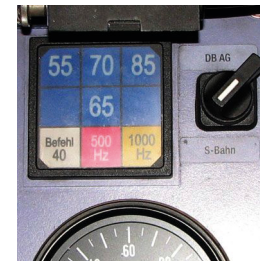
2.12.3.2.12 PZB90 — S-Bahn

The Hamburg S-Bahn deploys a PZB90 that features amended braking curves in order to make it more suitable for the special S-Bahn conditions. This was introduced with the commissioning of the BR 474 in the mid-1990s. These were the first vehicles in the S-Bahn network to be fitted with I60R devices, the normal operating program of which had not been harmonised with the short distance-to-signal found on the S-Bahn network. With the introduction of the PZB90, the S-Bahn PZB was also introduced in the older vehicles with ER24

hardware. The multi-system vehicles, which can also run on the standard railway network outside the conductor rail areas, are equipped with a system that can be switched between the standard PZB90 and the S-Bahn PZB90. The S-Bahn PZB90 differs from the standard one in the following ways:

2.12.3.2.12.1 1000 Hz inductor

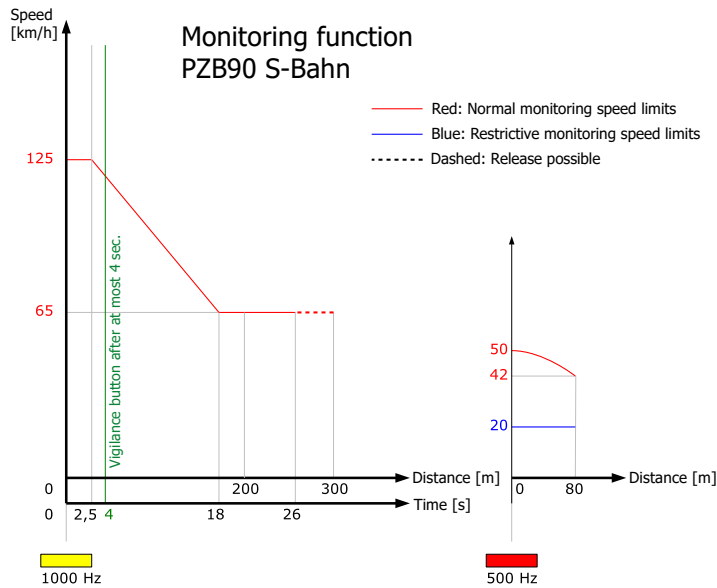
There is only one fixed train-type setting, with a braking curve of 65 km/h within 18 seconds after the 1000 Hz inductor. The yellow indicator goes out when the train has driven 200 m in a minimum of 26 seconds after the 1000 Hz inductor. The 1000 Hz monitoring section ends only 300 m after the 1000 Hz inductor. There is no restrictive mode.



Indicator block for the S-Bahn PZB90 with multi-system installation and system switching

2.12.3.2.12.2 500 Hz inductor

The monitored braking curve requires a decrease in speed from max. 50 km/h down to max. 42 km/h within a distance of 80 m. The restrictive mode is active for 80 m with a monitoring speed limit of 20 km/h. It becomes active if a 500 Hz speed limiter is activated within 90 m after a stop. 500 Hz magnets are located between 5 and 400 m before the main signal.



2.12.3.2.13 PZ80

The PZ80 was developed in the 1980s by the GDR and the CSSR and deployed in large numbers of vehicles. The operating status is displayed on the device shown below:

2.12.3.2.13.1 Program 04

Program "04" is designed for shunting. Inductors are ignored, and the vehicle speed is monitored for 40 km/h.

2.12.3.2.13.2 Programs 06 to 16

The monitoring speed limits set for these programs designed for regular operation are dependent on the maximum speed of the train. The value is one tenth of the permissible maximum speed (e.g. 120 km/h = "12"). The programs dictate the braking curves and monitor the maximum speed continuously. By way of illustration, the procedure is described below for Program 12: If the train reaches speeds in the region of 124–127 km/h, the horn sounds rhythmically and the

red "PZB on" indicator starts to flash. If the speed is further increased then emergency braking ensues. The emergency braking can be cancelled using the release button once the speed is brought back to 120 km/h.



PZ80 device (photo: Peter Buchholz)

The monitoring speed limits change accordingly in the other programs.

