【欧州】【鉄道】

Road/Railways - autonomous driving vehicles: The development of driverless and autonomous trains - SNCF plans semi-autonomous trains to enter market in 2020

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【概要：Summary】

The development of autonomous transportation systems has become a major aspect of the further development for several transport modes, including train systems. In recent years, railways have made important advances in the development of driverless and autonomous trains. There are currently around 42 cities in the world that run fully automated train lines. More than half of the existing 64 fully automated lines worldwide are located in Asia. China alone intends to operate 32 fully automated train lines by 2022.

The Automatic Train Operation (ATO) covers different levels of automation; from the driver still maintaining control of most functions; semi-automatic train operation of Grade-of-Automation (GoA) level 2 to GoA 4, where there is no train driver in the train anymore, or on-board attendants. Issues that need to be solved in order to reaching the full deployment of autonomous trains are considered by several railway companies. The demand for automated trains is especially increasing in China. Shanghai Shentong Metro Group placed an order for 49 fully automated trains in 2018. Bombardier Transportation has completed the production of first driverless train for Line 14 of Shanghai Metro in China. The production of the train, which features Bombardier Mitrac propulsion and control system, was completed in CRRC Nanjing Puzhen. The train was supplied by Bombardier NUG Propulsion System (BNP), the company's Chinese joint venture.

Also in Europe, there is an increasing interest in train automation. The challenge for automating train operations in Europe will be to adapt it to a railway system, in which there exist multiple freight and passenger operators, which share the same tracks for the utilisation of different train types. There are also numerous junctions and yards as well as links to industrial plants. Nevertheless, in several EU countries, research continues on remotely controlled, autonomous trains. In France, the French National Railways SNCF completed its first test run with a remotely controlled locomotive-hauled autonomous train in July 2019, as part of a project to develop driverless passenger and freight train prototypes by 2022. Following the establishment of two consortia of suppliers and research institutes to develop and implement the autonomous train technology, the French national railway SNCF expects to see "semi-autonomous" trains running on the French rail network by 2020 and fully automatic trains within five years.

【記事：Article】

1. Levels of automation in train systems

Automated train systems have different degrees of automation. The Automatic train operation (ATO) is an operational device, which helps to automate the

train's operations. It is still discussed if automatic train operation (ATO) is the future for mainline railways. ATO covers different levels of automation; from the driver still maintaining control of most functions to semi-automatic train operation, also known as Grade-of-Automation (GoA) 2, where the setting of the train in motion and stopping is automatic. The GoA 2 trains run automatically from station to station but a driver is on board, who is responsible for door closing, obstacle detection on the track in front of the train, stepping in if the system fails and handling of emergency situations. Accordingly, GoA 2 trains cannot operate safely without the staff member on board.

The first line to be operated with Automatic Train Operation (ATO) was the London Underground's Victoria line, which opened in 1967. The GoA 3 and GoA 4 represent higher levels of automation, up to the point where there is no train driver or on-board attendant and the train is automatically controlled without the presence of staff on board. These include self-position detection, sensor fusion to allow environment recognition, multiple driving assistance systems, sensors to anticipate human behaviour, and platooning. Such developments will help railway companies to drive automation forward and reach superiority over road transport regarding driverless operation. The Grade-of-Automation 3 (GoA3) includes trains that run automatically from station to station but a staff member is always in the train, with responsibility for handling of emergency situations. In a GoA3 system, the train cannot operate safely without the staff member on board. The Grade-of-Automation 4 (GoA4) systems are systems capable of unattended train operation (UTO), although some operators might choose to provide on-board staff for other purposes, e.g. customer service, but this staff is not required for safe operation. In fact, in the GoA 4 system, trains are capable of operating automatically at all times, including door closing, obstacle detection and emergency situations. For example there is the Barcelona Metro line 9, the Copenhagen Metro, the Sydney Metro or the Yurikamome in Tokyo, among others. The first fully automated driverless mass-transit rail network is the Port Island Line in Kobe, Japan. The second in the world and the first driverless system in Europe was the Lille Metro, France.

Besides the existence of GoA 3 and GoA 4 level trains in several countries, currently, most ATO train systems still maintain a driver (train operator) to mitigate risks associated with failures or emergencies.

2. Metro Lines around the world with automated trains

There are already several metro lines around the world in operation with GoA4 level of automation, including lines in Asia and Europe, including the first fully automated metro line opened in Kobe, Japan, which started in 1981. These automated rail and metro lines run on purpose-built lines such as Singapore's MRT service, but they can also run in hybrid systems where automated rail services co-exist with manually-driven ones such as London's Underground and the Sydney Metro. According to the International Association of Public Transport, UITP, in March 2018, the total line length of operational fully automated (FAO) metros reached the milestone of 1,000 km with the opening of the Pujiang Line in Shanghai. According to the International Association of Public Transport (UITP), by the end of last year there were 64 fully automated metro lines with a total length of 1026 km in operation, in 42 cities. However, the UITP forecasts a major acceleration in the development of automated metros with the total length expected to triple by 2023 and to reach a length of 3000 km.

