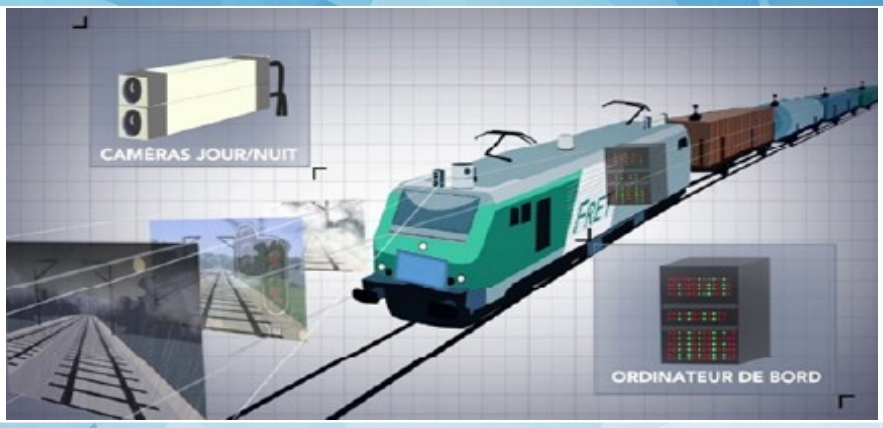
The CREOGN Research Notes

French Gendarmerie Officers Academy Research Centre

Issue 44 – December 2019

LCL (RC) Patrick MERVENT and ASP Axel LEMOINE

CREOGN
CENTRE DE RECHERCHE



AUTONOMOUS TRAINS : STAKES AND PROSPECTS

Following the example of the automotive industry, a paradigm shift is taking place in the railway industry for train driving. Today, it is still man who is at the heart of the decisions, accompanied by "catch-up loops" designed to control his action. The human being therefore remains at the helm, while the technical system ensures, in the background only, that the mission is running smoothly.
However, automation is increasingly coming to the forefront, with decision making based on artificial intelligence. Current projects, both those of the SNCF[1] and those of private players, show the desire for increasing automation of rail vehicles, with the aim of achieving total autonomy for trains on strategic railway lines as soon as possible.
While the implementation of such technology predictably presents technical challenges, we should not lose sight of the fact that users' feelings about these impressive advances embody a whole range of problems inherent in the societal upheaval caused by the radical transformation of an entire sector (as is the case of AI for IT, or the prowess of genetics for medicine) : will people have confidence in a driverless train ? What is the future of the current professions ? And above all, why are manufacturers and operators giving a boost to autonomous trains ?

I) A vital competitive challenge

Crucial advances such as the discovery of the steam engine, the invention of the automobile and the advent of information technology all share the same sine qua non condition of major economic interest. The same is true today for the concept of the autonomous train.
The SNCF must now face up to the increasing liberalisation of the railways[2], of which Sweden is a pioneer[3]. They will need to find a way to lower ticket prices, which seems inevitable given the Czech example[4]. The introduction of autonomous trains is one of the solutions the SNCF is contemplating to reduce its operating costs and become competitive.
The introduction of these autonomous trains will also allow the SNCF to improve the efficiency of existing lines by running more trains on them. Since most high-speed lines are already saturated, autonomous trains offer the promise of making traffic more fluid (and therefore denser).

1 Société Nationale des Chemins de Fer : France's national state-owned railway company
2 Made mandatory by Directive 2007/58/EC of the European Parliament.
3 Sweden was the first country to separate track management from train operations (as is the case in France today). Operating costs fell by 10% in the decade following deregulation.
4 The fare between Prague and Ostrava has fallen by 61% since the end of the state-owned company's monopoly in 2011.

It will allow "better regularity and punctuality of trains" according to the company's former president, Guillaume Pepy. Luc Laroche[5] plans to increase the number of trains per hour on the Paris-Lyon[6] high-speed line from 13 to 16 by introducing trains with a GOA 2 (Grade of Automation 2)[7] level of autonomy. Optimal operation of the lines avoids the construction of new tracks, which represent an ever-increasing financial and environmental cost.

Although France was until now one of the only European countries to have kept small railway lines running, the Spinetta[8] report denounces their low efficiency and use compared to their maintenance cost. The autonomous train could make them profitable again, as shown by the Taxirail project of the CEO of EXID C&D, who hopes to revitalise this part of the French network by dividing their cost by three[9]. The project, which, for the moment, is largely confidential, would be based on a GOA 4 level train with 40 seats, lighter and faster, electric or hybrid, with a range of about 50 km. The concept of "transport on demand" is thus under study, and promises to operate these "loss-making" lines, even outside peak hours.

With the imminent opening up of the French network to competition, manufacturers and operators are rallying to design autonomous trains. Although this solution seems to solve the economic issue, it is necessary to consider not only the technical difficulties but also users' mistrust, which will have to be overcome to make these projects a reality.

II) Which challenges will autonomous trains have to rise to ?

