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Mobilität für Baden-Württemberg

TramTrain connects city and region

An idea from Karlsruhe gaining ground.

Chronology.

Key milestones at a glance.

1958 Conversion of the Albtalbahn to standard gauge and connection to the Karlsruhe tram network (linking railway and tram systems)

1979 Karlsruhe's light rail vehicles operate for the first time on German Federal Railway tracks to Neureut (electrification with direct current)

1983 Research project on linking tram and railway systems

1986 Practical trials of the dual-system light rail using DC/AC traction

1988 Final trial report and order placed for the first vehicle series

1991 Pilot operation on the DB line between Karlsruhe and Pforzheim

from 1992 Launch of the first dual-system TramTrain line from Karlsruhe to Bretten

1994 Expansion of the TramTrain network through the introduction of light rail services on numerous railway lines in the Karlsruhe region

1996 Commissioning of the connecting line at Albtalbahnhof and opening of a continuous service from Karlsruhe city centre to Baden-Baden

1997 Adoption of the 'Karlsruhe Model' in Saarbrücken

2001 Opening of the inner-city tram line in Heilbronn

2002 Start of TramTrain operations on the Murgtal and Enztal lines

2003 Extension of the light rail service on the Murgtal line to Freudenstadt and opening of the inner-city line in Bad Wildbad

2004 The TramTrain reaches the Ortenau district: extension of line S4 to Achern and expansion of the Heilbronn inner-city route to Pfühlpark

2005 Opening of light rail services from Heilbronn to Öhringen

2006 Extension of light rail line S41 from Freudenstadt to Eutingen im Gäu

2007 In Kassel, a new connecting line between the railway and tram networks is opened for the 'RegioTram'

2009 Order placed for 30 Bombardier TramTrain vehicles

2010 Opening of light rail services from Wörth to Germersheim

2013 Opening of the Heilbronn North light rail line

2014 Final commissioning of the Heilbronn North light rail line

2017 Launch of the VDV-TramTrain project

2019 Signing of the cooperation agreement in March

2020 Publication of a Europe-wide tender in August

2022 Stadler awarded the contract for the VDV-TramTrain project in January

2022 Presentation of the mock-up of the new VDV-TramTrains in December

2025 Delivery of the first vehicle for Saarbahn in June

2025 Delivery of the first VDV-TramTrain vehicle to AVG, followed by further vehicles for VBK

Heilbronn station. TramTrain meets Regional Express (RE).

Passengers stay on board – the TramTrain changes system.

The success story of an innovative concept.

The idea

The concept developed in Karlsruhe involved connecting the well-established inner-city tram network to existing railway lines in the surrounding region. By making extensive use of existing infrastructure, the need for costly investment in new lines was largely avoided, enabling continuous services to operate directly from the surrounding area into the city centre. Passengers can remain on board while the TramTrain changes system. Since heavy locomotives and wide mainline railway vehicles are not suitable for pedestrian zones, existing tram vehicles were modified so they could also operate on railway lines. As part of a research project involving the then German Federal Railway and industry partners, with financial support from the Federal Ministry of Research, Albtal-Verkehrs-Gesellschaft developed a dual-system vehicle as early as the 1980s. This development was brought to series production readiness.

System changeover point.

Operation in the Murgtal requires the TramTrain to be approved for steep gradients.

The first VDV-TramTrain vehicle upon arrival at the Durlacher Allee site.

Tram in the city. Railway in the region.

The dual-system TramTrain is at home in both worlds – when it comes to power supply, tracks and safety.