2.12.3.2.13.3 1000 Hz inductor

The acknowledgement (vigilance) button must be pressed within four seconds, otherwise emergency braking will be applied until the train is at a standstill. After the acknowledgement button is released, the yellow "60" indicator starts to flash. This indicates that a (distance-only-dependent) speed monitoring curve with a target speed of 60 km/h is taking place. The target speed is always 60 km/h, irrespective of which program is operating. For Program 12, the monitoring curve takes place within a 750 m monitoring distance and a target speed of 60 km/h. After the curve has been completed, the yellow "60" indicator switches to continuous illumination. The speed of 60 km/h is monitored until the full 1400 m-section of track (after the 1000 Hz inductor) has been covered.

2.12.3.2.13.4 Cancelling the 1000 Hz inductor

500 m after driving over the 1000 Hz magnet, the yellow "LM" (cancel indicator) is illuminated. From this point onwards, the monitoring curve can be cancelled using the release button. However, the monitoring curve will continue to run in the background over a total distance of 1400 m. If a 1000 Hz speed limiter becomes active



again after cancellation, then the old speed monitoring curve is reactivated. This would mean that if, for example, the driver accelerated again after cancelling the monitoring curve and the 1000 Hz speed limiter kicked in again after 1000 m at 70 km/h, then the PZ80 would immediately activate emergency braking.

2.12.3.2.13.5 500 Hz inductor

At a 500 Hz inductor, the yellow “40” indicator starts to flash. A new monitoring curve is activated, that runs for 250 metres with a target speed of 40 km/h. When the curve has been completed or the locomotive comes to a standstill, the 500 Hz speed control is cancelled.

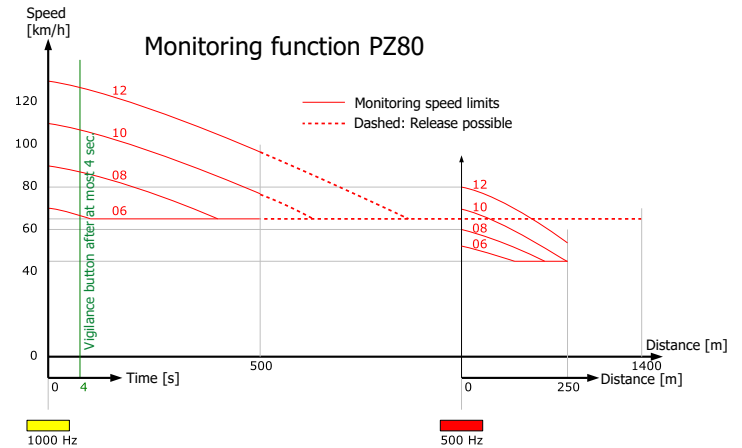
2.12.3.2.13.6 2000 Hz inductor

The 2000 Hz speed control activates emergency braking. Pressing the Befehl (command) button enables the driver to pass a stop signal. The yellow “40” indicator illuminates with a steady light and indicates that the 40 km/h speed is being monitored. If the Command button is enabled for 15 seconds, the horn sounds.

2.12.3.2.13.7 Emergency braking

In the event of emergency braking, the red “PZB on” indicator goes out, and the horn sounds continuously. The emergency brake can be released using the release button when the train is at a standstill.

The following diagram shows the curves for programs 06, 08, 10 and 12. The other curves not shown in the example run similarly, although curves above 12 are rather more theoretical, as the maximum permissible speed in the GDR network is 120 km/h.



The PZ80 was converted to PZB90 system logic by the DB AG, and was thereafter known as the PZ80R (section 2.12.3.2.11).

2.12.3.3 Speed monitoring for tilt technology (Geschwindigkeitsüberwachung für Neigetechnik — GNT)

For information on GNT-deployment on Zusi routes, see section 5.3.1.1.7

2.12.3.3.1 Development and deployment

Tilt technology trains were first introduced on the Bundesbahn in 1991 to reduce travel times on older lines. Trains equipped with this technology actively tilt on a bend, thereby counteracting the increased centrifugal force resulting from the higher speeds. The tilt mostly serves to improve comfort levels for the passengers, as it barely has any effect on track loading. The first trains to be fitted with the technology were the Class 610 trains on the network between Nuremberg and Bayreuth/Hof/Weiden/Furth im Wald. When this was deemed a success, subsequent classes 611 and 612 as well as the ICE-T classes 411, 415 and 605 were also equipped with tilt technology.

In order to enable tilt-technology trains to travel at higher line speeds (up to 50 km/h faster) than conventional trains, the line must be



equipped with a second, superimposed speed profile. This higher speed profile entails a further train protection system on the line and in the trains. The system is known by the umbrella term of GNT, of which there are two designs — the ZUB122 (which operates with track-side transponders which work in a similar way to the Indusi magnets) and ZUB262 (which works with Eurobalises).

