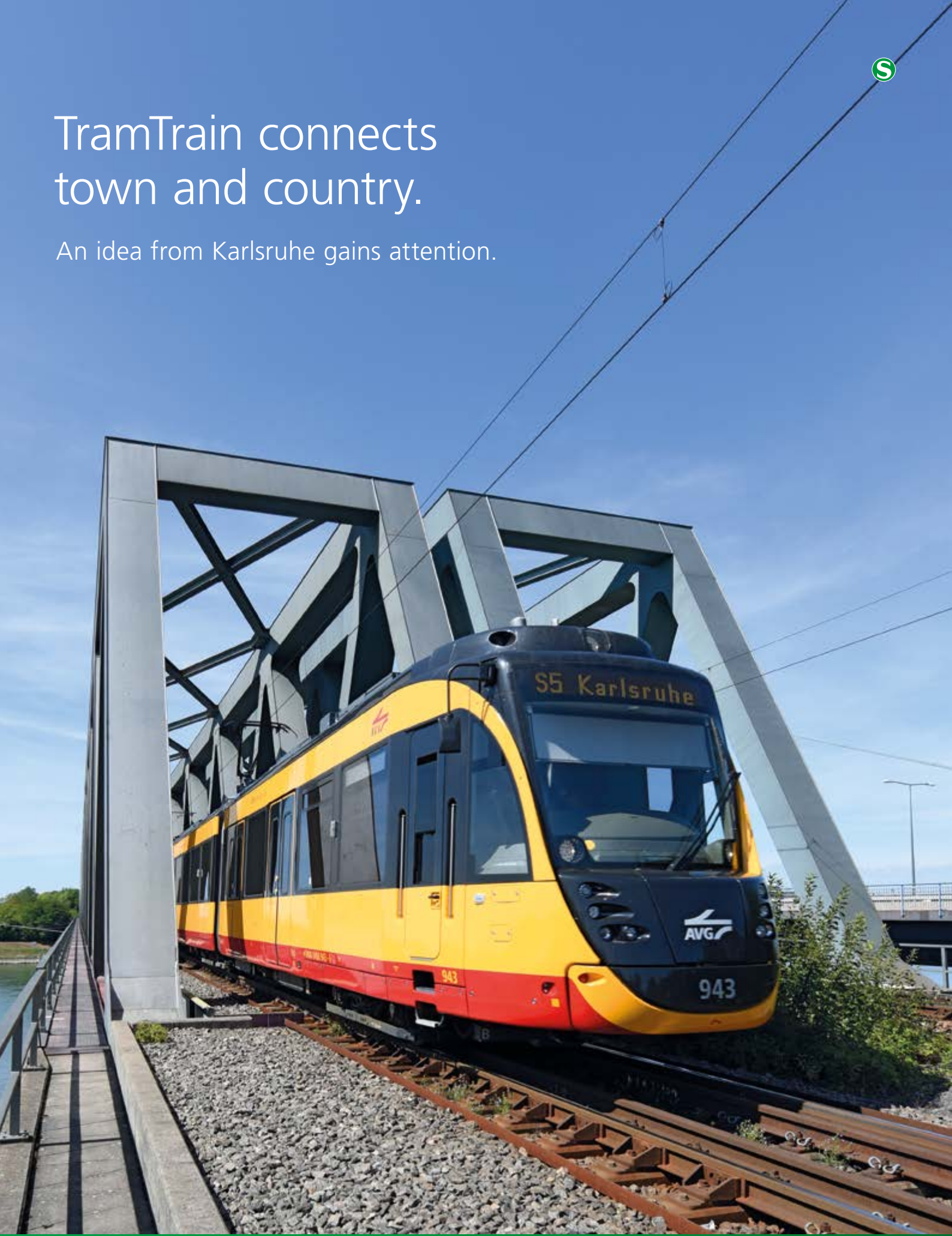
TramTrain connects town and country.

An idea from Karlsruhe gains attention.



AVG. *Provides travel for everybody.*

Chronology.

