Semi-automatic, driverless, and unattended operation of trains

IRSE International Technical Committee

SUMMARY

The mission of any metro transportation undertaking is to provide safe, reliable, efficient, high quality service to its passengers in a cost effective fashion. To meet this business need, our metro systems are increasingly being automated. Any new metro system constructed today would almost certainly incorporate some level of automation with many modern metro systems now providing driverless or unattended train operation. In addition, higher levels of automation are also being introduced into the older metro systems around the world in response to demands for increased capacity on the existing infrastructure, enhanced levels of safety, improved customer service, and reduced operating costs.

This article examines the benefits of automation, the various levels of automation that can be deployed, the maturity of the technology, and the challenges of selecting the appropriate level of automation for a specific application. The article focuses on automation of metro systems. Automation of our intercity main lines, high speed railways, and freight lines will be addressed in a separate article.

THE BENEFITS OF AUTOMATION

Metros are an expanding business with many existing metros operating at or near to their capacity limit. Given the often prohibitively high costs of constructing new metro lines or extending platform lengths, the benefits of automation are therefore invariably linked to maximising the operational performance of the existing or planned transportation infrastructure. The characteristics of automation that support this goal include the following:

α) Automation of the train driving functions can provide for more regular and predictable run times between stations, eliminating the variations inherent with manual driving, and providing for a more uniform ride quality and reduced wear-and-tear on train propulsion and braking systems;

β) Driverless/unattended train operation, with automatic passenger door opening and closing and automatic train departure from station platforms, can further reduce the variations in line operation. Unattended train operation also frees the metro operator of the constraints imposed by the need to provide for the rostering of train crews and provides the flexibility to operate shorter trains more frequently;

χ) Unattended train operation, when combined with fully automated maintenance yards and stabling tracks, also provides the flexibility to respond to unexpected increases in passenger demands by adding additional trains to the service, all without requiring additional train drivers or manual intervention;

δ) While automation can reduce operating staff costs, the reductions in cost associated with a reduction in train drivers have to be offset by any increase in staff costs for any additional passenger service and security personnel, as well as any additional maintenance costs associated with the automation system itself;

ε) Automation of turnbacks at terminal stations can reduce turnover times, reducing the number of train sets needed for operation;

φ) Automation of train regulation, train dispatching and train routing functions can more effectively regulate the performance of trains in relation to timetable (schedule) and/or headway adherence. Regulation can be achieved by automatically adjusting dwell times and/or by automatically controlling run times between stations (e.g., through adjustments to train acceleration and service brake rates, and speeds);

γ) Automation of train regulation functions can also facilitate appropriate train meets, such as transfers between local and express tracks, and at the merge point between different lines in order to minimize overall system delays;

η) The automatic, real-time control and coordination of train acceleration, train coasting, and train braking can also be utilized to implement energy optimization algorithms for example though coasting controls or by synchronizing the acceleration of one train with the braking of another train to maximize use of brake energy recovery;

ι) Automated failure detection and response can be more effective in responding to system disturbances and emergencies through the elimination of human error.

While subjectively the benefits of automation may be self evident, quantifying these benefits in order to develop a specific business case is very application-specific and dependent upon the particular level of automation that is adopted.

LEVELS OF AUTOMATION

The first step in automating any metro system is the automation of the primary safety functions through continuous, automatic train protection (ATP). With this foundation in place, the driving functions themselves can then be automated through the provision of automatic train operation (ATO). With the driving functions automated, real-time automation of the train management and train regulation functions becomes possible, through more sophisticated automatic train supervision (ATS) systems, providing operational benefits at the line/network level.

The term ATO is used to cover a wide range of levels of automation, from the automation of the basic driving operation alone to the running of trains with no staff member on board. An IEC working group (TC9 Working Group 40) and the European MODURBAN project have therefore adopted the concept of levels of “Grade of Automation” (GOA), with GOA level 1 being ATP only with no ATO (ref. IEC 62290-1).

At its most basic, ATO enables trains to run automatically from one station to the next, under the protection of an ATP system and under the supervision of a train driver. This mode of operation is referred to as Semi-automatic Train Operation (STO) or GOA level 2. With STO, the operation of the train’s 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, provides the start signal for the train to leave a station, and monitors the performance of the train and the track ahead.