The vehicle

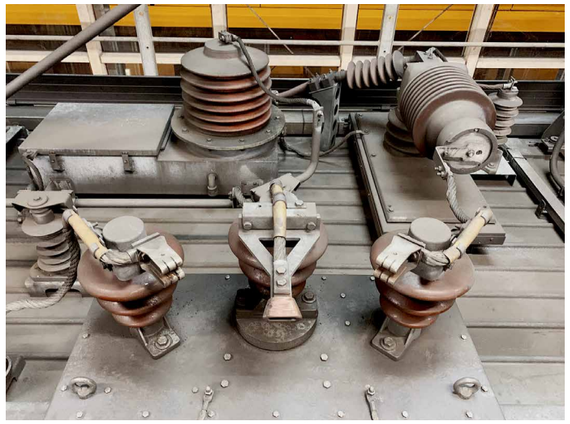
After examining several traction concepts, the direct current/alternating current option was chosen. Karlsruhe's tram network operates on 750 volts direct current, whereas Deutsche Bahn uses 15,000 volts 16 2/3 Hz AC. The dual-system TramTrain can run under both the tram and railway overhead lines.

A number of technical conditions had to be considered when developing the vehicle, regardless of the traction concept. It must comply with both tram regulations (BOStrab) and railway regulations (EBO). One issue was the different vehicle widths: trams may not exceed 2.65 metres, whereas railway vehicles are often over three metres wide. This issue was resolved by incorporating extendable steps. Another challenging task was developing a wheel-tyre profile that works on both the tight grooved rails used on Karlsruhe's tram network and the points used on the mainline railway.

In order to enable as barrier-free access as possible, the dual-system TramTrain in Karlsruhe was designed as a medium-floor vehicle with an entrance height of 57 centimetres. This entrance height was introduced with the medium-floor vehicles of the 837 ff series onwards; previously, high-floor vehicles were used. At 57 centimetre high platforms, passengers can board level with the platform. At platforms that are 38 centimetres high, however, passengers must negotiate a small step. At platforms measuring 76 centimetres in height, the extendable step adjusts to the 57 centimetre level, meaning passengers only need to step down once. However, platforms measuring 76 centimetres are only used in exceptional circumstances.

Barrier-free upgrades across Karlsruhe's TramTrain network are being continuously progressed. Due to its lightweight design, the TramTrain has lower frame stiffness than mainline railway vehicles. However, this is offset by its strong braking performance, given that it shares the tram network with general road traffic.

The requirements for active and passive safety are set out in a recognised guideline used by the Federal Railway Authority for 'light local trains with several carriages'.



System switch on the vehicle roof.

In Karlsruhe city centre, the dual-system vehicle operates as a tram.

A system change has enabled the TramTrain to move from the railway network into the tram network.

System change

To link the two systems, several connecting lines were built between the tram and railway networks, enabling continuous operation. The operational transition at the system change point happens automatically, so passengers do not notice anything – much like changing from a federal road to a local road. The dual-system TramTrain first switches from direct current to a short neutral section with no power, and then to alternating current. Ideally, the system change point is located on a slight downhill gradient. If necessary, the 750 volts overhead line voltage can be switched on.

Operation

AVG, a non-federal railway (NE) owned by the City of Karlsruhe, is the system operator for Karlsruhe's TramTrain network. AVG operates the TramTrain network in cooperation with the city's public transport operator, Verkehrsbetriebe Karlsruhe GmbH (VBK), and Deutsche Bahn.

In Baden-Württemberg, the state is responsible for local rail passenger transport (SPNV). The state commissions services on DB lines, and the TramTrain is treated like any other SPNV service.

Depending on demand, the dual-system TramTrain runs at intervals ranging from hourly services to a 10-minute service. On the railway network, speeds of up to 100 km/h are reached, whereas on the tram network the TramTrain runs with closely spaced stops and a maximum speed of 70 km/h.

Within the Karlsruher Verkehrsverbund (KVV), more than ten TramTrain lines are currently operated using dual-system vehicles. As the dual-system TramTrain has all the characteristics of an S-Bahn, the KVV lines are designated accordingly.

Karlsruhe sets the standard: from pilot project to proven principle.

A denser network and new infrastructure made it a success story.

The TramTrain connects Karlsruhe city centre with the surrounding region.

Access and connectivity
Thanks to its high acceleration and short braking distances, the TramTrain can stop more frequently without increasing journey times. These additional stops improve public transport access for towns and municipalities. Passengers' overall travel time is reduced because the walk to the stop becomes shorter.