1979 In Karlsruhe, AVG pioneers the operation of LRVs on the national railway network under 750 V DC overhead electrification

1983 Research project on track sharing

1986 Test run of the first TramTrain vehicle with dual-mode technology (AC/DC)

1988 Final report and order of the first vehicles

1991 Test run on the federal railway line between Karlsruhe and Pforzheim

1992 Inauguration of the first TramTrain route between Karlsruhe city centre and Bretten

from 1994 TramTrain extension by introduction of light rail operation on several heavy railway lines in Greater Karlsruhe

1996 Inauguration of a system change-over at the Albtalbahnhof and a direct connection from Karlsruhe city centre to Baden-Baden

1997 Inauguration of a new TramTrain-system in Saarbrücken inspired by the "Karlsruhe Model"

2001 The City of Heilbronn opened a new tram section within the city centre with a system change-over at the main-station

2002 Start of TramTrain operation along two adapted railway lines into the Black Forest: Murg Valley Railway and Enz Valley Railway

2003 Extension of the Murg Valley Railway to Freudenstadt and the opening of an urban tram section in Bad Wildbad

2004 TramTrain operation reaches the Ortenau district, S 4 extension to Achern. Heilbronn extended the urban tram section to Pfühlpark

2005 Inauguration of the TramTrain between Heilbronn and Öhringen

2006 Extension into the Black Forest, TramTrain operation between Freudenstadt and Eutingen

2007 The German city of Kassel started TramTrain operation based on the "Karlsruhe Model"

2008 AVG commence structural alteration works along the railway line between Wörth and Germersheim (Rhineland-Palatinate)

2009 30 TramTrains of Bombardier are ordered

2010 Inauguration of the TramTrain between Wörth and Germersheim

2013 Inauguration of the TramTrain route Heilbronn Nord

2014 Final commissioning of the TramTrain route Heilbronn Nord

Karlsruhe main station: TramTrain meets ICE.

No need for interchange, the tram becomes a train.

A success story of an innovative concept.

The idea

In Karlsruhe a fully developed tram-system has been operating since 1900, also Karlsruhe is an important railway junction where many main lines and branch lines meet together. This situation creates the idea of track sharing, connecting the tram and rail network. Using existing infrastructure should help to avoid big investments in new railway or tramlines and a direct connection between city centre and countryside making interchanges unnecessary. The idea is that there is no need for interchange because the tram becomes a train. It is hard to imagine that heavy locomotives and wider EMUs run through a pedestrian precinct and that is why the existing LRVs would need to be modified for heavy rail operation. For this the Albtal-Verkehrs-Gesellschaft (AVG) developed a "dual-mode vehicle" so that it was ready for production within a federal research project during the 1980s. The study was partly funded by the Federal Ministry of Research and Development; the Federal Railway and the industry gave technical support.

System change-over.

A special permit allows the TramTrain to navigate steep gradients in the Murg Valley.

TramTrain at Heilbronn station forecourt.

A tramway in the city centre, a railway in the region.

The TramTrain is at home with both systems: in terms of power supply, rails and safety.

The TramTrain vehicle

Different power supply systems were investigated during the research project. The final decision was made for the direct current/alternating current (DC/AC) option. In the city of Karlsruhe the trams run under 750 V DC, the German Federal Railway system uses 15 kV (16 2/3 Hz) AC. The dual-mode vehicle is able to operate both: 750 V DC within the tram network and 15 kV on the heavy rail system.

A lot of basic conditions were taken into consideration during the construction regardless of the drive system. The TramTrain vehicle had to be designed meeting the needs of both the German regulations of tram operation (BOStrab) and the German railway operation regulations (EBO). One issue was the difference in the vehicle width. The maximum width of trams is 2.65 metres, but heavy rail vehicles are often wider than 3 metres. Using retractable steps bridging the gap between vehicle and platform solved this problem. Another difficulty was the geometry of the wheel profile. It had to be designed so that it would fit both the narrow grooved tram rails and heavy rail switches.

To achieve an almost barrier-free access to the vehicles, the Karlsruhe dual-mode LRVs are designed with a middle floor and an access height of 570 mm. At standard platforms of this height a level boarding is possible for passengers. At 380 mm high platforms passengers have to climb a small step and at 760 mm high platforms the retractable step can be lifted up.

Because of the lightweight construction of TramTrain vehicles the crashworthiness is much lower than for heavy rail vehicles. This fact was compensated by a higher braking performance of the LRVs, which is necessary to operate along streets with car traffic in any case. The issue of passive and active safety is now regulated in a LRV directive of the Eisenbahn-Bundesamt (Federal Railway Authority).