More sophisticated systems free the driver from the need to be at the front of the train – referred to as Driverless Train Operation (DTO) or GOA level 3. In DTO the driver is able to move away from the front of the train, but remains 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 imposes a greater demand on guideway security and platform controls. In DTO, train doors and train departure from a station platform may be controlled automatically or manually from a location other than a drivers cab at the front of the train. The increased flexibility that derives from freeing the train service operation from having to provide a driver at the front of each train means, as a minimum, that the time that would be required for a driver to walk from one end of the train to the other when reversing can be saved, thereby increasing the throughput at terminal stations and sidings.

Driverless ATO without an on-board attendant is referred to as Unattended Train Operation (UTO) or GOA level 4. UTO can range from empty train movements only (to a siding, or in an automated depot for example) to the operation of trains in passenger service with no attendant on board. The latter requires that the train can be operated remotely under failure conditions, or at the minimum can be reached by shore based personal in a short period of time. Passengers need to be reassured and hence good communication links between the vehicle and an informed staff member are essential. Automation of the door operation is now mandatory and requires means of detecting trapped articles of clothing or children. Increased protection of the guideway from intrusion or some form of obstacle detection is also required. Apart from the savings in staff costs the greatest benefit with unattended operation is that train service can be tailored directly to demand with trains being brought into service as and when the demand increases.

The benefits of the various levels of automation are summarized in the following table:

Benefit	STO	DTO	UTO
Automatic Train Protection (ATP)	√	√	√
More predictable run times between stations	√	√	√
More uniform ride quality	√	√	√
Reduced wear-and-tear of train propulsion/braking systems	√	√	√
Energy optimization	√	√	√
Reduction in variations in line operation / improved service regulation		√	√
Automation of turnbacks		√	√
Remove constraint of rostering train crews			√
Flexibility to operate shorter trains more frequently			√
Ability to respond to unexpected increases in passenger demands			√
Potential for reduction in operating costs			√
Automated failure detection/response			√

Whilst signalling and train control systems provide the foundation of an ATO railway, it is improvements in the security and communication systems that are the main difference between traditional manually driven trains and driverless or unattended operation. UTO for example typically requires the addition of passenger operated plungers on stations and trains to summon help in an emergency, extensive CCTV with links to a manned control centre, obstacle detection systems, and automatic platform area supervision to detect persons on the track. As an alternative to intrusion detection systems, platform edge doors may also be used to prevent access to the track in platform areas.

An IEC working group (TC9 Working Group 45) has recently completed a document addressing the safety requirements for fully automated (driverless/unattended) metro systems which should be released as an official IEC standard (IEC 62267) by late 2009. This document specifically addresses safety aspects applicable to driverless systems and does not include functions that would be the same whether or not there is a driver onboard the train (e.g. interlocking functions). In addition, the safeguards that are recommended in this standard to mitigate identified generic hazards may not apply in all situations and the metro authority and specific regulatory regime has the ultimate responsibility to determine, through hazards analysis, if a given safeguard is required.

ATO TECHNOLOGY MATURITY

ATO can be superimposed on any form of continuous supervision-based ATP and as a consequence the introduction of ATO on urban mass transit railways was closely linked to the transition from wayside signalling technology to cab-signalling technology in the latter half of the last century. London Underground’s Victoria Line, which entered service in 1968, is generally regarded as the first ATO metro line. The Victoria Line signalling is based on fixed-block technology and the train driver closes the train doors and presses a pair of "start" buttons to depart a train from a station platform. If the way ahead is clear, the ATO system drives the train at a safe speed to the next station and stops there. The Victoria Line would therefore be classified as semi-automatic train operation (STO). The only other STO line on the London Underground currently is the Central Line which introduced ATO as part of a major upgrade of the line during the 1990s. The simultaneous renewal of trains and signalling - and the introduction of ATO – was introduced to make the best use of the Central Line's capacity and provide important benefits for passengers in terms of more frequent trains, greater comfort, shorter journeys and improved reliability. The implementation of ATO on other lines in the London Underground network is currently underway.