Since there have been frequent malfunctions with GNT operation, and the technology has proven to be very high-maintenance, it is unlikely that there will be further vehicle developments using GNT in Germany for the foreseeable future. On some routes (e.g. Vienenburg — Hildesheim), GNT is no longer used at all.

2.12.3.3.2 Operating principle

GNT trains operate on the basis of signals, in the same way as conventional trains, with the only difference being that they are permitted to drive at a higher line speed, which is set out in a separate column in the working timetable. The signal system for the route must be suitable for mixed operation with conventional as well as GNT trains. This means, then, that the GNT train must heed main and distant signals in the same way as the conventional train, but the Lf 6/7 signal boards do not apply to it. So as not to have to display doubled-up or confusing signals, GNT speeds are not shown at all on the line but have to be ascertained from the working timetable by the driver.

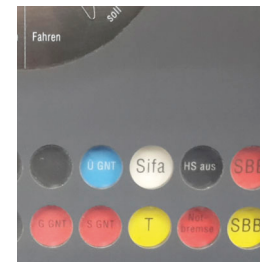
Speed monitoring is carried out on the basis of a full, static speed profile for the entire route, which is communicated in the form of data telegrams to the train from the track at regular intervals (a few kilometres) via transponders in the case of the ZUB122, or balises in the case of ZUB262. In contrast to the Indusi system, the train-side device is always informed of the permissible speed at every moment, which can be precisely monitored accordingly, including the corresponding braking curves. The aspects shown at the distant and main signals, however, are not included in the information the system receives, and protection for this must be carried out conventionally by Indusi.

When the speed changes in the conventional speed profile are protected by Indusi systems, these speed controls must be suppressed for GNT operation as appropriate, in order to allow the GNT train to drive at the higher speed profile. This is done by means of a tran-

sponder or balise being installed just before the speed control, which informs the train that the Indusi magnets located in the next 150 m are to be ignored. If there is also a distant signal located within the said 150 m, then the Indusi speed control would also be suppressed even though it would be relevant for GNT trains. For this reason, when GNT technology was installed, locations which originally had both Lf 6 boards and distant signals in the same place were separated into two different locations.

2.12.3.3.3 Vehicle devices

The ZUB122 was installed in BR 610, 611 and 470 (Cisalpino) trains. The more modern ZUB262 operates with Eurobalises and was installed from 1999 onwards in all ICE-T trains and in the BR 612. The BR 611 was subsequently retrofitted with the ZUB262. Both ZUB systems can only be used in conjunction with I60R or LZB80 systems. In terms of their displays and driver operation, there is very little difference between the two systems.



GNT-indicators in the MFA20 of the BR 605 (Photo: Carsten Begemann)

2.12.3.3.4 Cab displays

There are up to 7 indicator lights which display the status of the system:

- GNT Steady light: GNT is in operational readiness; Flashing light: Error (ZUB122 only). No function in Zusi.
- Ü Steady light: GNT is active; Flashing light: Fault
- G Steady light: Notification of speed limit; Flashing light: Braking curve is active



S Steady light: 10 km/h too fast; Flashing light: 6 km/h too fast

Testing Button for activating functional test. No function in Zusi.

GSt on Steady light: Tilt technology in operational readiness. No function in Zusi.

GSt fault Steady light: Fault with tilt technology. No function in Zusi.

ICE vehicles are only fitted with indicator lights Ü, G and S. The other information is displayed in text format on the display.

2.12.3.3.5 Activation and deactivation of GNT

Activation and deactivation of GNT operation happens automatically without the driver having to do anything. While the GNT is in active operation the Ü indicator light in the cab is illuminated.

2.12.3.3.6 Driving with GNT in operation

The driver operates the train in exactly the same way as a conventional train. The only exception to this is as follows: The driver can ascertain the permissible line speed only from the working timetable, to which columns 1b and 2b are added for this purpose. This means that the driver ignores the Lf 6/7 signals along the track.

The main and distant signals apply to all trains without exception. The GNT technology therefore only raises the line speed and not the signal speeds, and the Zs 3 speed indicators at distant and main signals are therefore fully applicable. This means that the Indusi system must also be operated as normal, and works as for conventional operation. The Lf 6/7 boards are again ignored, and these do not have to be acknowledged by pressing the Acknowledgement (vigilance) button.

