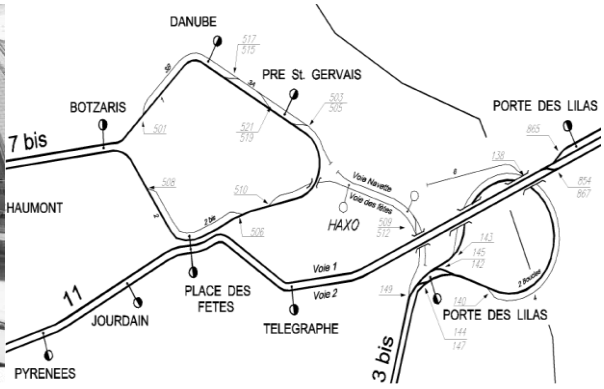
# PARIS METRO AND AUTOMATIC DRIVING SYSTEMS

Laurent FOURTUNE – Nicolas BUTRUILLE

RATP

## Overview of the Paris metro ATO systems

The first automatic driving system (ATO: Automatic Train Operation) has been implemented in the 50s on Paris Metro network, and since the beginning, it has been considered as a main tool for operating safely and efficiently RATP's metro system. The first prototype of this kind of system was designed in 1952 and the first tests were held on a 750m track during 4 years.


From the late 60s onwards, most of the Paris metro lines were progressively equipped with automatic driving systems.

| Line | Type | System installation date |
|---|---|---|
| M1 | GOA2 (track side calculated) | April 1972 |
| | GOA4 | Oct 2011 |
| M2 | GOA2 (track side calculated) | July 1979 |
| M3 | GOA2 (track side calculated) | July 1973 |

| Line | Type | System installation date |
|---|---|---|
| | GOA2 (CBTC) | March 2010 |
| M4 | GOA2 (track side calculated) | Feb. 1971 |
| | GOA4 | 2020 |
| M5 | GOA2 (track side calculated) | April 1978 |
| | GOA2 (CBTC with cab signal) | July 2015 |
| M6 | GOA2 (track side calculated) | Feb 1975 |
| | GOA2 (CBTC) | By 2022 |
| M7 | GOA2 | July 1977 |
| M8 | GOA2 | July 1976 |
| M9 | GOA2 | June 1975 |
| | GOA2 (CBTC without cab signal) | July 2015 |
| | GOA2 (CBTC with cab signal) | 2019 |
| M10 | GOA1 | No automatic driving systems |
| M11 | GOA2 (track side calculated) | Nov 1967 then updated in 1975 |
| | GOA2 (CBTC) | By 2020 |
| M12 | GOA2 (track side calculated) | December 1977 |
| M13 | GOA2 (track side calculated) | April 1977 |
| | GOA2 CBTC | 2015 |
| M14 | GOA4 | 1998 |

The first systems implemented from the 1960's till 1980s were "track side calculated" GOA 2 ATO using a fixed block linked trackside code. The trackside code has to be designed as to accommodate for the less performing train in order to avoid unexpected Emergency Braking sequences. These systems are still on operation on lines 2, 4, 6, 7, 8, 11, 12 of the Metro.

From 1967 till 1980, the use of ATO systems has proved that they can lighten driving tasks: This allows changing the way trains are operated by reducing trains attendance from two staff attendants (one train

controller in charge of doors managements and one train driver in charge of driving) to a one-man operation throughout the network. This implied a real effort on the ergonomics of ATO for the operator now in charge of both safe driving and door closing.

In 1998 the first GOA4 driverless UTO line has been implemented on the newly built line 14. The train driving and the passenger exchange management are completely handled by the system that includes Platform Screen Doors.
Following that success, line 1 GOA2 system has been replaced in 2011 by a driverless CBTC based on a GOA 4 UTO that includes Platform Screen Doors. The line 4 will be the next line to be fully automated; a GOA4 CBTC system is to be fully operational on that line by 2020.

Since 2010, a new generation CBTC type of GOA 2 ATO has been implemented on lines 3, 5, 9 (OCTYS) and 13 (OURAGAN) replacing progressively the current systems.

The OCTYS ATO system is based on an interchangeable CBTC system that has been fitted with different industrial solutions for on-board and trackside sub-systems; these systems are to be implemented by 2022 on line 6 and 11 concomitantly with the renewal of the rolling stocks on these lines. This new generation is based on ultimate SIL4 on-board calculators that allow better performance in terms of practical running speed by adapting the traction and braking effort to stick the train speed to the limits.

The Line 5 OCTYS ATO system features, in addition to the common GOA2 functions, onboard cab signaling and trackside signals cancelation functionalities.