Fully automated metros currently represent 7% of the total length of installed metro assets. However, it should be kept in mind that fully automated metros with GoA level 4 emerged in the 1980s and 1990s, compared to 150 years of conventional metro history. Over the period 2015-17, ten new metro lines designed to run with a fully automated operation train system (FAO/GoA 4) entered in service in ten cities, with a total length of 157 km. Together with nine line

extensions, new GoA 4 lines have a total of 274 km and represent 12% of the total of the metro infrastructure installed in the years 2015-17. If China is excluded, which is only starting to introduce fully automated operation (FAO) metro lines and is disproportionately affecting the growth figures, new GoA 4 metros represent 32% of all new metros opened in the years 2015-17. The strong "mainstreaming" of GoA 4 metros worldwide will be confirmed in the next years, when also China will resolutely embrace the fully automated metro approach. UITP expects that in the next five years, over 200 new lines (conventional and GoA 4) and even more extensions are expected to open in most regions, including in Sub-Saharan Africa.

While the chairman of the UITP's Observatory of Automated Metros Ramon Malla states that it is difficult to see anyone building a new line that is not automated and reaches level GoA 4, the automation of existing lines is progressing only slowly. The reason is that converting an existing line to automatic operation is a real challenge, because usually the operation of the lines needs to be continued. Instead, the cost is not the main issue; it is the complexity of managing the project and suppliers and the same time to give operators more confidence. In 2018, around 5,400 km of railway lines were reported to be in construction phase or at testing stages. Another 1,700 km of lines was in design and tender stages.

The expected cumulative infrastructure developments over the next five years, and the strong mainstreaming of GoA 4 level metro lines worldwide will also include the planned establishment of 32 GoA 4 lines in 16 Chinese cities by 2022.Meanwhile, Shanghai Shentong Metro Group placed an order for 49 fully automated trains in 2018 and in September 2019, Bombardier Transportation announced to have completed the production of first driverless train for Line 14 of Shanghai Metro in China. The production of the train was completed in CRRC Nanjing Puzhen. The train was supplied by Bombardier NUG Propulsion System (BNP), the company's Chinese joint venture. The Line 14 of Shanghai Metro, which is currently under construction and scheduled to open in 2020, will consist of 31 stations. In April 2018, Bombardier INNOVIA automated people mover (APM) system started operation on Shanghai Metro's Line 8, Phase 3 project in China. Furthermore, Bombardier Transportation and Delhi Metro Rail Corporation have been working together since 2007 to provide signalling and control systems on the Delhi Metro rail network. Recently, the second fully automated line equipped with Bombardier's CITYFLO 650 rail control improving passenger experience opened in Delhi, India.

The first section of Line 9 (Grey Line) was opened on 4 September 2019 and the trains are equipped with Bombardier's CITYFLO 650 communications-based train control (CBTC) solution. In 2018 Bombardier's proven CITYFLO 650 CBTC solution has started operating on 58.5-km long Delhi Metro's Shiv Vihar-Majlis Park corridor Line 7, also called Pink Line. Although it is a GoA 4 system, initially the trains run with an attendant on board. According to Bombardier Transportation, the opening of Delhi Metro's Line 9 brings the total of CITYFLO 650-equipped track in India to more than 60 km with a further 1.2 km planned to open in 2020, which will also be equipped with the technology.

In Germany, driverless train trials are being carried out at the Smart Rail Connectivity Campus in Erzgebirge, Germany, using the French company Thales Group's "Lucy" laboratory train for the 5G driverless trials. The test train ran for the first time on 17 September 2019 on a section of the 25 km Erzgebirgische Aussichtsbahn between Annaberg-Buchholz and Schwarzenberg in Saxony. It consisted of Thales rolling laboratory railcar "Lucy", and was operated using a 5G-telecommunication network provided by Vodafone, which offers a bandwidth of more than 500 megabit/sec. In order to enable the train to be controlled remotely, Vodafone uses the 5G technology Network Slicing, which helps different virtual networks share a physical network structure, but provides a separate 5G network for railway trials. This means that remote-controlled mobile radio capacities are always available to control the train

remotely, even if numerous users in the immediate vicinity also use the Internet. In addition, the data is processed directly on-site in a small data centre in the immediate vicinity of the mobile base station via a Mobile Edge Cloud (MEC). Thales has provided the control and safety systems for the 5G project. This includes the installation of the test environment and sensors, along with a remote control system for the train in cooperation with the German Aerospace Centre (DLR) and Railergy.