The actual driving speed must be precisely monitored, given the higher speeds than normal at which the train drives around bends. If the currently permissible speed is exceeded by 3 km/h, a buzzer sounds intermittently at first, and if the speed is exceeded by 6 km/h, the brakes are activated and the red S indicator light flashes. The

brakes are automatically released again when the permitted speed is no longer being exceeded. The speed currently being monitored for is not displayed to the driver.

2.12.3.3.7 Speed change

Increases in the permissible speed are not displayed to the driver. These must be ascertained from the working timetable. During monitoring, the length of the train is automatically taken into account. The vehicle device also determines this automatically in the case of multiple-unit traction.

Where there is a reduction in the maximum permissible speed, a buzzer sounds 200 metres before a braking activation point, and the G indicator illuminates. While the braking curve is active, the G indicator flashes.

2.12.3.4 Continuous train protection (Linienzugbeeinflussung — LZB)

For information on LZB-deployment on Zusi routes, see section ??

2.12.3.4.1 Development and deployment

In the 1960s the Deutsche Bundesbahn forged ahead with moves to increase driving speeds on the railways. Since the conventional signal system can only be used with speeds of up to 160 km/h because of the distances between the distant signal and the main signal, a solution had to be found to ensure that trains travelling at higher speeds would still come to a stop before a signal at danger. Two solutions were developed: The first solution was to extend the distance from the distant signal by several block lengths, with braking occurring in several stages on approaching the stop signal, while the second was to transmit the signal aspect to the cab.

The Deutsche Bundesbahn decided on the second option and developed the LZB system through to series production, whereby the signal aspects and permissible maximum speeds were continuously transmitted to the train protection system via track-side antenna. The LZB belongs to the family of continuous train protection systems.

After the initial trial operation, begun in 1963, between Bamberg and Forchheim, the Munich — Augsburg line was equipped with the

1a	2a	1b	2b	3a	3b	4	5
120				ZDF A 73 - Berthausen Sak 16	123,0		0,01
	120,6				120,6		
118,2		118,8		Sak 14	117,4		0,01
110		117,4		Sak 12	114,8		0,01
	117,4				113,8		
				Stp	112,3		
112,3		112,3			112,3		
00				Sak 10 Altenbofen	111,2		0,01
					110,8		

The driver operates the train in exactly the same way as a conventional train. The only exception to this is as follows: The driver can ascertain the permissible line speed only from the working timetable, to which columns 1b and 2b are added for this purpose. This means that the driver ignores the Lf 6/7 signals along the track.



system in 1965 for the International Transport Exhibition, and trains were driven at 200 km/h in regular demonstration runs for the public. The system then underwent extensive testing on the line Hamburg — Bremen line from 1974, and from 1977 onwards, the definitive version of the trackside equipment, named the LZB72, was put into operation on the line.

A further expansion of trackside equipment followed in 1999 on the Offenburg — Basel line, where CIR-ELKE was introduced in order to increase line capacity. This system is known as LZB72-CE, and was later introduced on other lines, too. The main difference between the two is that the LZB72-CE gives the option to install LZB blocks within stations also. This means that a train on a turnout track is able to move off straight away once it has been overtaken, and follow closely behind the train that overtook it. Well-placed, closely spaced blocks after the overtaking track in the acceleration zone mean that the distance behind the train that has passed can be kept small, which increases the capacity of the line.

A more recent generation, the LZB72-CE II, was introduced on the high-speed line between Cologne and Frankfurt in 2002, which has been installed as standard on new track sections ever since.

The LZB system is technologically far more complex and challenging to install than conventional signalling systems, and is therefore reserved for the most important routes. German LZB technology has also been installed on high-speed lines in Spain and on the ÖBB's Westbahn since 2001. Over the long term, however, the LZB will be replaced by ETCS Level 2.

2.12.3.4.2 Operating principle

From the track-side perspective, all signals along the route must be connected to LZB control centres so that the signal aspects can be evaluated by the LZB. The data are then transmitted via the track-side antennae to the LZB on-board computer in the train and displayed to the driver in the cab. The driver is not shown the entire route profile all at once, but just the next relevant braking point with the maximum permissible speed and his current distance to this point. A braking curve is selected according to the tilt status and braking capacity of the train, which brings the speed of the train down gradually until it reaches a new, lower speed.

When the LZB system is active, it is only the so-called movement authority variables displayed in the cab that apply, and not the distant and main track-side signals on the route. In most cases, however, the track-side signal aspects do in fact correlate with what the LZB is displaying. Stop-block signals are not connected up to the LZB computers, and so these apply even when LZB mode is active, when they only display a stop aspect in the event of a signal fault. Since the line speed is shown by the LZB, the Lf boards similarly do not apply when LZB mode is active.

