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Ingenuity for life

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Avenio M

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From the Combino to the Avenio M

Following a Europe-wide tendering process, SWU Verkehr GmbH and Siemens signed a contract for the supply of 12 Avenio M series vehicles on May 22, 2015. This order marks a new chapter in the success story of the Combino, a modular low-floor tram system originally introduced in 1994.

This article will take a closer look at the development of the Combino and its progression to the Avenio M, and introduce the Avenio M version adapted to the special requirements in Ulm.

As a response to the introduction of low-floor technology at the beginning of the 1990s – and the accompanying trend towards the purely project-specific development of tram cars – in 1994, Siemens, together with its rail vehicle manufacturing subsidiary Duewag, started a project for the development of a low-cost modular system of standardized elements for 100% low-floor vehicles with the product name "Combino". A high level of standardization of the subsystems and a predefined, customizable functional range were seen as the way to make high-quality low-floor trams affordable for smaller transport companies. More than 500 Combino vehicles were then successfully sold to 13 transport companies across the globe.

At the beginning of the new millennium, the first instances of damage to the innovative aluminum bodyshell structure were reported. The structure itself consisted of a welded underframe with the bodywork screwed on. Analysis showed that the normative load assumptions for the car body valid at the time did not reflect the real loads of low-floor vehicles. To counter this, Siemens developed a number of strengthening and relief measures and performed endurance tests to prove their suitability before subsequently upgrading all the vehicles already in service.

The next projects in Almada (Lisbon) and Budapest were based on Combino components, but with a modified car body concept that consisted of a single-articulated vehicle made of steel. At the same time, knowledge gained from the Combino upgrade was incorporated into the appropriate standards and guidelines for car body construction by the respective committees.

Starting in 2007 and based on the projects in Almada and Budapest, Siemens developed the Avenio platform (single-articulated steel vehicles), which has since been used as the basis for projects in The Hague, Doha and Munich. 2013 saw Siemens expand the platform further with the "Avenio M", a multi-articulated vehicle with a fully welded aluminum car body. The project in Ulm is the first to be based on this new platform.

Multi-articulated vehicles in aluminum construction

Combino Basic
1996–2003

Combino Advanced
2001–2010

- Completely welded fatigue endurable aluminium bodyshell
- Future crash requirements
- Current fire protection

Avenio M
2017

Utilisation of:
- Electrical equipment
- Roof-mounted containers
- Bogies

Utilisation of:
- Electrical equipment
- Roof-mounted containers

Combino Plus
2004–2007

- Conversion to a platform concept
- Equipment update
- Fire protection and crash update