First of all, technical problems. The automation of the metro network is a complete success (metro lines 1 and 14 in Paris run without a driver), but this technology cannot be transposed to the rail sector as it stands. If we can draw from the solutions developed for the metro to teach trains how to read signs, we must also consider the fact that the tracks will continue to be used by non-autonomous trains. This situation means that autonomous trains will have to incorporate all the artificial driving intelligence to adapt to the existing infrastructure rather than setting up a second signalling system dedicated to them on all the infrastructure, which would be costly and require disruptive works. Furthermore, trains are more exposed to the vagaries of the external environment, bringing the challenges closer to those of autonomous cars, with the addition of the constraints of a considerable braking distance and the absence of any avoidance capacity. All of this requires a capacity to detect obstacles and incidents at a distance[10] of several kilometres, which is far beyond the sensors developed for autonomous cars. Finally, the technologies chosen will have to contain a whole range of connected objects, thus making autonomous trains vulnerable to cyber attacks with potentially catastrophic consequences. The protection guarantees for these systems will be a key element in their validation.

However, these technical difficulties appear less complex to overcome than the question of the acceptability of such a technology, both by users, by railway workers who would see their jobs transformed or even abolished, and by the authorities in charge of regulating rail transport. Guillaume Pepy, who is planning on autonomous

5 Director of the Automatic Train project at the SNCF.

6 WASSERMAN, Maïa, Le train autonome est sur les rails, *Le Parisien*, 29 November 2018. Available on : http://www.leparisien.fr/economie/le-train-autonome-est-sur-les-rails-29-11-2018-7948737.php

7 The International Union of Public Transport (UTIP) distinguishes five levels of incremental automation: GOA 0 (train driven on sight), GOA 1 (automatic speed control), GOA 2 (automatic starting and stopping), GOA 3 (automatic driving functions but presence of a conductor able to regain control) and GOA 4 (fully autonomous, unmanned train)

8 Entitled "L'avenir du Transport ferroviaire" (The Future of Rail Transport) and submitted to the Prime Minister on 15 February 2018

9 VAILLANT, Julien, Taxirail, Un train autonome pour sauver les petites lignes ferroviaires ?, *Le Télégramme*, 19 November 2018. Available on : https://www.letelegramme.fr/soir/taxirail-un-train-autonome-pour-sauver-les-petites-lignes-ferroviaires-04-01-2019-12160142.php

10 A double TGV train of 1 000 tonnes at 200 km/h will take 1 300 m to stop. This stopping distance increases to at least 3 km if the train is running at 300 km/h.

trains to operate as early as 2025[11], is perfectly aware of this issue and is counting on the first experiments in real operation to dispel any doubts.
The increasing use of technology, and artificial intelligence in particular, inevitably reopens the debate on the place of the human being and the risks for employment. Historically, if each industrial revolution has led to the elimination of certain jobs, the new technologies discovered had kept a need for maintenance and perpetual improvement by technicians and specialists. But Luc Laroche is reassuring: "New jobs will appear, such as teleconductor or supervisor"[12] and if some jobs disappear, others are created for the design and maintenance of these new materials. If we can deduce from this that there will always be a need for "human know-how" in the field, the gradual retraining of controllers and drivers remains to be devised.[13]
As far as regulations are concerned, the State and the European Union will have to strengthen the normative framework surrounding railway safety, which will make the implementation of new technologies more complex, as the number of safety standards to be met and the necessary authorisations have multiplied. Autonomous trains will not escape this long and meticulous validation process. Indeed, each component of the technology will be subjected to various technical test benches in order to obtain the approval of the Public Railway Safety Establishment (EPSF), which may or may not issue an Authorisation for Commercial Operation (AMEC) to run on the national railway network. This "certification" will also have to be obtained from our neighbours or at European level for cross-border trains.

III) Situation in France and abroad

To design and develop autonomous trains in France, two consortia were set up in 2019, for a period of five years[14]. Both led by the SNCF and the IRT Railenium[15], one is dedicated to the creation of an autonomous freight train prototype ; the other is responsible for automating a TER (Regional Express Train). It should be noted that the issue of cyber security has not been neglected, with the company Apsys in charge of providing solutions.
In France, a real-life test was carried out during the summer of 2019 to test the automation of the reading functions of lateral signalling along the tracks. For this, a demonstrator equipped with sensors (camera, infrared camera, radar, lidar, etc.) carried out signal reading tests on the Villeneuve Saint Georges - Montereau line. Thanks to an on-board cartographic database and the location of the train in real time, it knows the exact position of the signals it will pass. As it approaches a signal, the sensor identifies and interprets it. Although the reading system has not yet reached the absolute safety performance level, the experiment is considered a success: the sensors interpret the signals correctly and transmit the information to the train so that it implements the correct procedure. The system will continue to develop and improve in order to move from demonstrator to prototype and be integrated into the autonomous freight train prototype.