2.12.3.4.3 Vehicle devices

In the paragraphs that follow, the LZB system is explained in terms of the LZB80, which can be considered as the standard LZB in Germany. The LZB100 which was introduced initially is not particularly significant, given the short length of time for which it was deployed, and the small scale of the high-speed network at the time.

2.12.3.4.3.1 LZB100



LZB100-device (Photo: Tobias Zwirnmann)

To coincide with the track-side installation of the LZB72, the vehicle-side equipment known as LZB100 was deployed, and was installed in Class 103, 403 and 420 trains. The basic operation of this system was similar to the LZB80, although the main signals also applied when LZB mode was active. Zusi is not yet set up for LZB100.

2.12.3.4.3.2 LZB80/180

In view of the new stretches of track being built at the time, a new generation of the system was developed in the 1980s that was based



on microprocessor technology. This system combines the LZB and Indusi in an integrated system, as well as providing an interface to AFB and being designed for a maximum speed of 280 km/h. The LZB80 is immediately identifiable from the then newly-developed modular cab display (MFA) in the cab.

The LZB function is referred to as LZB80, and the Indusi function as Indusi I80. The operating program of the I80 is the same as that of the stand-alone Indusi I60R system. The vehicle-side equipment is referred to as the LZB80/I80.

The LZB80 was initially tested on a 103, 224 and BR 410, 120.0 and another 103 vehicle, and then rolled out from 1987 onwards on the newly delivered BR 120.1. The vehicles that had originally been fitted with LZB100 were then retrofitted with LZB80. With an eye to freight traffic on the newly-built routes, some BR 151, 140 and 110 locomotives were also equipped with LZB80. On the Offenburg — Basel CIR-ELKE route, the LZB80 system was upgraded to what is referred to as LZB80 CE. The LZB80 CE was even deployed on shunting locomotives on this route, as the route is designed to only take vehicles that are equipped with LZB CE.

A new, more compact generation of hardware was developed using current semiconductor technology, which was named the LZB80E. This grew out of the space restrictions in the ICE-T trains, which do not have a separate engine room.



MFA8 with the LZB80 display in the ICE 1



MFA20 with the LZB80 display in the ICE 3

The meanings of the various indicators and displays are explained in the chapters that follow.

2.12.3.4.4 Cab displays



The image shows the LZB80 display:

Distance to target is indicated on the left-hand side as a bar of lights going from 4000 down to 0, and above that in the form of a digital display for values above 4000 m (here showing 6900 m). This is the distance to the next speed change.

Speed display in the dial (yellow needle), showing the current speed of the train.

LZB permitted speed indicated by the small red arrow on the outside of the dial. This is the maximum speed that is currently permitted (shown here as 100 km/h).

LZB target speed is shown by the red digital display at the bottom of the dial. This is the new speed that will apply after the target distance has been covered (60 km/h here).

Indusi indicators (55, 70, 85, Befehl (command), 500 Hz, 1000 Hz). These are dark-switched when LZB mode is active.

LZB indicators (H, E40, Ende (end), B, Ü, G, EL, V40, S, Stör (fault))

2.12.3.4.5 Brief overview of indicators

H: flashing light: LZB emergency stop by another train; steady light: emergency stop cancelled or: unauthorized passing of LZB stop

G: steady light: actual current speed (v-Ist) is greater than target speed (v-Ziel); flashing light: actual current speed (v-Ist) is greater than the permitted speed (v-Soll)

E40: steady light: LZB Backup order; flashing light: LZB Wrong-track order or, from 2003 onwards LZB Opposite Track order

El: steady light: main switch off; flashing light: lower pantograph



Ende (End): flashing light: LZB end process begun; steady light: end process acknowledged

V40: flashing light: LZB Caution order; steady light: LZB Caution order acknowledged B: steady light: LZB vehicle device in operational readiness

S: steady light: LZB/Indusi emergency braking

Ü: steady light: LZB mode is active; flashing light: transmission failure Störung (Fault): steady light: malfunction; flashing light: input train data

2.12.3.4.6 Commencement of LZB mode

The operational readiness of the LZB is indicated by indicator “B”. Trains automatically enter LZB mode when they enter an LZB route, as soon as the train is fully inside the LZB zone. During LZB mode operation, the “U” indicator (which stands for “Übertragung”, or transmission) illuminates, and the PZB indicator lights go out.