The CBTC system that is operated on the line 13 (OURAGAN) includes an automatic turn-back system at the Châtillon terminus in order to reduce the headway at the turn-back. The system performs automatically the reverse movement at the turn-back while the driver remains in the rear cabin. Consequently, as there is no driver in the front cabin during the reverse movement to visualize the tracks and eventually stop the train, all the platforms at this station has been equipped with PSD to ensure there is no passenger on the tracks.

By 2018, the Line A of Paris suburban Mass Transit Line is to be fitted with a GOA 2 ATO system as an additional system that will be interfaced with the current SACEM system that has been operated since the 90s. The SACEM system features continuous speed control along with on-board cab signaling and trackside signals cancellation.

Since they have been operated on line 3, 5, 9 and 13, this new generation of “on board calculating” ATO CBTC systems s on line 3, 5 and 9 have brought better performance for the line operation

- By reducing by 7% the running times compared to an average manual driving,
- By reducing the variability of speed between different trains and therefore improving trains regularity especially in peak hours. Indeed, the variability of speed between different trains is lowered by the fact that slower the driver is, the more often he may be encouraged to use the ATO driving mode.

## Drivers' responsibility in Automatic driving modes depends on the company policy.

Automatic Driving system allows the automatic movement of a train from a station to the next one. However, it doesn't remove drivers' key role in the safety of a transportation system. The drivers remain responsible for the passengers' exchange, the monitoring of trackside signals and the track itself and any miscellaneous failures that may occur and require driving the trains in a manual mode.

Concerning human factors issues, the system design depends mainly on the company background/policy and the network features. In the Paris metro system, the following choices have been made concerning human interventions:

1- An automatic warning system is operational: an alarm is triggered every time the driver forgets to open the passenger doors; this alarm has to be acknowledged by the driver and, if not, it is sent to the OCC (Operation Control Centre). This should allow the detection of any driver malaise. This choice brings better personal safety for the driver by allowing a faster assistance in case of malaise, and less disruption of service for travelers. It is proven has being safe after more than 40 years of operation in our environment.
Considering the dead man system, it has been considered for the Paris metro, it can be inhibited while driving in the automatic mode; indeed the average distance between two stations remains limited and therefore, if it occurs, the malaise driver will be detected shortly.

2- Transitioning between automatic and manual driving mode can only be performed while the train is at a full stop. This choice brings practical economies on the design and implementation of ATO, simplifies training by reducing the number of degraded modes to accommodate, improves reliability by avoiding the risk of unexpected emergency braking in operation, and does not have any practical impact on overall line performance

3- All the drivers are requested to perform daily 2 trips in manual mode in order to keep practicing driving skills. This decision has been implemented in Paris after a significant accident that happened in 2000 due to an over-speed in a curve without ATC. This choice has been driven by the fact that the ATC systems implemented on most of RATP's line may not be always fully operational (for a specific zone or for a specific train) and in that case drivers may have to drive without ATC. Therefore, it is important to maintain drivers driving skills through a permanent training.

4- The ATO mode has been designed in the perspective that it is considered as an additional feature to help the operation of the line while the Manual mode remains the nominal mode.

5- Many risks come from events that occur when the train is leaving the station such as passengers being trapped or dragged; from a legal perspective, the departure of the train – especially when leaving a station - remains to some extent under drivers' responsibility. It is therefore impossible to let GOA2 ATO systems to perform a fully automated departure from a station without additional systems (such as Platform Screen Doors).
As a consequence, in Paris lines fitted with GOA2, the departure of the train remains fully triggered by and under the responsibility of the drivers. That means that:

- All stations are equipped with rear viewing features (mirrors and or camera) to help the driver to perform a safe door closure.
- The driver is requested to press permanently the automatic driving start button during the first 10 seconds. If he fails to do so, the emergency brake is triggered. This ensures that the driver may easily intervene and stop the train if anything occurs during the first seconds after the departure.

## Transitioning towards CBTC systems.

The ongoing modernization of the systems of the Paris metro network includes the widespread use of CBTC systems that may feature the cancelling of trackside signaling. For this particular case (Line 5 for example), it turns out during the system design that it is essential to give to the driver a relevant information about the on-going train movement as this movement is under full control of the CBTC.

To do so, the trains have been fitted with a device that gives to the driver a dynamic indication when in the automatic driving mode. The objectives of the device (called Automated Operation Driving Assistance Device) are to

- Maintain permanently the driver's attention especially on the speed limits to be respected and also on any track obstacles or other risks,
- Give information to the drivers in case of the system's malfunctioning; he can therefore react properly if it occurs.

