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# Siemens Mobility and Transport Company VIP Postdam: On the path to an autonomous tram

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**Fully automated and driverless airport rail systems from Siemens have long been operating in Chicago, for example, as well as in metros in Paris, Taipei, and Nuremberg. Val systems have operated in Lille since 1983 followed by other cities, and a new fully automated cityval system will be inaugurated in Rennes in 2020.**

Automated operation is primarily suitable for closed-rail systems like metros and mass-transit systems running on completely isolated rail lines. Autonomous operation in an open infrastructure, as is typical of urban trams, requires completely different technologies: An autonomous tram has to learn to function intelligently in a complex environment.

Because mature infrastructure in urban areas can be altered very little, the technology needs to be installed in the tram itself. And the technology must be able to handle even the most complex traffic situations occurring with mixed traffic.

## On the path to an autonomous tram

Trams normally operate in a complex environment where other road users like cars, bicycles, and pedestrians are constantly on the move. Traffic lights and signaling systems regulate traffic at critical points. Driving a tram basically requires driving by sight at prescribed speeds with scheduled stops along the line, monitoring the boarding and departing of passengers, and quickly dealing with any unusual situation or emergency. A tram driver has to be able to handle at least 25 different tasks, many of them simultaneously. These include everything from reacting to car drivers, pedestrians, and trams ahead, maintaining set speeds and schedules under all weather conditions, stopping precisely at traffic lights, signals, and passenger stops, coordinating connections, and responding quickly and appropriately to any problems that occur in the tram or along the line. The driver ultimately is responsible for the well-being of the passengers. With experience, a driver can intuitively master all of these situations.

A partially or fully autonomous tram, on the other hand, has the advantage that it doesn't tire, it can react faster than a human, and it has a more extensive field of perception. Sensors replace eyes and ears, and pattern recognition, basic behavioral patterns, and reactions need to be incorporated into the tram control programs. However, human intuition and experience can be standardized only to a limited extent, and not every situation is predictable. The tram control system needs to be gradually programmed so it can react flexibly to each new situation. The software has to learn to make decisions at lightning speed – or request support.

Human operators still aboard: Testing semi-autonomous tram operation in the depot and on the line in Potsdam with a Siemens Combino.

## Autonomous Combino tram in Potsdam

Transport company ViP Verkehrsbetrieb Potsdam GmbH has been a customer of Siemens Mobility since the 1990s and has provided a Combino tram that's been equipped for autonomous driving tests with GPS, computers, and several types of sensors, including cameras, laser (LiDAR), and radar scanners. The joint development project will study the technological challenges of autonomous driving under real-life conditions in order to develop and test viable solutions. The world's first test vehicle was presented at InnoTrans 2018, but it wasn't designed for commercial operation. Over the long term, however, Siemens Mobility GmbH will develop a tram that can operate at the GoA 3 level of automation (accompanying a driver to handle emergencies) or the GoA 4 level (without accompanying operators).

The space ahead of and to the sides of the tram is captured by an array of cameras. The system's analytic software is trained with methods of artificial intelligence to recognize countless objects and people of any shape and in every position. Among other things, the algorithms recognize signals and signal conditions, people, other vehicles, and objects and obstacles on the tracks ahead. Camera images are analyzed and stop the tram when traffic lights or signals block further movement. When the light or signal changes to "go," the Combino automatically resumes its journey.

Information from the cameras is continuously combined with data from the three radar detectors. The reflected radar waves identify items like metal objects such as cars and other trams and enable the speed and distance of these objects to be precisely calculated. Three LiDAR scanners operate as digital eyes to scan and capture a 270° image of the space around the front end of the Combino. They scan horizontally and vertically and can detect people, measure their speed, and calculate and position their movement in a stylized three-dimensional image of the detected surroundings. Complex algorithms running on powerful computers are the "brain" of the tram. They analyze the real-time traffic situation, predict its ongoing development, and make the right decisions that are then performed by actuators for the Combino's bell, drive system, control electronics, and braking system.