The LZB commencement points (LZB zone signs) are also shown in the working timetable.

2.12.3.4.7 Driving with LZB

Trains that are running in LZB mode (indicated by the illuminated “Ü” indicator light) adjust their speed entirely in accordance with the LZB movement authority telegrams. The track-side distant, main and Lf signals do not apply, nor is the Indusi system operated. Although the vehicle device receives the track-side Indusi speed control signals, all effects of these are suppressed in LZB mode. On the basis of train and track data, the LZB on-board computer calculates the current permitted speed and the braking curves for upcoming speed reductions. The most critical braking curve at any time is the definitive one. The following displays inform the driver of the resultant permissible speeds:



LZB permitted speed: This is the (maximum) speed that the train should be running at currently, and is indicated by a small red marker at the outside edge of the tachometer (indicating 100 km/h in the picture).

LZB target distance: A new speed applies once this distance has been covered. The distance is displayed on the light bars between the tachometer and the tractive power display. The bars

range from 4000 metres down to 0 (shown at c. 500 m here). If the target distance is longer than 4000 m, then it is shown as a figure in the digital display above the bar. The maximum target distance depends on the train data, and can be up to 9900 m.

LZB target speed: This is the speed that applies once the target distance has been covered; it is shown at the bottom of the tachometer by a red digital display, (shown here as 40 km/h).

If the train is travelling faster than the permitted speed specified, then an intermittent buzzer sounds, and the red “G” indicator flashes (speed conformity), and if the speed is exceeded by a higher margin the brake is automatically applied, which is then released once the train is travelling below the permitted speed again.

If the vehicle is equipped with AFB, then the AFB can be set to full speed. The LZB intervenes directly in the AFB and enforces the LZB permitted speed if the AFB preset is higher. A lower speed can, however, be specified with the AFB, which can be useful if following a slower train, as the LZB does not replace economical driving behaviour. When driving in a combination of LZB + AFB modes, the train will be completely automatic, and the driver only has to operate the Sifa. The red indicator always shows the LZB permitted speed. When the “G” indicator button is clicked (with the mouse), the display switches to the AFB target speed.



The red “S” indicator lights up in the event of enforced braking by the LZB or PZB.

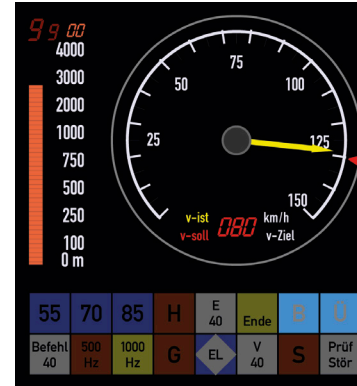
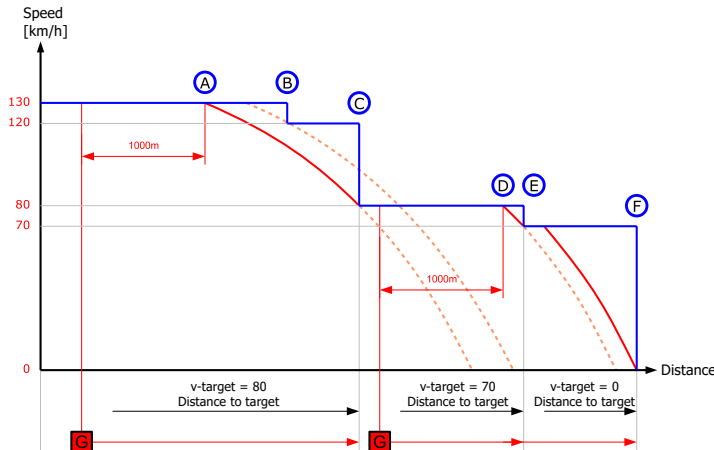
2.12.3.4.8 Speed change

Speed changes to a higher speed are notified by the LZB target distance display, and shown as the new permitted speed when they are currently in force, once the train length has been counted down in 100 m increments in the target distance display.

The process for speed changes to a lower speed is more complex:

- As soon as the lower speed appears in the LZB target speed display, the buzzer sounds.
- 1000 m before the braking point, the buzzer sounds again, and the “G” indicator illuminates with a steady light.
- At the braking point, the buzzer sounds once again, and the LZB permitted speed starts to sink to the new target value in accordance with the braking curve. The speed is monitored during the braking curve for any infringements, as described above.
- When the new speed has been reached, the “G” indicator goes out.