## Concerning the suburban network.

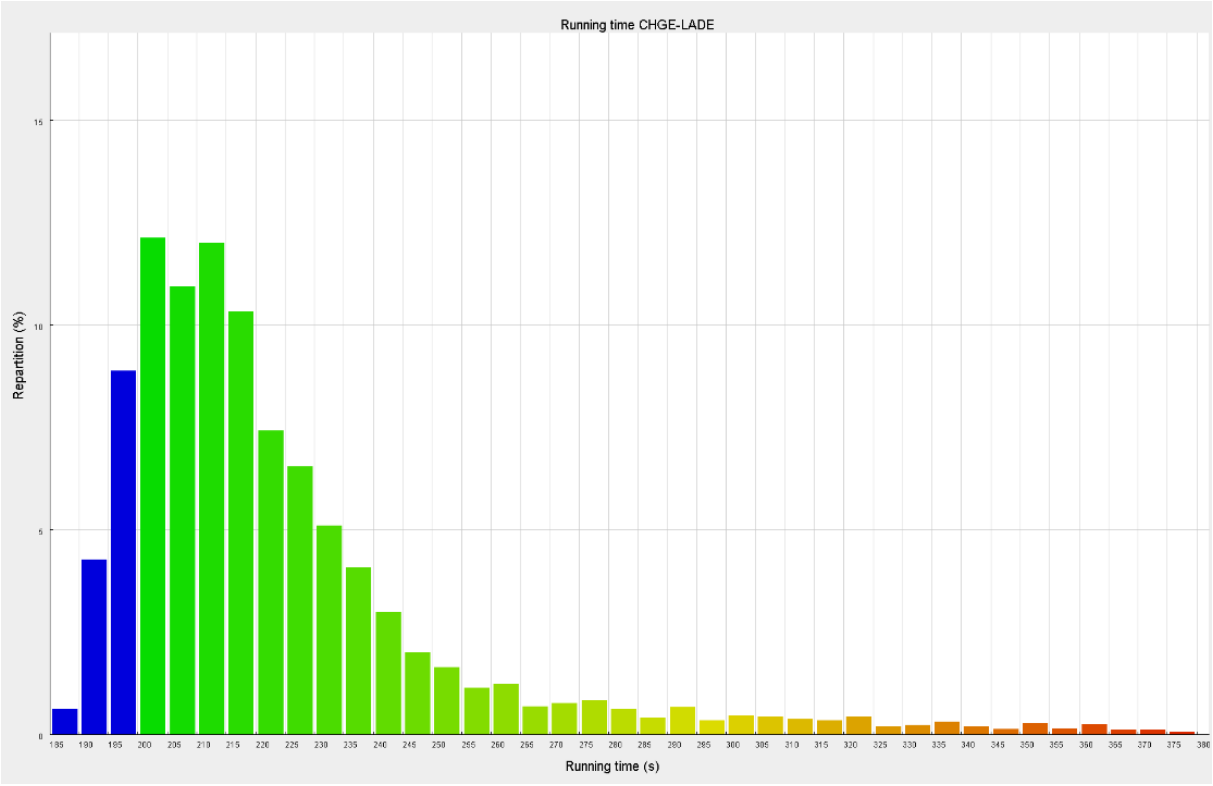
RATP has gained a considerable experience in operating a urban network with automatic driving system but the issues concerning human factors and ergonomic have to be adapted to a suburban operation context as it differs slightly from the urban one: longer distance between stations, trips with skipped stations, less protected outdoor tracks,…

New projects, in partnership with SNCF – the French national railways – have been introducing automatic driving in the suburban network.

RATP plans to implement an "on board calculated" ATO on both Line RER A of the suburban Mass Transit Network as an overlay over the SACEM ATC cab Signal (by 2020) and on line B (project under study).
These systems are expected to improve the practical performance by increasing by 2% the punctuality and by 5% the operation speed.
RATP and SNCF are also planning to implement an Interchangeable and Interoperable CBTC on the common part of line B and D of RER suburban mass transit network.

Indeed, our experience has showed that the ATO mode allows the speed of train to be closer of the limit that can be performed for a specific interstation. The variability of speeds is also much lowered ensuring better intervals.
By retrieving the running times in a specific interstation of the RER currently operated in manual mode, it turns out that more than 75% of the running times exceed the practical running time accepted.

The following shows the repartition of the running time of trains (manual driving) on the RER A line between Charles de Gaulle Etoile and Auber considering normal operations only.




It is thought that the functionalities of the current metro ATO systems will be replicated as they have proven to be efficient in terms of safety and performance:

- The Inhibition the dead man system while driving in the automatic mode,
- The transitioning between automatic and manual driving mode allowed only at full stop,
- drivers obligations to perform part of their duty in manual mode,
- the departure of train under driver's responsibility

RATP keeps an eye on the industry effort to implement ATO as an overlay over ETCS and is available to share its decade-long experience in design, implementation, maintenance and operation in order to help industrials to bring to the market simple practical performing products that take into account real safety and therefore driver's ergonomics