Avenio
2013

Single-articulated vehicles in steel construction

From the Combino to the Avenio M

Highlights of the Avenio M

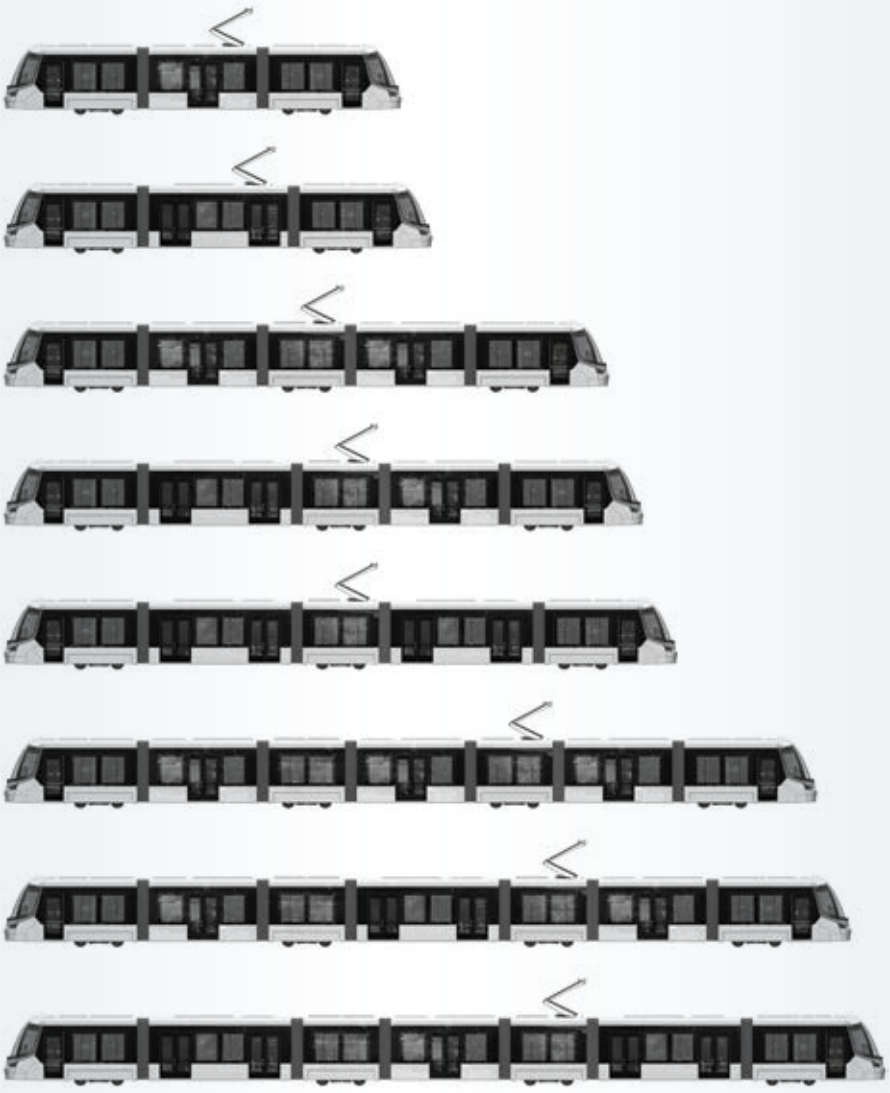
Continuation of the modular Combino system

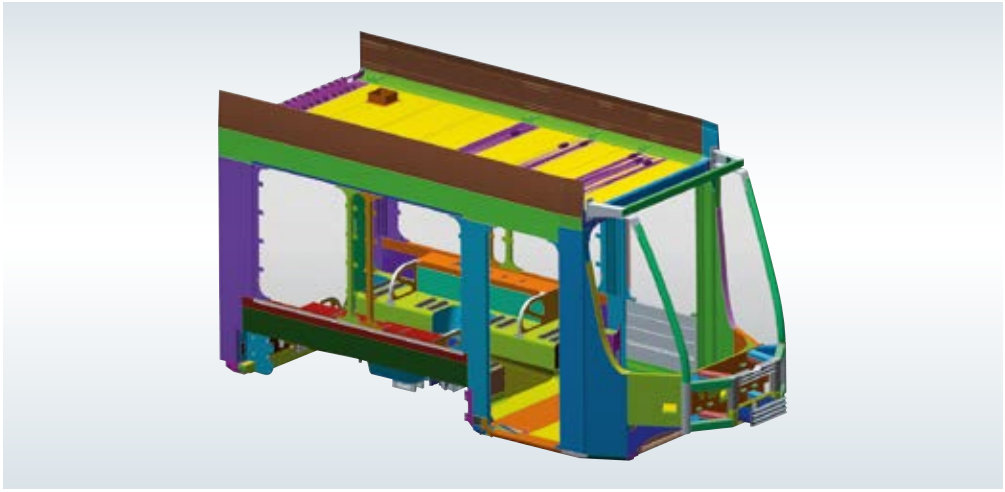
The Avenio and the Avenio M are based on experience gained with the modular Combino system with regard to modularization and standardization. Tried and tested Combino components were integrated during the development of the Avenio and Avenio M vehicles as far as the relevant applicable standards (fire protection in particular) allowed.

Overall layout

The main dimensions and variability were largely adopted from the Combino system. The vehicle is available as a 3-car, 5-car and 7-car version in standard or meter gauge, enabling the creation of vehicles with a length of between approximately 20 and 43 meters. These vehicles can have widths of 2,300 mm, 2,400 mm and 2,650 mm (standard gauge only). The single door at the vehicle ends has been widened to an inner width of approximately 800 mm, and can now also be located on both sides behind the driver's cab.

