IRSE INTERNATIONAL TECHNICAL COMMITTEE

ATO for Suburban and Main Lines

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Many previous articles have described Automatic Train Operation (ATO) for metros, either in general, or focussing on a specific metro network or line, or a new technology.

However, the possibilities that ATO could bring to Main Line Railways have seldom been presented in the trade press. This article is intended to address this shortcoming.

Terminology

For readers that are not familiar with signalling and railway operating terminology, there are different types of **Automatic Train operation (ATO)**, that mostly apply to Metro Railways but, as we shall show in this publication, are becoming more and more applicable for suburban and main lines operation.

In short, **Automatic Train Protection (ATP)** makes the train stop safely when needed. ATO is all about making the train go. The business case for ATO can come from one of three sources : to increase capacity ; to reduce staff ; to save energy, or from a combination of these. Without a business case, no one will adopt ATO.

In fact the term ATO is used to cover a wide range of levels of automation, from the automation of basic driving functions alone to the running of trains with no staff member on board at all. These terms can apply equally to metro or main line operation.

At its most basic level, ATO enables trains to run automatically from one station to the next, only stopping between stations if required by the signalling system. When this arrangement is implemented under the supervision of a train driver it is often referred to as **Semi-Automatic Train operation – STO**; or just as ATO. With STO the operation of the train motors and brakes is automated providing a more consistent form of driving with fundamental benefits to the railway in terms of capacity and energy consumption. Typically, the driver remains in the cab of the train, operates the doors of passenger trains, and actually starts the train to leave the station. The train speed profile can generally be varied by a centralised traffic control system to optimise the running of the railway in order to achieve the business requirements of the line.

More sophisticated systems build on this basic level of ATO functionality and can additionally include the operation of the doors, freeing the driver from the need to be at the front of the train. This mode of operation is often referred to as **Driverless Train Operation (DTO)**. In DTO mode a driver or an attendant remains on-board, available to provide customer facing duties and to drive the train in the event of a failure of the ATO system. As the driver is no longer able to see the route ahead this mode imposes a greater demand on the signalling system.

A step on from DTO is **Unattended Train Operation (UTO)** which can range from empty train movements (to allow trains to turn back automatically at terminal stations with head-shunts, to moving trains to/from and within sidings or depots) to the operation of trains in passenger service with no attendant on board at all. This mode requires that the train can be operated remotely under any failure conditions, or at the minimum can be reached by shore based personal in a short period of time. Under UTO mode, increased protection of the guide-way from intrusion or some form of obstacle detection is required.

Unlike metro applications, for Main Line operation ATO is not “all or nothing”. There can be various in-between cases, not necessarily requiring precise stopping in stations. Frequently, this provides “cruise control” allowing the driver to select a constant speed ; “intelligent cruise control” that follows a speed profile taking into account speed restrictions, gradients, timetable and energy saving (e.g. on the High Speed Lines in Spain). These systems are aids to the driver (as in STO mode, with several additions to it) but do not necessarily stop the train automatically at stations.

Whilst signalling and train control systems provide the foundation of an ATO railway, the main differences between traditional manually driven trains and trains driven with some kind of Automatic Train Operation (Semi-automatic, Driverless or Unattended Train Operation) lies in improvements in the security and communication systems.

The next most important difference is the algorithm that is used to meet the specified application requirements.

Among other things, operation whilst the railway is undisturbed and all the equipment operating correctly is relatively simple. It is when considering failures i.e. graceful degradation that the main differences between the various ATO modes of operation can be best understood.

Safety Implications

T**he fundamental ATO system design is built on the Automatic Train Protection (ATP) System to provide the high integrity SIL 4** (“Safety Integrity Level” 4 as specified in CENELEC – European Norms) safety functionality. The ATP is indeed the safety net that makes sure that under any conditions the train speed is never exceeded at any time whether for train separation, interlocking or over-speed protection (depending on both the infrastructure and the train characteristics), and for preventing collisions (such as at level crossings), etc…

Because of the SIL4 ATP System, the basic ATO system is not considered safety critical. In theory it is possible that it can be considered as just SIL 0, but complementary to ATP. It is most often an addition to the ATP, building an integrated system. It can also be more like a parallel item, using several common interfaces or inputs/outputs with the ATP. In any case, there are always some interfaces between ATP and ATO; for example ETCS (the European Train Control System which is installed on many Main Lines in Europe and outside) is designed as SIL-4 and could provide the ATP platform for ATO operation. However ETCS has been designed for operation by a driver. Therefore careful consideration of system requirements, system architecture and system interfaces will be necessary if ATO is designed to operate in conjunction with ETCS.

However there may be a few functions of the ATO that could, for specific applications, require a much higher safety level.