For example, in the town of Bretten, which has 28,000 residents, there used to be six stations. Today, there are 17 TramTrain stops, providing excellent access to the town centre as well as schools, business parks and residential areas.

Incidentally, the dual-system TramTrain does not operate as a tram only in Karlsruhe. In Wörth, Heilbronn and Bad Wildbad, new tram lines were built starting from the stations to provide better connections to the city centres.

Infrastructure
The dual-system TramTrain operates not only on the tram network, but also on AVG's NE lines (non-federal railways), such as the Kraichtalbahn line from Bruchsal to Menzingen and Odenheim. It also uses Deutsche Bahn main lines, such as the Rheintalbahn line from Karlsruhe via Baden-Baden, as well as so-called 'leased lines'. These lines are owned by DB, but have been leased to AVG so they can be upgraded and operated for TramTrain services, for example the Murgtalbahn line from Rastatt to Freudenstadt. On DB lines, the TramTrain pays track access charges and station fees, just like other regional trains. Using infrastructure with different technical systems and different owners highlights the high level of flexibility of the TramTrain system.

Demand
The first dual-system TramTrain line from Bretten into Karlsruhe city centre opened in 1992. Passenger numbers exceeded all forecasts. Immediately after TramTrain services started, passenger numbers between Bretten and Karlsruhe increased fourfold. Significant increases were also recorded on all routes converted to TramTrain operation.

Network development
The pilot line between Karlsruhe and Bretten has since been extended several times, and additional lines have been added. Today, the TramTrain operates on almost all railway lines in the Karlsruhe region. The Karlsruhe TramTrain network now covers 544.6 kilometres, exceeding the size of most S-Bahn systems in major metropolitan areas.

This expansion would not have been possible without investment in infrastructure. Connecting lines between the tram and railway networks were built, as well as junction stations and additional stops. Numerous line sections have been electrified, existing stations have been refurbished and signalling technology has been modernised. Nevertheless, the investment required to adapt the infrastructure for TramTrain operation was significantly lower than the cost of constructing a completely new network.

Inspiration
Due to its success, the 'Karlsruhe Model' has inspired many others. Since 1997, dual-system TramTrains based on the Karlsruhe approach have operated on a newly built inner-city tram line and regional railway lines in the Saarbrücken region. In Kassel, the 'RegioTram' connects the city centre with the surrounding region via the main station. The Karlsruhe Model has also been implemented in several other German cities.

The concept has also become firmly established across Europe. In France, it has been implemented in places including Mulhouse and Nantes. The TramTrain system is also used in other regions, for example in Sheffield in Great Britain and in Cádiz in Spain (see the graphic for an overview of locations).

The Karlsruhe Model: a role model for Europe.
Status: December 2025

The Murgtal is home to one of Germany's few steep railway sections, including the spectacular Tennetschlucht near Forbach. AVG's dual-system vehicles have been granted approval to operate on this steep section. Special approval is required for gradients of four percent or more.

An inspirer for environmentally friendly mobility – sustainable and forward-looking.

AVG: environmentally friendly travel

Over the past year, Albtal-Verkehrs-Gesellschaft (AVG) has made a significant contribution to climate protection by providing environmentally friendly rail mobility services. Since 2017, AVG has operated its light rail vehicles exclusively with green electricity from renewable energy sources, saving several tens of thousands of tonnes of harmful carbon dioxide (CO_2).

Compared to cars, public rail transport has a significantly smaller ecological footprint. A local train produces only 44 grams of greenhouse gases per passenger kilometre (source: Federal Environment Agency, 2024), whereas a car emits 164 grams – almost four times as much. Therefore, AVG's TramTrain services are also an important part of the transition to climate-friendly mobility, particularly in this region.