The route first needs to be learned by the tram. Test runs have been conducted in Potsdam since May 2018 accompanied by a driver who intervenes only in the event of danger. Information processed in real time from data provided by the cameras and sensors is displayed on a large monitor in the test tram. The test route has been extended from the original six to 13 kilometers and now runs from the ViP depot to the final stop at Marie-Juchacz-Strasse. Buses also travel along an 800-meter-long roofed and fenced stretch where various scenarios can be tested.


On all test routes, the tram from Siemens Mobility GmbH stops precisely at each station platform and resumes its journey on its own when allowed by the signal. People approaching the track quickly are warned by the tram bell before the tram applies its brakes, as usual. The tram reacts to cars crossing the tracks just like a driver would. There are no jerking movements, no sharp braking ahead of curves, and no leisurely acceleration, all of which indicate that the tram is operating autonomously. Testing on the extended route and on automated depot runs are proving that the autonomous control system can be used successfully with the skills it has learned.

## Future challenges

The ability to recognize obstacles and signals should soon be so advanced that the system can be used in normal tram operations. Because there are currently no approval procedures for autonomous rail vehicles, the Association of German Transport Services and Siemens Mobility are working together even at this early stage to define the necessary safety and legal framework for the new technology.

The sensors used on the test tram came from the industrial and automotive sectors. Different conditions for pricing and durability apply in those areas and for the specific operating conditions of a tram. Although Siemens Mobility is drawing on existing automotive technologies, it's adapting the basic pattern recognition and signal processing algorithms to the requirements of tram operations. Automotive sensors, for example, record many more objects in front of and alongside a car than are relevant for a tram. To correct this, stationary objects like power masts, fences, and street markings that are no danger to the tram must be filtered out in the data processing.

Deriving appropriate warning and action strategies poses another challenge. Although the components have algorithms useful for recognizing people, only a specialist can develop algorithms that recognize when a person presents a danger. In pedestrian zones and at tram stops, for example, people move very close to the danger zone of a tram but must be assessed completely differently than in the case of a car.

The research prototype of a smart autonomous tramway has been successfully tested under real road traffic conditions on a six-kilometer section of the Potsdam tram network

In addition to these new functions for the Siemens assistance systems, the first intermediate levels of automated operation will be achieved in the next few years. The first commercially useful step is being planned: automated depot operation using an autonomous tram. This means that time-intensive marshaling processes in the depot – like service runs through a washing system to the storage track – can be performed automatically. Because the depot is largely separate from the rest of the public transportation system, this simplifies technical controls and eases approval from authorities. The project is called AStriD (from the German for "autonomous tramway in depot") and is sponsored by Germany's Federal Ministry of Transport and Digital Infrastructure (BMVI) in accordance with the Modernity Fund ("mFUND") funding guideline.

The project is being implemented at the Potsdam Transport Services depot. From the very start, the development process will take into account the legal provisions governing approval and operation of an autonomous tramway system and the economic framework in which this system could operate. The AStriD project was launched in October 2019, with a planned duration of three years.

Another potential option is to run line sections with a separate track on an automated basis, which would eliminate the need to perfectly master participation in mixed traffic with other road users. That would take the burden off the driver and provide improved safety, while programmed driving behavior, which would also be able to take account of trams ahead, would save energy on these sections.

Because the sensors in the tram precisely register the tram's surroundings, they can also be used to assist the driver in a conventional tram or to monitor the condition of the infrastructure for maintenance purposes. Automated procedures can continuously check the clearance gauge and condition of the tracks and overhead lines and warn of fallen trees or other obstacles on the track.

They can also monitor the integrity of signals, points, and balises and see where vegetation is intruding onto the tracks, for example. In all cases, the new technology helps the driver and provides greater safety, higher availability and improved passenger comfort, punctuality, and energy savings. Fewer accidents, less wear and tear, and lower repair costs also reduce operating costs and ensure a lasting increase in value throughout the entire lifecycle.

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