The first example concerns Suburban lines, i.e. lines that can have a traffic operation similar to metros. It is here of vital importance in ATO mode to **manage the automatic operation or enabling of the train doors**, a high integrity safety function. This is to be considered even if all the doors are enabled by the ATO system but do not open systematically at all stations, as in Paris, where (except on Line 14 that is driverless/UTO-operated) each door opens only when a passenger, from inside the train or standing on the platform, actually operates a door lever or a push button. No operator would accept the possibility that doors could open in a station on the side opposite to the platform. Therefore there is a need for a system, that could be independent from ATO, to prevent the doors opening on the wrong side or in the wrong place. This is commonly already provided to prevent the driver making this error, so should be the same with ATO.

Another example is for the operation of freight trains on lines that are dedicated to freight traffic only, lines having no passenger operation at all, means there is no need to follow the requirements, rules, standards imposed where passenger operation exists. This can be the case of lines that run in very remote areas and that are usually carrying heavy bulk trains such as for coal, and iron ore. For these trains, several kinds of situation can have a wrong-side safety implication. In mountainous areas, for instance, any –even slight- increase in the speed above the limit could have dramatic consequences and make the train derail. In places where the line goes up and down to follow the terrain, and with very heavy trains which have several locomotives spread between the head, the middle and the rear of the train, precautions have to be taken to make sure that some locomotives in the train do not accelerate when they should brake or the other way round. Even if, of course, it is the ATP that deals with the safe aspects of speed control, wrong outputs to the traction motors and/or brakes from the ATO could actually break the couplings, or even worse cause a derailment, with dramatic and costly consequences.

Indeed, the operation of freight trains downhill must be treated as a safety critical function in order not to overheat the brakes.

ATO Applications

Having considered ATO functionality and its safety implications, this section identifies the main line business segments that could benefit from the introduction of ATO. These segments include Suburban lines, Freight lines, High-Speed Lines (HSL) and Conventional main lines carrying mixed traffic.

To illustrate the differences between these segments, and to compare them with metros, where Automatic Train Operation of some kind is common place, the attached table summarizes the main characteristics of the different segments.

The table identifies the main business driver for ATO for each business segment. Generally, moving to ATO augments the line throughput for a Suburban line, just as it does for metros. For freight operation the main benefit is to increase driver’s flexibility, optimise train running, reduce energy costs and reduce operating costs. Intercity and High Speed operators would go to ATO to avoid instabilities in the running of the trains, i.e. smoothing the acceleration and braking actions to allow a better ride, a higher level of running comfort and achieve energy savings. Full automation could also be one way for a conventional main line or network to minimise conflicts in hub stations and at the main junctions, and enhance its line throughput.

As shown, the table of characteristics gives an indication of the maximum speed, of the minimum headway target (the headway being the time interval separating two trains following each other on a given track), the dwell time (that is the stopping time at stations), the average distance between two stations, the capacity of the trains (passengers or tons) and various other items of comparison. (These include the need for punctuality; the requirements for compatibility with other rolling stock types or with existing (legacy) signalling systems; the impact on carbon emissions, safety issues where relevant, and so on.

Based on the above some preliminary questions can be asked, in order to construct the Business Case for ATO on Main Lines. Some may be more general, and this list of suggested questions is not exhaustive.

“Do business benefits exist for an ATO system for the railway industry on a particular line of route ? “

“Then, does the operator of this Main Line or network actually need ATO ?” And, for this particular case : “What is the n°1 driver to i mplement ATO ? “

“Also, does the Infrastructure Manager have plans for the future of their signalling to achieve operating benefits, and why and how would ATO fit in ? “

“Are the mix of rolling stock fitment and costs/benefits fully understood ? “

“Is there a need to drive all trains in ATO mode, in normal operating conditions, without exception, or will some non-ATO-operated trains be allowed as well ? “ The consequences of this on the global architecture of the system and, on safety for both normal and degraded conditions are important.

Is “never mix safety-related and non-safety-related functions the motto” or is it possible to allow some kind of mix, e.g. for the transmission buses ?

Depending on the answers provided to such questions and more, the team of designers will be able to produce the optimal specification, and then to allow for the best possible solution to meet the traffic objectives from the commencement of ATO operation and beyond, according to future business needs.

Examples of proposed applications for ATO on Main Line operation

The benefits of ATO depend on the application segment. Among the benefits are items such as the much smoother ride and also the 7 day – 24 hours service that ATO can provide. There will (can) be several steps towards achieving this: drivers (when they are kept on-board) should firstly get information on advisory speeds; a next step is to actually follow these automatically where the ATO will help to be more efficient than the drivers. The last step could be moving to DTO/UTO solutions, which would add more flexibility in the response to short-term demand for traffic increases and possible reduction of personnel.

To complete this paper are a few different examples that are, or are about to be, in operation, in the different segments that have been considered - Suburban lines, Freight lines, Intercity/High Speed lines, as well as Conventional mixed traffic lines.

Passenger Operation

An example of ATO on top of ATP on a Main Line railway application which has been in service for almost 10 years is **in the Czech Republic**, with about 50 suburban trains in service fitted with the system : the driver provides the start signal and the rest of the operation until the train stops at the next station is fully automated.