The modular Avenio M system





Bodyshell head module Ulm

Lightweight construction, crash

One of the outstanding characteristics of the Avenio M platform is the low vehicle weight – attributable to the aluminum car body construction. The fully welded integral construction mainly consists of extruded sections with the appropriate mounting options for components and interior fittings already integrated. The roof is no longer glued on and now forms part of the welding structure itself. The bodyshell was designed in accordance with the latest crash standard, EN 15227 Category C-IV, and already meets future crashworthiness requirements (side collisions with trucks) which are still being reviewed for inclusion in the standard. The longitudinal compressive stiffness is 400 kN. Despite all of these requirements, Siemens was able to keep the overall weight of the fully air-conditioned vehicle considerably below 1.2 t/m.

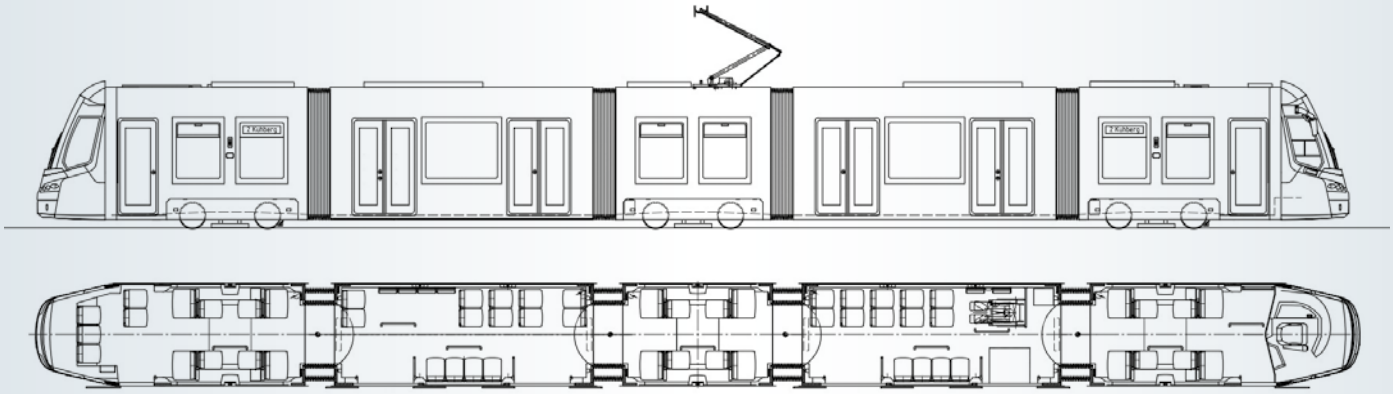
Drive and bogie technology

The drive equipment for the Avenio and Avenio M is, to a large extent, identical to that of the Combino. Only the mounting situation in the roof containers had to be changed due to new fire protection requirements. This involved reducing the number and size of the openings to the passenger area roof to a minimum.

The two traction motors in the powered bogie are fed in parallel by a traction converter. This in turn is fed from the overhead wire via an automatic overcurrent switch and a line contactor with a parallel pre-charging device. The converter is fully capable of regenerative feedback and the control system enables electro-dynamic braking to standstill.

The tried and tested bogies with independently rotating wheels were adopted from the Combino, making for a mostly level floor without ramps or steps in the passenger area. Only the areas where the bogies are connected are slightly higher and thus require a low ramp.

In the powered bogie, both wheels on one side are mechanically coupled via the two bevel gears and the rotor. In combination with the omission of joint dampers, this leads to a considerable reduction in the tendency to slip and glide at low friction coefficients and to a clearly increased tire service life compared to multi-articulated low-floor trams with axle bogies. Transport companies using both concepts in typical tram networks (tight radii, flat track points) report a near doubling in the resulting possible mileage. The diameter of the new wheels for the Avenio M was increased from 600 mm to 610 mm, while keeping the minimum diameter of 520 mm. This increases the service life of the tire.