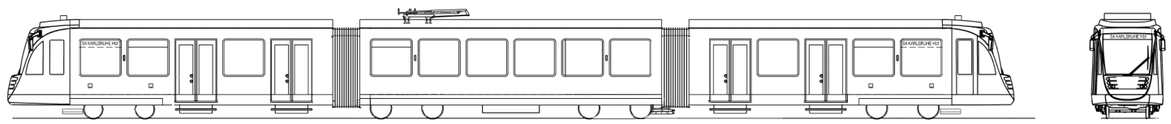
Rail transport in numbers (rounded)

Track length in km	544.6
TramTrain vehicles	211
of which dual-system vehicles	110
Lines	16
Passengers in 2024	45.52 million
Operational performance (bus and rail)	15.8 million km
Freight transported by rail	528,900 t

Status: 31.12.2024

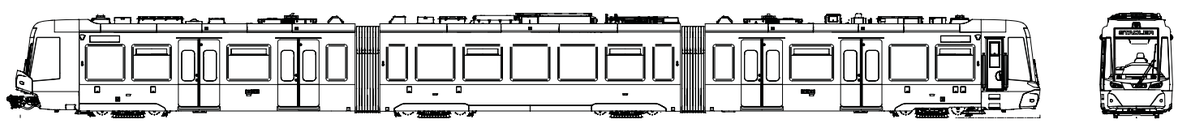
AVG TramTrain network
Status: 31.12.2024

The dual-system vehicle Flexity Swift.



Manufacturer/vehicle type	Bombardier Flexity Swift
Design	Bi-directional vehicle
Vehicle length	37.03 m
Vehicle width	2.65 m
Entrance height	580 mm
Wheel diameter (new)	740 mm
Track gauge	1,435 mm
Minimum horizontal curve radius	23 m
Drive	Dual-system technology for 750 volts DC and 15 kV, 16 2/3 Hz AC
Motor power (asynchronous induction motors)	4 x 150 kW
Average acceleration (2/3 loaded) from 0 to 80 km/h	0.6 m/s²
Maximum speed	100 km/h
Deceleration service brake (2/3 loaded)/emergency brake (2/3 loaded)	1.6 m/s²/2.73 m/s²
Maximum passable gradient	60 ‰
Seating capacity	93 seats/151 standing places, 3 multipurpose areas
Empty weight	63 t
Air-conditioned interior, passenger information system, universal toilet, air suspension	

The dual-system vehicle TramTrain TT-2S.



Manufacturer/vehicle type	Stadler Citylink TramTrain
Design	Bi-directional vehicle
Vehicle length	37.2 m
Vehicle width	2.65 m
Entrance height	550 mm
Wheel diameter (new)	700 mm
Track gauge	1,435 mm
Minimum horizontal curve radius	22 m
Drive	Dual-system technology for 750 volts DC and 15 kV, 16 2/3 Hz AC
Motor power (asynchronous induction motors)	6 x 125 kW
Average acceleration (2/3 loaded)	1,2m/s²
Maximum speed	100 km/h
Deceleration service brake (2/3 loaded)/emergency brake (2/3 loaded)	1.67m/s²/2.64m/s²
Maximum passable gradient	100 ‰
Seating capacity	93 seats/136 standing places (including multipurpose areas)
Empty weight	64.5 t
Heat pump for heating and air conditioning, universal toilet, air suspension, Wi-Fi, USB charging points, 29-inch infotainment displays	

TramTrain in Heilbronn.

VDV-TramTrain: securing future mobility today.

The VDV-TramTrain is a symbol of forward-thinking mobility.

A model from Karlsruhe that has a strong impact
The Karlsruhe Model is a pioneering solution for seamless public transport between the city and the surrounding region, allowing passengers to transfer between tram and railway infrastructure without changing vehicles. This innovation has been successfully adopted in numerous regions. However, the future of the model was under threat: for small and medium-sized transport operators, acquiring new dual-system vehicles had become barely economically viable due to high unit costs combined with low vehicle numbers, making it difficult for these companies to enter the market.