Current system selection relay on the roof of the TramTrain.

In the Karlsruhe city centre, the dual-system-vehicle is a Tram.

Signposts at a system change-over.

System change-over

Several connections between the existing tram and railway networks were built to link both systems and to allow through running operation. The change between tram and railway operation proceeds automatically at the system change-over. Passengers don't notice this change of electrical power system and regulations; it is like changing from an A-road to an urban street. The dual-mode LRVs change from the direct current to a short neutral (track) section and finally to alternating current. The section for the system change-over is ideally located on a slight gradient, to allow a vehicle rolling back into a live section if an emergency break stopped it inside the neutral section. If worst comes to worst the neutral section can be supplied with current.

Operation

AVG is owned by the city of Karlsruhe and is a so-called non-state owned railway company (NE-Bahn). AVG operates light rail services in cooperation with the Verkehrsbetriebe Karlsruhe as the local tram operator, and with the Federal Railway company, Deutsche Bahn AG (DB AG).

The state of Baden-Württemberg is responsible for regional railway services. The Nahverkehrsgesellschaft as a federal authority orders rail services on the DB network. TramTrain services are handled in the same way as other regional railway services.

The dual-mode LRVs run with a fixed frequency between every hour and every 10 minutes depending on the demand. On the railway tracks the vehicles reach a speed of 100 km/h. On the tramway network the LRVs running straight into the pedestrian precinct with short stop distances and a maximum speed between 25 km/h within the pedestrian precinct, 50 km/h on street-running sections and 70 km/h on segregated tracks.

Seven TramTrain routes are operating within the area of the Karlsruher Verkehrsverbund (KVV, transport association of Greater Karlsruhe) at the moment. Because the dual-mode service features all aspects of a typical S-Bahn, these lines are classified as such in the KVV area.

Flexible travel. Closer to the passengers.

With new opportunities TramTrain represents best practice.

Catchment area
A high acceleration and a short braking distance allow the Tram-Trains to stop more often compared with former heavy rail rolling stock without extending the journey time. The additional stops improve the accessibility to the system. The distance to the stops and stations and thereby the travelling time is reduced. Example: In Bretten, a town with 28,000 inhabitants, that formerly had 6 railway stations, there are now 13 TramTrain stops which extend the catchment area and give the town centre, schools, industrial estates and residential areas optimal accessibility to the system.

The dual-mode LRVs not only run in Karlsruhe on tramway tracks. In Wörth, Heilbronn and Bad Wildbad new infrastructure was created in the form of tramway tracks to bring regional rail transport into the town centre.

Infrastructure
TramTrain vehicles also run as "trains" on railway infrastructure in AVG ownership like the Kraichtalbahn from Bruchsal to Menzingen and Odenheim, on the railway tracks of the Deutsche Bahn AG such as the section between Karlsruhe and Achern, as well as on "leased tracks". These tracks are in possession of the Deutsche Bahn, but they are leased to AVG allowing them to be adapted to the needs of TramTrain operation. An example of this kind of operation is the Murg Valley Railway from Rastatt to Freudenstadt, the Murgtalbahn. As a result of using tracks of the Deutsche Bahn, AVG has to pay track and station fees for its TramTrain operation like any other railway company. The use of infrastructure with different technical systems and in different ownership underlines the high flexibility of the TramTrain concept.

Enz Valley Railway: TramTrain on a street-running tramway section at Bad Wildbad.

Demand
In 1992 the first TramTrain line opened from Bretten direct into the city centre of Karlsruhe. The increase in passengers exceeded all forecasts. Shortly after the introduction of the light rail service the patronage increased by four times between Bretten and Karlsruhe. Only 2,000 trips per day were made before the TramTrain service was established, by now 18,000 trips per day are being monitored along this corridor. This result has encouraged local politicians in the region of Karlsruhe to extend the TramTrain-system in stages.

On all lines where TramTrain operation was introduced a significant increase in patronage were experienced.