Outside the European Union, Russia tested an autonomous train in the summer of 2019 at the railway fair. It transported top Russian railway executives and managers as well as the Deputy Prime Minister to the outskirts of Moscow. During the journey, an emergency situation was simulated: the vehicle successfully stopped after detecting a dummy lying on the rails. Ultrasonic sensors and video cameras with computer vision ensure that the train brakes smoothly and stops automatically with an accuracy of 50 cm. However, the transport of passengers by autonomous trains is not planned at this stage. Although the role of the drivers will change, humans will remain in charge of system monitoring, the director general of Russian Railways underlined. This

11 GLISZCZYNSKI, Fabrice, La SNCF se lance dans l'aventure du train autonome : les voyageurs seront-ils prêts ? *La Tribune*, 12 septembre 2018. Available on : https://www.latribune.fr/entreprises-finance/services/transport-logistique/la-sncf-se-lance-l-aventure-du-train-autonome-les-voyageurs-seront-ils-prets-790236.html

12 LEGRAND, Baptiste, Faut-il avoir peur du train sans conducteur ?, *L'Obs*, 12 September 2018. Available on : https://www.nouvelobs.com/economie/20180912.OBS2237/faut-il-avoir-peur-du-train-sans-conducteur.html

13 The safety issues raised by travellers and the fears of workers about losing their jobs echo Marlene Bel's monograph on the acceptability of autonomous vehicles.

14 All information on these consortia is available in the SNCF press kit: https://www.sncf.com/sites/default/files/press_release/dossier_de_presse__train_autonome-_11092018_-_v7.pdf

15 The Technological Research Institute coordinates the implementation of innovation projects that meet the challenges of the railway sector in conjunction with public authorities.

automated train will either be controlled from the cab by the driver or from the control centre by the traffic controller. The development team will test and monitor the technology for several months in order to use the results to refine the learning of algorithms and continuously improve them.
In October 2017, in Australia, mining company Rio Tinto launched its first driverless train in the country's desert west without encountering any problems[16]. This train, reserved for miners and loads of ore, is a precursor to a more ambitious project for autonomous transport between the extraction site and the industrial exploitation sites.

The 2025 deadline for the first autonomous trains in France seems ambitious, but the spur of opening up to competition over the next decade will powerfully reform the railway landscape and practices. Autonomous trains are not the only likely innovation in the medium term.

IV) What other innovations for rail transport ?

While Guillaume Pepy recently admitted that he could not predict what mobility patterns would look like in 2049, he was more assertive about the role of hyperloop: "It will exist at least for goods in 2049". Hyperloop is a research project, launched by Elon Musk in 2013, of a magnetic levitation train (no friction with the rail), propelled by a magnetic field in a tube at very low pressure (reduction of air resistance).[17] The challenge is to reduce the amount of energy needed to move the train and enable it to reach speeds of over 600 km/h by reducing friction with the environment (rail and air) to a maximum.
Asia (China, South Korea, Japan) is also implementing magnetic levitation technology with the "Maglev" trains, for "Magnetic Levitation", with a world speed record for the Japanese train.

The railways were at the origin of the first industrial revolution with the steam train almost a century and a half ago, and they continue to innovate in order to maintain their place, and even gain market share, in the mobility modes of the 21st century, while highlighting a respectable carbon footprint. Law enforcement agencies will have to keep pace with these developments in order to successfully investigate rail accidents involving these autonomous trains. It will be essential to develop specific tools and methodologies. The long-standing partnership between the gendarmerie and the SNCF should facilitate this technological transition, particularly if the needs of law enforcement agencies are integrated into the design of the equipment.

Webography :

SNCF, Des trains entièrement automatiques en circulation dès 2023. Available on : *https://www.sncf.com/fr/innovation-developpement/innovation-recherche/trains-autonomes-circuleront-en-2023*
SNCF, La signalisation ferroviaire. Available on : *https://www.sncf.com/fr/itineraire-reservation/informations-trafic/reportages/signalisation-ferroviaire*
RATP, Des lignes de métro centenaires totalement automatisées, 3 May 2017. Available on : *https://www.ratp.fr/groupe-ratp/ingenierie/des-lignes-de-metro-centenaires-totalement-automatisees*
Établissement public de sécurité ferroviaire, Rapport annuel sur la sécurité des circulations ferroviaires 2018, October 2019. Available on : *https://securite-ferroviaire.fr/les-donnees-chiffrees-de-la-securite/rapport-annuel-sur-la-securite*

Translated by SLT Julie ORPEL and the French Gendarmerie Officers Academy Language Department

16 PROUILLAC, Nicolas, SCHEUER, Arthur, Ce train autonome australien est le plus grand robot au monde, *Ulyces*, 29 December 2018. Available on : https://www.ulyces.co/news/ce-train-autonome-australien-est-le-plus-grand-robot-au-monde/

17 In this respect, competitions are organised between universities all over the world. Germany (Technical University of Munich) and Switzerland (EPFL) are the most awarded countries.