Made-to-order trams

Tried-and-tested components plus innovative technology: with the new Avenio, Siemens Mobility has further developed the low-floor tram concept for the challenges of tomorrow's world

Urban planners and transport companies all across the globe are once again turning to the tram as a powerful, environmentally friendly and also highly economical means of transport. Existing lines are being extended and whole new tram networks are in planning, often for the heart of busy urban districts. Low-floor concepts with low-level entrances, car floors without steps and the right level of comfort are the main criteria for such trams. Siemens Mobility is also leveraging this concept with its new Avenio. The platform behind the well-known Combino has been rigorously developed and now features a range of technological innovations that make it one of the world's most modern 100 percent low-floor trams.

Low-floor concepts pose special challenges to engineers, as requirements often stretch the limits of what is technologically possible. For example, a tram's traction power should be great enough to properly accelerate full cars. A low car floor that is flat throughout, however, leaves very little space for wheelsets and drives. Other factors such as stability and low weight (important for durability, resistance to wear and energy efficiency) are also difficult to combine. The number of doors and their arrangement are not only decisive factors for the amount of available seats, but also affect the length of stopping times for board-

A platform for flexible operation: the new Avenio low-floor tram.

> For more than two decades Siemens has constructed 100 percent low-floor trams, and the Avenio is a continuation of this tradition.
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> **Silke Vandersee, Head of Light Rail, Siemens Mobility**

ing and deboarding the trains, and therefore also the journey time along the entire route. Finally, the construction of the undercarriage determines how comfortably, efficiently and ecologically a tram runs.

Bogies for all train modules

In the past, trams were mostly built as multiple articulation trains with a long, wheelless body supported like a sedan between two short car sections with rigid bogies. This asymmetrical arrangement places enormous stress on articulating joints and the structure, since not only the "suspended" car sections are exposed to strong transverse acceleration when cornering at speed. This is why Siemens engineers chose a concept for the new Avenio that had already proven itself in tram projects in Budapest and the Portuguese city of Almada near Lisbon: the modular single-articulated vehicle. Both the end cars and the nine-meter-long intermediate cars have their own powered or unpowered bogie. This optimizes cornering characteristics and makes it possible to form multiple-unit trams of different lengths: from 18-meter short trains to vehicles with six intermediate cars and a total length of 72 meters and space for over 540 passengers. This allows the Avenio to be arranged as the longest 100 percent low-floor tram in the world.

With broad doors, optimized floor plans and air-conditioning, the Avenio offers greater travel comfort for passengers.

Broad double doors take up around 30 percent of the total length, starting directly behind the driver's cabin. These ensure that passengers with limited mobility can access the trams without obstruction and allow fast boarding and deboarding even when trains are full. This shortens stopping time and, together with the maximum speed of 80 km/h, enables shorter total journey times. The Avenio is also at the cutting edge when it comes to production methods: state-of-the-art lightweight steel construction and fewer parts compared to previous models reduce both weight and construction costs.

An innovative wheel bogie

Unlike the Combino, the Avenio does not have a conventional undercarriage but instead has bogies with independent wheels, which are situated individually in a frame unit as opposed to being connected via an axle. Externally mounted motors power pairs of wheels, arranged longitudinally. One advantage of this arrangement is that the motor, gears and hollow-shaft coupling are sprung and situated externally on the bogie, making them easily accessible for maintenance work. What is special about the new Avenio bogie is that it has the characteristics of a conventional wheelset bogie on straight tracks, moves freely when entering curves, and takes turns with little resistance like an independent wheel bogie.

For the engineers from Siemens, it was particularly important to have a balanced distribution of weight among the individual train sections. To achieve this they placed the Avenio's bogies centrally under the vehicle modules, significantly reducing lateral forces on both the wheels and the tracks. This results in greater travel comfort for passengers. The tram runs very quietly and takes curves smoothly without screeching or rattling on tight bends and across poor stretches of track. Rolling noises and ground vibrations are absorbed efficiently, even at high speeds. The longest 100 percent low-floor tram in the world is therefore also one of the quietest.

The innovative train concept not only offers considerably improved passenger comfort but also presents actual economic advantages. It reduces stress on the car body and articulations, allowing an energy-saving lightweight construction, and also minimizes wear on the wheels and tracks. Wheel rims on conventional low-floor vehicles often need to be replaced after just over 100,000 kilometers. The Avenio, however, can travel up to 500,000 kilometers on the same wheel rims, because the concept allows for lower loads on the wheels.

Added safety is another core feature of the Avenio. The sophisticated crash concept, which meets the requirements for crash protection under the EN 15227 standard, offers optimum protection for drivers and passengers in the event of a collision. Passive safety for pedestrians in the design of the end module and the shape of the front shell were also important criteria. Safety functions operate at stops, including a complex door-monitoring system and optional platform lighting when doors are open. The latest fire-safety standards, fireproof

Point by point: An overview of the Avenio

- 100 percent low floor with a single-articulation concept
- Minimal wear to wheels and tracks and therefore reduced operating cost
- Several broad double doors, optimized floor plan and air-conditioning for greater passenger comfort
- Redesigned bogies with excellent smoothness, even at the maximum speed of 80 km/h
- Designed for both tram and light rail lines
- Designed for service in tunnels
- Optional energy storage units to further improve the energy balance
- Operation without overhead contact lines optional

The Avenio: economic operations and an exemplary energy balance.

bulkheads as well as the consistent use of fire-retardant materials also increase safety on board. With these features, the Avenio can even be used safely on light rail lines with long tunnel sections.

Over the several decades of a tram's expected service life, one of the most important characteristics is low energy consumption – a requirement that is more urgent today than ever before. An array of features in the new Avenio contribute to energy efficiency, starting with the undercarriage: Driving wheels are traditionally coupled transversely via an axle shaft, and they waste energy due to friction since the wheels have to cover different distances on the inner and outer rails. The independent wheels in the Avenio, however, can rotate at different speeds on curves, and therefore energy losses caused by friction are avoided.

There are also many other innovations, for example the electric brakes, which decelerate until the train comes to a standstill, meaning the mechanical brakes are only needed for emergency braking and as a parking brake. The optimized auxiliary equipment switches off or reduces output when the vehicle is stationary. Intelligent energy management, the latest generation of traction converters and a traction control system with an efficiency rate of over 98 percent also contribute to a very efficient use of energy.

> The Avenio offers passengers a very comfortable ride and holds solid economic advantages for operators.

Optional on-board energy storage units store the energy generated during braking and use it again to accelerate the vehicle and to heat or cool the passenger compartment. These auxiliary storage units can relieve consumption peaks in the contact lines, meaning investment in more powerful catenary systems is often no longer necessary. In total, these measures result in a reduction in energy consumption of up to 30 percent.

With the energy that is stored on board, the Avenio is also able to run up to 2.5 kilometers without contact to overhead lines: for example, across complex road intersections, through old city gates, through tunnels and historically protected areas, under bridges, through construction sites or over any route sections where an overhead contact line would disturb the cityscape or be impossible to install. This has already been demonstrated in Almada.

Even after reaching the end of their service in decades to come, the trams offer further energy savings and environmental advantages: over 90 percent of the materials used can be recycled. After all, with its efficient, reliable and environmentally friendly design, the Avenio is above all an investment in the future. □