The diagram below illustrates how the LZB process works:



The four images below show the modular cab displays at different stages during the trip in the diagram:

The first image shows the situation at the far left-hand side, at the start of the chart. A speed of 130 km/h is permitted, which is indicated by the small red marker (v-Soll). The next speed reduction occurs at point B, down to 120 km/h, and shortly thereafter to 80 km/h at point C. The dotted braking curve line

shown for additional information tells us that the braking process leading up to point C is the more critical of the braking curves. This means that the jump at B is not visible to the driver, and that what is displayed in the cab is point C with v-Ziel=80 km/h and the target distance (c. 2800 m here, being the current distance from the front of the train to point C). In the case of a train with a higher-capacity braking system and thus a steeper braking curve, point B might become visible to the driver, and the speed reduction to 80 km/h would take place in two stages.



The second image basically shows the same status, although the train is now closer to point C, so that it is within 1000 m of the braking point A. In order to alert the driver to the upcoming braking process, the “G” indicator (speed conformity) lights up, and the buzzer sounds. The indicator does not illuminate if the train is already travelling at a speed of less than 30 km/h under the v-Soll (permitted speed) or has already slowed



down to below the v-Ziel (target speed).



The third image shows the situation between points A and C. The LZB brings the permitted speed continually downwards from 130 km/h in accordance with the braking curve until it reaches the target speed of 80 km/h in the exact target distance.



The fourth image shows the situation straight after point C, when the values for the next braking point are in force. From the braking curves shown in the diagram, we can ascertain that there is a required speed change from 80 km/h down to 70 km/h at point E. The target speed of v-Ziel=70 km/h is displayed with its correlative target distance. The "G" indicator light will remain off until the train comes within 1000 m of braking point D.

2.12.3.4.9 Stopping at a platform

The LZB does not take the correct approach to the stopping point at the platform into consideration. The train driver is responsible for achieving this himself by bringing the train to a halt using the train brake valve at the correct time. In active AFB mode, the "forced reset of power handle" (also present without LZB mode) must also be heeded.

2.12.3.4.10 LZB-end process



LZB mode normally ends shortly before a main signal in order to ensure a seamless transition to signal-based operation. When LZB end is approaching, the LZB-end indicator starts to flash. The driver then has 10 seconds to acknowledge this using the PZB release button, otherwise the v-Soll permitted speed will drop to 0 km/h. After the alert has been acknowledged, the indicator switches back to a steady light. The track-side

signals must now be heeded.

The LZB-end process is only commenced if the final main signal is showing the proceed aspect, and, in any event, 1700 m before LZB end at the earliest. It can also be the case that the train comes to a stop before a signal at danger without the driver having been aware of the upcoming LZB end. When the signal changes to the proceed aspect, the LZB-end process then kicks in — only a few metres before LZB end.

At the point of transition into signal-based operation, the "Ü" and "LZB end" indicators go out, and the PZB indicators illuminate again. In locomotives with AFB, the driver must take note of the "Forced reset of power handle" for the AFB speed control handle (as this would normally be set at maximum speed during LZB operation, whereas a lower speed may now apply), otherwise there will be no tractive power. Particularly in the case of the PZB90, the driver needs to be aware during the LZB-end process that the Indusi system also receives and processes all speed controls during LZB operation, but does not display any of the information or activate enforced braking. The Indusi system thus comes out of background mode and becomes momentarily active at LZB end. If, therefore, a 1000 Hz speed control transmission was received, for example, the corresponding braking curve will immediately be activated, possibly even in restrictive mode



after a stop, and will initiate an Indusi-enforced braking at LZB end. When the LZB-end process begins, the driver must therefore be able to identify from the trip profile what the status of the Indusi is when it becomes active, and drive at an appropriately low speed.

2.12.3.4.11 LZB Backup order

The LZB Backup order is linked to the Zs 1 at the main signal, and controls the corresponding process in LZB mode. As the train approaches a signal showing the Zs 1 aspect, the E40 indicator lights up, and the target speed is displayed as 40 km/h. The train is operated in the same way as for LZB mode, and is driven on the basis of movement authority telegrams, so the Befehl (command) button does not need to be used.

2.12.3.4.12 LZB Caution order

The LZB Caution order is linked to the Zs 7 at the main signal, and controls the corresponding process in LZB mode. As the train approaches a signal showing Zs 7, the V40 indicator flashes. The target speed is shown as 0 km/h in the run-up to the signal. Once the release button has been pressed to acknowledge the alert, the V40 indicator switches to a steady light, and the permitted speed is displayed as 40 km/h.