3. SNCF plans to introduce autonomous trains

The main challenge for automating train operations in Europe will be to introduce the automated trains into a railway system, which allows multiple freight and passenger operators sharing the same tracks, and with trains of different types and weights. There also exist numerous junctions and yards as well as links to industrial plants. Nevertheless, French National Railways (SNCF) completed its first test run in July 2019 with a remotely controlled locomotive-hauled autonomous train. The projects aim is to develop driverless passenger and freight train prototypes by 2022. On 12 September 2019, the French National Railways SNCF provided an update on progress with the "Train Autonome" research programme.

Having identified various opportunities for automatic train operation, including commuter and high-speed trains as well as freight, SNCF is working closely with the French state-owned research institute IRT Railenium, the French national rail safety authority EPSF and the information security agency ANSSI. SNCF has reached agreements with two consortia to develop and integrate autonomous passenger and freight train prototypes for main line infrastructure at Grade of Automation (GoA) 4 within the next five years. Partnering with Railenium, SNCF will work with Alstom, Altran, Ansaldo STS and Apsys on a freight project, which will involve equipping an Alstom locomotive for GoA4 operation.

The passenger project teams SNCF and IRT Railenium with Bombardier Transportation, Bosch, Spir.ops, and Thales and will involve fitting a Bombardier Francilien commuter EMU for GoA 4. They will pursue a number of tests using Grades of Automation 2, 3 and 4. By 2023, SNCF says EOLE trains will be running through the RER Line E tunnels under Paris in GoA2, using the NExTEO train control system. This is expected to allow the operation of 22 trains/h at speeds up to 120 km/h. A Bombardier Regio2N double-deck EMU will also be fitted with GoA 2 technology and will be tested in commercial service on "any line" in northern France.

Following the establishment of the two consortia of suppliers and research institutes to develop and implement the technology, SNCF expects to see "semi-autonomous" trains running on the French rail network by 2020 and fully automatic trains within five years. The first TGV applications at GoA 2 level are expected to be introduced in 2023-25. Automation is expected to provide increased capacity, more fluid and punctual operation and a reduced environmental impact. The project will cost EUR 57 million, with SNCF contributing 30%, Railenium 30%, and the other partners 40%. The agreements were formally announced during a press conference in Paris on 12 September 2019. According to SNCF Group President Guillaume Pepy, the long-term objective was "to change from drivers to pilots". SNCF president Pepy and other SNCF representatives emphasise the benefits of autonomous operation of trains. They expect automation to increase capacity on the Paris - Lyon TGV high-speed line to 16 trains per hour per direction, compared to a maximum of 12 at present, and enable the maximum speed of ground level commuter train services RER, which connects suburbs and popular destinations in Paris, to increase from 80km/h to 120km/h. In addition, autonomous operation is expected to reduce energy consumption by 20% and offer a capacity increase of 30%, which combined with improved reliability, will open up more paths for freight trains.

The French railway company SNCF has already performed the successful tests of autonomous trains and in July 2019, SNCF announced to have successfully tested a train, remotely controlled including a drone over a distance of 4 km in the Paris suburbs. Representing

a key stage in SNCF's programme to develop automated operations, the "drone train" ran from Villeneuve-Saint-Georges (Val-de-Marne) to Juvisy (Essonne). This was preceded by an 18-month period of researches performed by SNCF in cooperation with its partners Institut de Recherche Technologique Railenium, Actia Telecom, CNES and Thales. The train was driven from a control centre established at Vigneux-sur-Seine. SNCF stated to have tested two types of technology including satellite transmission and the use of a private cellular LTE network equivalent to 4G. The train was equipped with optronics, infrared sensors and other integrating leading technologies. Cameras fitted on the locomotive provided real-time images for the driver in the control centre, who accelerated and braked the train. The drone flew ahead of the train, monitoring the tracks and switches. The vehicle ran a distance of four kilometres with the help of remote control. SNCF intends to develop its own prototypes of the autonomous freight and passenger trains by 2023.

Considering the European level of railway services, Executive Vice-President for Systems & Technologies Pierre Izard stated that SNCF and the German railway company Deutsche Bahn agreed to co-operate on the development of autonomous train standards for Europe, with the backing of the European Commission, in order to avoid the emergence of different standards that could create technical barriers between individual EU Member States.

Meanwhile, French technology group Thales is developing a concept of special drones for Automatic Train Operation (ATO). In Germany, the first rail projects are also under way for automated train operations. The DB railway company is working with Siemens on digitalizing operations for the Hamburg S-Bahn. The Digital S-Bahn Hamburg project is the first to be implemented as part of Deutsche Bahn's Digital Rail for Germany program.

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