Another example that is definitely a main line application since it involves mixed traffic operation and is **in the Suburban lines domain is the Marmaray project**, also called “Bosphorus strait railway tunnel” project (76km; 41 stations). Marmaray will consist of a new double track tunnel bored under the strait that will see 90 second headway traffic (with plans for up to 70,000 PPHPD – “Passengers Per Hour Per Direction” , at rush hours), connected at both ends by more conventional suburban lines going to various destinations. The central trunk of the Marmaray network including the tunnel and its approaches will be equipped with CBTC (Communication Based Train Control - the very last kind of metro ATP+ATO signalling system), with all branches of the network being equipped with ETCS Level 1 without ATO (no headways shorter than 120 seconds are planned on the branches). In addition the central trunk section will be equipped with ETCS Level 1 as a fall-back arrangement as part of the graceful degradation strategy for this line.

The business case for equipping all rolling stock of the Marmaray project not only with ATP but also with ATO comes from the fact that only ATO will allow the required headways of 90 seconds to be achieved with 225m long trains, running at speeds up to 100km/h in the tunnel. The Marmaray project is planned to start operation in 2011-2012.

Another case where ATO for main line passenger operation does exist is on Spanish High Speed Lines. RENFE has on some of its high speed trains an “ATO-like” system although they call it to be an ATO. It is basically a system that tracks the ATP permitted speed curve from the ETCS system in order to drive the train according to the speed permitted by the ATP. This means that the train will always run at the maximum permitted speed for each section of the line. It does not actually receive any regulation information from the way-side.
There are several drawbacks in this operation method. For instance, in the case the next stop is in a passenger station, as the train comes closer to the station all the signals are cleared. Which means that the ETCS will give the train a Movement Authority with the permitted line speed ; which in turn means that the train will not stop in the station, at least automatically, as any ATO would do. The RENFE HSL "ATO" will then not stop the train ; it will simply get the train through the station at the maximum permitted speed.
This is how RENFE has implemented its “ATO” for the Spanish HSL.
For the Cercanias (main line suburban) contracts, a real ATO system has been offered. Will that actually be implemented ? It is today too early to tell.

Freight operation.

In this domain, the very first example was probably the so-called **German “Cargo-Mover”** where this (so called “lorry-on-rails” system) demonstrated its possibilities although it never left the testing phase. Cargo-Mover used a combination of radar, laser and GSM-R data communication to find its way to its destination fail-safely and by the quickest possible route at a given time. The on-board computer working in conjunction with the CTC –Centralized traffic Control- allowed the Cargo-Mover trains to move –as automatically as possible- in the gaps left between the passenger trains and any other normally-operated freight train. Cargo-Mover was active in the years 2003-2005 although nothing much has happened since then.

Another more recent application of ATO for freight is the project on **the Rio Tinto** freight-only line **in North-Western Australia**. This “railroad” announced in June 2008 their decision to move their operation to the “next generation driverless”. The intention of Rio Tinto is to have driverless only operation on the whole 1,300km network in 2012 in order to move their 320 million tonnes of iron ore more easily and efficiently. As a matter of fact the trains on Rio Tinto are among the very heaviest in the world, carrying up to 30,000 tonnes in 2.4km long trains. Currently the average cycle time for these iron ore trains is 33 hours with as an average of one train every 25 minutes.

In North America, a system called **“Trip Optimizer”** is indeed a sort of ATO for freight operation, a system designed to provide automatic throttle and dynamic brake control. It drives the train to a dynamic plan that is a result of optimisation based on multiple parameters to prioritise objective functions e.g. to minimize fuel/energy consumption and desired arrival time. The Trip Optimizer system calculates the precise velocity profile from origin to destination to reach the optimum solution considering the train mass and distribution of mass, type and efficiency of each locomotive, position of locomotives in the train, geometry of the track infrastructure, and the profile of maximum speeds allowed. The optimum throttle and dynamic brake settings may be displayed continuously to the driver. When the driver chooses to engage automatic control, a closed-loop control system drives the train precisely to the velocity profile. For example, when a train has crested a hill the lead locomotives can go to idle while remote units at the rear are still powering to minimize coupler forces. Implementation is being done in phases, with dynamic braking and asynchronous remote control being enabled in 2010 after the operators have confidence in the base line throttle function. Integration of the signalling functions raises the level of functionality from a smart "cruise control" to full ATO. During 2009 approximately 1.6 million train-kilometres have been run with the system engaged on trains from 2000 to 24,000 tons in the initial deployments. Depending on train type and territory profile, fuel savings measure from 5% to 16 % with controlled arrival times. Every driver becomes better than the "best driver" when the system is engaged. However, periods of manual driving are still deemed necessary to maintain the special skills for handling very large trains that have not yet been equipped with the system.

As of today there is no application on **Intercity or High Speed or conventional main lines**, in service or under test or in the short term pipeline. However it is most probable that ATO projects will appear in these areas of main line operation in the near future.