Network development
The pilot line between Karlsruhe – Bretten has been extended several times. Additional routes have been included in the network. In the meantime AVG operates TramTrain services along all heavy railway lines in the Karlsruhe region. The overall track length of the Karlsruhe light rail system has reached a figure of more than 663,4 kilometres, which has exceeded the track length of most of the S-Bahn systems in Germany's metropolitan areas.

The development of the network would not have been possible without any investments in infrastructure. It was necessary to construct connecting tracks between the tramway and railway network, junctions and additional stops. Several track sections were electrified, railway stations were upgraded and the signalling system was modernised. Overall the capital investment for upgrading for Tram-Train operation was significantly less than the construction costs for a complete new system.

Consequences
Several cities were encouraged by the success of the "Karlsruhe Model" and since 1997 the Saarbrücken region has operated Tram-Train services based on the "Karlsruhe Model". A new inner city tramline was constructed and connected to the railway line leading to the neighbouring French city of Sarreguemines. In 2007 the city and region of Kassel inaugurated the "RegioTram" based on the Karlsruhe experience but using two different types of vehicles. One powered by AC/DC the other by diesel/DC. In Germany further projects exist in Bremen, Braunschweig and Chemnitz. Also in other countries TramTrain is seen as an economical useful application. In France there are plans being undertaken for ten regions. Mulhouse started TramTrain operation between the city centre and the city of Thann in 2010, Strasbourg in 2012.

Dual-System-Vehicle Flexity Swift LRV in front of Karlsruhe Central Station.

One of the few steep gradient railway lines in Germany leads up to the Murg Valley. Amongst others the Tramtrain travels over the breath taking Tennet gorge by Forbach.
The AVG dual-system-vehicles have a special permit, which allows the TramTrain to travel on steep gradient railway lines. This permit is needed from a 4 percent gradient upwards.

Continuous growth in a dynamic region.

Key figures:

Track length in km:	663,4
Total number of LRVs:	249
of which TramTrain vehicles:	121
Number LRT-routes:	19
Passengers per year:	170 m
Train kilometres per year:	22 m

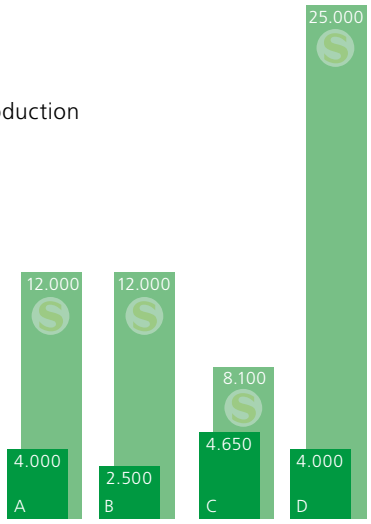
Passengers per day:
Before and after TramTrain introduction
(selected lines)