The Avenio M for Ulm

The city of Ulm in Baden-Wuerttemberg is located roughly halfway between the large urban centers of Stuttgart and Munich and currently has a population of around 122,000. Adjacent to it, across the river Danube, is the city of Neu-Ulm, which has roughly 50,000 inhabitants. May 17, 1897, saw the inauguration of Ulm's first tram service, which also crossed the Danube to serve stops in Neu-Ulm. During the Second World War, this link was cut, and, along with other track sections, never entered service again. By the mid-1960s, only one tramline was left in Ulm. Eight Combino vehicles were ordered for this line in 2003 to replace the GT4 vehicles built in 1964 and originally transferred from Stuttgart.

Two additional vehicles were ordered in 2007 and supplied in 2008 for the extension of the route from the Donauhalle to Böfingen. Until this time, Line 1 had only had a length of 5.5 km. This was nearly doubled to 10.2 km, providing an east-to-west connection across the municipal area of Ulm. The new part of the route includes a two-kilometer-long inclined section with a difference in altitude of roughly 100 meters that leads to the city district of Böfingen. This city district, with a population of roughly 12 000, developed in the postwar period. In order to be certified to travel along this steep section, the active bogie wheel brakes of all Combino vehicles had to be retrofitted to operate with a fail-safe hydraulic accumulator system. Additionally, a Siemens ZUB222c train protection system was installed in the vehicles. This equipment continuously monitors the maximum permissible speed during the downhill run.

Planning for the extension of the tram network in Ulm through the addition of a second, north-south line began as early as 2007. At the same time, plans to extend the line to the neighboring Bavarian city of Neu-Ulm were examined. While this part of the planning process has been put on hold for now, construction of the 10.5-kilometer-long Line 2 (www.linie2-ulm.de) was approved by the municipal council on May 6, 2015.

This second new line will run from Ulm's university and research quarter to the city center and has a difference in altitude of roughly 160 meters. At the moment, the existing high transport demand on this route is met by several bus lines. During peak times, services need to run every two minutes. Bus line 3, the busiest of the services, will be replaced by the tram, offering additional potential for future developments in passenger volume.

Line 2 leads past the main station, where the new high-speed route to Stuttgart will be taken into service soon, up to the Kuhberg area. This city district is characterized by dense residential areas and a number of schools, with student numbers of over 8,000. Here, too, the existing bus line has reached its capacity limit, even despite additional services.

Twelve additional tram vehicles are required for the new Line 2. The new vehicles have to be as similar to the existing Combino vehicles as possible in terms of dimensions and technical equipment so that maintenance costs for the whole fleet can be kept within acceptable limits. Of course, the new vehicles must also be suitable for steep inclines. The Avenio M and the Combino units will form a common vehicle pool that serves both lines.

The Europe-wide bidding process showed that the refined Avenio M from Siemens is not only a close technical fit to the existing vehicles but that it is also being offered at an economical price point. A comparably large number of identical parts and the fact that important modules are sourced from the same sub-supplier ensure cost-effective maintenance of the whole fleet.

Summary & outlook

The successful Combino vehicle platform from Siemens has, in a sense, been reincarnated in the form of the improved and refined Avenio M. Existing proven Combino systems and components have been adopted and the vehicle platform has also been consistently adapted to meet current and future requirements. As the first ever user of this new system, SWU Verkehr GmbH in Ulm will more than double the size of its existing Combino fleet for the current network extension.

Martin Walcher
From 1989 to 1994, Martin Walcher (47) studied electrical engineering at Friedrich Alexander University in Erlangen, majoring in power supply, as well as control and drive engineering. He started working for Siemens AG in 1994 and has since held a variety of positions in the street car and light rail vehicle sectors. His roles included accompanying the development of the Combino platform and heading the projects for Potsdam, Erfurt and Nordhausen, later becoming head of national and international sales groups. He is currently responsible for the Avenio M platform.

Jürgen Späth (45) started his career with Stadtwerke Ulm/Neu-Ulm GmbH with his vocational training as mechanic. After passing his examinations for the master craftsman's certificate in mechanical engineering (1994) and electrical engineering (1998), he studied mechanical engineering with focus on design from 2005 until 2008. He has been responsible for the rail vehicle sector at SWU since 2004 and took over as head of the tramline 2 vehicle sourcing project in 2011. Since 2016, having successfully completed the prerequisite training, he is deputy operations manager for trams in accordance with BOStrab (German ordinance on the construction and operation of street railways).

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