The train continues in normal LZB mode, and the command button does not need to be pressed. The train must be driven on sight until the next main signal.

2.12.3.4.13 LZB Opposite Track order

The LZB Opposite Track order (originally known as the Wrong Track order) is linked to the Zs 8 at the main signal, and controls the corresponding process in LZB mode. As the train approaches a signal showing Zs 8, the E40 indicator flashes. The target speed is shown as 0 km/h in the run-up to the signal. Once this has been acknowledged by pressing the “Wachsam” button, the permitted speed is shown as 40 km/h.

The train continues to be operated in the same way as for LZB mode, and is driven on the basis of movement authority telegrams, so the Befehl (command) button does not need to be used.

2.12.3.4.14 LZB transmission outage

A transmission outage triggers a shift into signal-based operation if LZB communication fails and the correct movement authority information can no longer be transmitted. On routes with partial-block operation, the LZB blocks are spaced at shorter intervals than the blocks with signals. When reverting to signal-based operation, the train could therefore find itself in the same signal block section as other trains. In order to prevent accidents, a train is only permitted to continue after it has received an order from the traffic controller. This is known as “transmission outage assisted by traffic controller”.

In whole-block mode where there are no additional LZB block posts between main signals, the train can be switched directly over to signal-based operation.

The transmission outage is notified by the Fault indicator (“Stör.”) illuminating, and the “Ü” indicator flashing. The target speed will then be displayed as 0 (with traffic controller) or 40 (without traffic controller). This transmission outage alert must be acknowledged within 10 seconds by pressing the release button.

The next steps will depend on the type of transmission outage, as explained in the next two paragraphs.

2.12.3.4.14.1 LZB transmission outage not assisted by traffic controller

If the train’s speed has dropped to below the 1000 Hz monitoring speed limit (e.g. 85 km/h), then the relevant train-type indicator will flash. The release button must again be pressed (to acknowledge that the signals are now being heeded again), at which point the PZB is activated and displays a combination of the 1000 Hz indicator (steady light) and the train-type indicator (steady light) for about the next 2000 metres. The speed that is appropriate for the train type is then monitored continuously for that distance.

2.12.3.4.14.2 LZB transmission outage assisted by traffic controller

The train must first be stopped, after which the “Befehl” (command) indicator will flash. Once an appropriate order has been received (and

the train continues in signal-based operation), the “Befehl” (command) button can be pressed for 10 seconds, after which the indicator switches to a steady light and the LZB movement authority information is deleted. For the next 50 metres, an intermittent horn will sound to remind the driver that he/she has switched to signal-based operation.

2.12.3.4.15 Basic data, Replacement train data, Train data

As mentioned previously in relation to the Indusi I60R, when in LZB mode also, standard train data are used if the actual, specific train data cannot be entered in the system. The system starts up initially from the basic data. These are very restrictive, however, and have such a low braking percentage that it is not possible for the train to enter LZB mode. Like the replacement train data in the I60R, they become active if the train moves off without the relevant actual data having been entered.

The replacement train data in the LZB are not quite so restrictive, however, and reflect the normal operating range of the train. If it is not possible to enter the specific train data, and the replacement data are suitable for the train, then the driver can activate these by holding the reverser in the R position for 15 seconds. Once this has been done, all three train-type indicators will light up to indicate that the replacement train data are active. If a PZB test program is running, however, this will be displayed as normal, after which all three train-type indicators will be illuminated again.

As far as the LZB is concerned, there are a number of additional brake types (BRA), the use of which is laid down in the specific rules for each vehicle. A few examples of these are outlined below:

- 1: PZB90: G
- 2: LZB80: G + block brakes
- 3: LZB80: G + disc brakes
- 4: Freight train in P
- 5:
- 6: LZB80: P/R + block brakes



- 7: as for 9 except vehicle sensitive to cross winds
- 8: PZB90: P/R
- 9: LZB80: P/R + disc brakes

BRA 6 is normally used for the stored basic data, including in vehicles with disc brakes.

2.12.4 Austria

2.12.4.1 Inductive train protection system (Indusi)

2.12.4.1.1 PZB 60

The PZB60 is the same as the German Indusi I60, except train-type U is not available, and monitoring speed limits of 90 km/h for train-type O and 70 km/h for train-type M apply. The variants that are also found on the ÖBB on locomotives 1044, 1042/1142, 1043 and ET 4030.2 can be replicated by using the German Indusi I60 and I60DR.