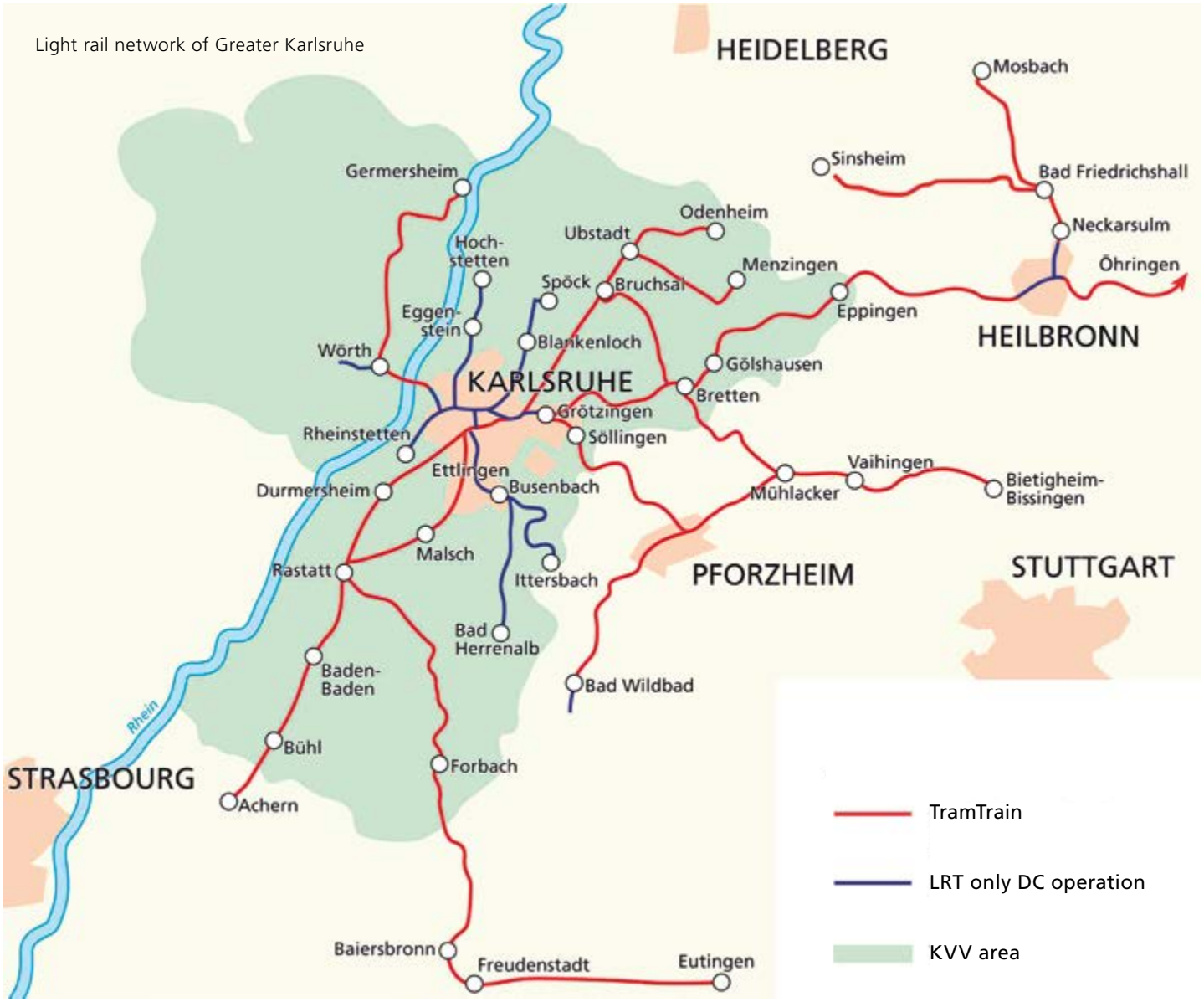
A Murgtalbahn
Rastatt – Freudenstadt

B Bruchsal – Menzingen –
Odenheim

C Karlsruhe – Wörth

D Karlsruhe – Pfinztal



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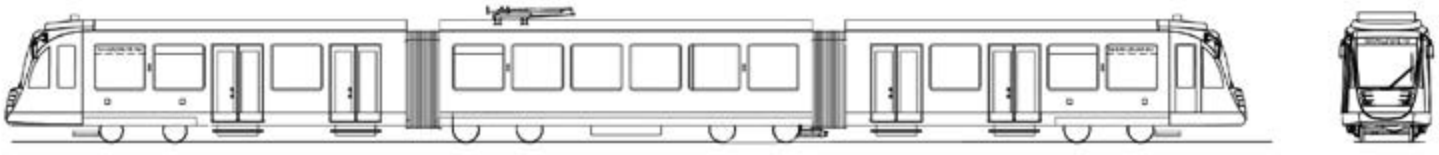
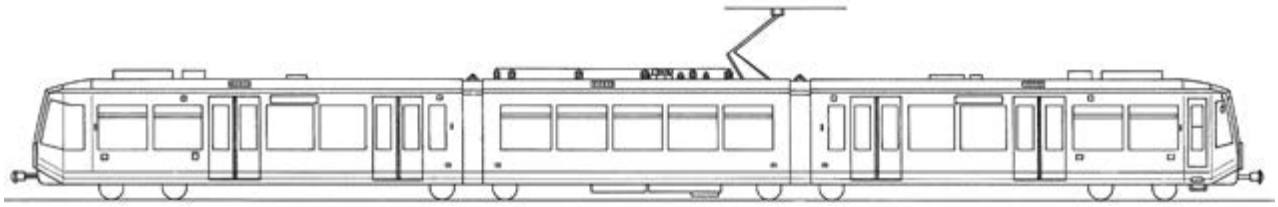
Dual-System-Vehicle Flexity Swift LRV.