Similar STO systems appeared in the USA in the late 1960s with the PATCO (Port Authority Transit Corporation) Lindenwold line in Philadelphia in 1969, the San Francisco/Oakland BART system in 1972, the Washington Metro (WMATA) system in 1976, the Atlanta Metro (MARTA) system in 1979 and the Miami Metrorail in 1984, for example. The Hong Kong MTR system also adopted fixed-block STO technology when that system first entered service in 1979. Metro Madrid automated its first line, Line 7, in 1996 and has subsequently automated the majority of its other lines with STO.

In all ATO applications the basic principle is to provide a command to the train's propulsion and braking systems to cause the train to drive at a speed below the safe speed limit, with ATP enforcing the speed limit through the train's emergency brakes should the train attempt to exceed the safe speed. ATO functions may be implemented in equipment independent of the ATP equipment, or may be integrated with the ATP equipment.

The initial ATO applications used fixed block, coded track circuit technology with "speed codes" to indicate the maximum enforced speed. ATO functionality can also be provided with fixed block "digitally encoded", profile-based track circuit technology as well as Communications-Based Train Control (CBTC) technology which can support moving-block operations through continuous train-to-wayside and wayside-to-train data communications, and train location determination that is independent of track circuits.

The first example of semi-automated train operations (STO) using CBTC technology was the Scarborough RT line in Toronto which entered service in 1985. Other examples of STO utilizing CBTC technology would include, for example, San Francisco MUNI (1997), Ankara Metro (1997), Hong Kong KCRC West Rail (2003) and New York City Transit Canarsie Line (2006).

The first examples of unattended train operation on a metro line, with no person aboard (UTO), were in Kobe (Japan) in 1982, Lille (France) in 1983 and Vancouver (Canada) in 1985. The Kobe and Lille systems were based on fixed-block technology whereas the Vancouver system utilized CBTC technology. Other examples of UTO utilizing CBTC technology would include, for example, Lyon Line D (1992), Paris Meteor Line (1998), Kuala Lumpur (1998) and Singapore North-East Line (2003). Examples of UTO based on fixed block technology would include Osaka (1982) and Copenhagen Metro (2002).

An example of a driverless train operation but with an onboard attendant (DTO) would be the London Docklands system that first entered into service in 1987 with fixed block technology. In 1994 the line was re-signalled using CBTC technology to increase capacity in response to an order-of-magnitude change in forecast demand.

The examples above are not intended to be an exhaustive list of all ATO systems world-wide, but rather to demonstrate the widespread application of ATO technology over the past 40 years, and to provide an indication of the significant maturity of this technology.

SELECTING THE APPROPRIATE LEVEL OF AUTOMATION

While ATO technology is certainly mature, and there are many suppliers capable of providing a wide range of ATO systems, there is however currently no universally accepted methodology to determine the appropriate level of automation that should be adopted for a specific metro application. When selecting the level of automation for a new metro line, or when upgrading an existing metro line, the desired operational performance and life-cycle costs should be two important starting points.

It is the operating authorities (and possibly local or national laws or regulations) that typically have the strongest influence on the selection of the appropriate level of automation. Operating authorities in turn often rely heavily on the experience of their own technical staff and/or on the advice of consultants contracted to assist in planning and development activities. Typically, the criteria for selecting a particular level of automation are more subjective in nature, rather than based on a systematic, top-down, business case analysis of the various alternatives.

The selection process is further complicated by a lack of unified standards to document and quantify the benefits of ATO drawn from world-wide experience. Selecting the appropriate level of automation is also often seen primarily as a "signalling" or "train control" decision, rather than considering the desired operating characteristics of the metro system as a whole.

Organised labour unions can also have a significant influence on the selection of the appropriate level of automation given concerns over potential job losses if train drivers cannot be retrained to take on the additional customer service or security functions that are typically required in driverless and unattended train operations.

There may be concerns that some passengers could be reluctant to ride on driverless or unattended trains and this can also influence a decision on the level of automation to be adopted. However this concern is seen to be more of a perception than a reality given the widespread acceptance of such systems by passengers around the world and the proven safety record of such system.

CONCLUSION

This article has highlighted the benefits and wide spread use of automation on metro systems around the world, and the trends towards increased levels of automation in the future. While this article has focused specifically on metro systems, surely it can only be a matter of time before the benefits of increased levels of automation on metro systems will similarly be realized on our main line and high speed railways.