Cooperation instead of individual procurement
Three transport operators, including AVG, joined forces to reduce vehicle costs. The aim was to keep comfort, safety and quality unchanged. They decided to spread the one-off costs of development, design and approval across a larger number of vehicles.
It was not possible to create a fully standardised vehicle due to differing requirements; instead, the common elements were standardised and individual adaptations were defined separately, similar to the automotive industry. This made it clear how special requirements affect the price. This pragmatic solution also convinced other transport operators to join the 'dual-system self-help group'.

Synergies that pay off
Close cooperation brings advantages in vehicle approval and development:
- joint assessors providing consistent evaluations
- coordinated verification plans between manufacturers, operators and authorities
- standardised dossiers with operator-specific additions
- partial mutual recognition of approvals by different authorities
- in addition, personnel, consultancy and legal costs were shared, including knowledge transfer

Maintenance: ensuring long-term reliability
The scope of supply includes long-term maintenance contracts that guarantee the availability of spare parts. Under these contracts, the workshops act as subcontractors for Stadler. This ensures not only the technical quality and availability of the vehicles, but also safeguards jobs.

A European flagship project
As part of the VDV-TramTrain project, Albtal-Verkehrs-Gesellschaft (AVG), Verkehrsbetriebe Karlsruhe (VBK), Saarbahn, Schiene Oberösterreich (Schiene OÖ GmbH), Schiene Salzburg GmbH, and Regional-Stadtbahn Neckar-Alb are collaborating. The vehicles for AVG and the Regional-Stadtbahn Neckar-Alb project are being procured by the state of Baden-Württemberg.

The joint Europe-wide tender was launched in August 2020, featuring:
- a standardised technical specification (plus operator-specific appendices)
- a joint draft contract with individual adaptations
- a coordinated evaluation methodology

In January 2022, the contract was awarded to Stadler. The target set in 2017 of savings of up to € 1 million per vehicle was achieved, proving the efficiency of the project (price level January 2022).

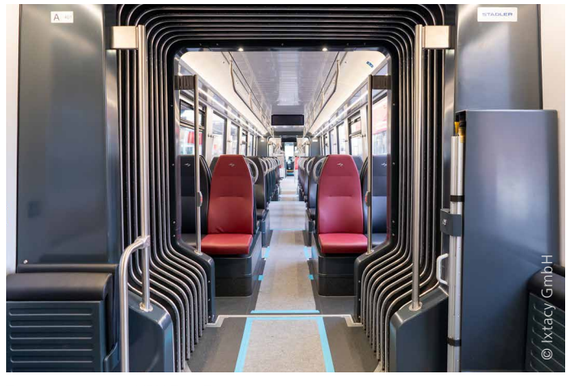
VDV-TramTrain: the vehicle of the future
The VDV-TramTrain (TT-2S) is a new generation of TramTrain vehicles that connect urban centres with the surrounding region in an accessible, efficient and environmentally friendly way:

- dual-system capability (e.g. 750 volts DC + 15 kV AC)
- barrier-free access, adaptable to different platform heights
- high-performance braking and collision warning systems
- lightweight design with stainless steel structure
- capacity for approx. 230 passengers
- energy-efficient air conditioning with CO_2 heat pump
- modern, attractively designed passenger interior
- new generation of passenger seats with high-quality, sustainable eLeather upholstery
- spacious, barrier-free universal toilet
- numerous charging options for mobile devices in the passenger area
- modern passenger information system with large screens; plus Wi-Fi, USB and video surveillance

Figures and facts
- Planned delivery period: until approx. 2032
- Total contract value: around 4.2 bn €
- Total number of vehicles: up to 504 (of which 258 optional)
- AVG order: 75 vehicles with an option for a further 73
- Vehicle length: 37 m
- Vehicle width: 2,65 m
- Track gauge: 1,435 mm
- Maximum axle load: 11.5 t

A model of exemplary character
This project demonstrates how collaboration, standardisation and shared responsibility can create a system that is both economically viable and future-ready. The VDV-TramTrain is not just a vehicle – it represents the mobility of tomorrow.

The new VDV-TramTrain generation has seats that are upholstered with sustainable ELeather.



The interior of the VDV-TramTrain is both modern and spacious.

Information

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