Manufacturer/Type	Bombardier Flexity Swift
Operating mode	Bidirectional operation train
Length	37,03 m
Width	2,65 m
Boarding height	58 cm
Wheel diameter (new)	74 cm
Track width	1.435 mm
Minimum track radius	23 m
Power supply	dual-mode technology 750 Volt DC and 15 kV, 16 2/3 Hz AC
Engine performance	4 x 150 kW
Average acceleration from 0 to 80 km/h	0,6 m/s^2
Maximum speed	100 km/h
Regular deceleration (2/3 load) / Emergency deceleration (2/3 load)	1,6 m/s^2 / 2,73 m/s^2
Maximum gradient	60 ‰
Capacity	93 seats / 151 standees, 3 multi-purpose compartments
Net weight	63 t
Air condition, passenger information system, passenger toilet, pneumatic suspension	

Near Rastatt: TramTrain meets TGV.

Dual-System-Vehicle GT8-100 mid-floor.



Manufacturer/Type	Consortium Bombardier/Siemens GT8-100 D/2-SM
Operating mode	Bidirectional operation with train
Length	36,5 m
Width	2,65 m
Boarding height	57 cm
Wheel diameter (new)	74 cm
Track width	1.435 mm
Minimum track radius	23 m
Power supply	dual-mode technology for 750 V DC and 15 kV (16 2/3 Hz) AC
Engine performance	4 x 127 kW under 750 V DC
Average acceleration from 0 to 80 km/h	0,53 m/s^2
Maximum speed	100 km/h
Regular deceleration (2/3 load) / Emergency deceleration (2/3 load)	1,6 m/s^2 / 2,73 m/s^2
Maximum gradient	60 ‰
Capacity	97 seats, 118 standees
Net weight	58,5 t
Partial air condition, partial passenger toilet, pneumatic suspension	

Press commentary.

Süddeutsche Zeitung
Karlsruhe owns two totally different honorary titles: "capital of justice" and "Mecca of public transport " – the former because of the Federal Constitution Court, Federal Supreme Court and the office of the attorney of the Federal Supreme Court, the later because of its exemplary light rail network which is spreading into the whole region.

Frankfurter Rundschau
With the TramTrain to the economic upswing. An efficient public transport is not only useful for the ecology but also as a first-class economy benefiting feature. A TramTrain network on more than 400 km track length connects the city of Karlsruhe even with the remotest corners of Northern Baden. It is possible to travel quickly and cheaply from villages and smaller towns to the city centre of Karlsruhe.

Tageszeitung
Karlsruhe is the Mecca of the transport planner. Politicians and public transport experts make a pilgrimage to Karlsruhe from far and near. In Baden it is possible to study a revolution in public transport.

Spiegel
The inhabitants of the Karlsruhe region are travelling into the city faster and more comfortable than ever. Thanks to some technical tricks the train is mutating into a tram at the city limit and is taking commuters directly to their workplaces or for shopping to the boutiques and department stores in the city centre.

ADAC Motorwelt
Espresso double: that is the way for having a lot of fun with public transport. First the TramTrain is trotting at a comfortable speed as a tram through the pedestrian precinct, than it is hurrying at 90 km/h as a train on heavy rail tracks to Bretten 30 km away. It would be difficult to find a more comfortable way of travelling.

Die Zeit
The tramway on the tracks of the Federal Railway stands for the "Karlsruhe Model" whose inventor is Dieter Ludwig. Public transport is not only his profession it is his passion.

Focus
Dieter Ludwig wasn't stopped by technical regulation prohibiting the operation of trams on heavy rail tracks. In tough negotiations he forced a concession from the Deutsche Bahn to operate adapted trams on ICE-tracks.

Newsweek
Ridership has jumped fourfold since trams rolling through the German city of Karlsruhe and the nearby town of Bretten, and now other towns in Karlsruhe's orbit are demanding to be linked to the system.

Stuttgarter Nachrichten
Germany's most innovative traffic manager is showing in Karlsruhe how to lure car drivers into the tram.

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Albtal-Verkehrs-Gesellschaft mbH, Tullastraße 71, 76131 Karlsruhe, Telefon +49 721 61 07-0, info@avg.karlsruhe.de, www.avg.info